YIELD AND TUBER QUALITY OF POTATO VARIETIES AS INFLUENCED BY ORGANIC MANURE AND MULCH MATERIAL

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ABSTRACT

Five experiments were conducted at agronomy field laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh and two others potato growing regions of Rajbari and Thakurgaon districts of Bangladesh during three consecutive years from 2014-2015 to 2016-2017 to study the performance of some selected potato varieties and their quality improvement through agronomic practices. The first four experiments were conducted at SAU experimental field and the fifth was conducted in three AEZs like AEZ-28, AEZ-12 and AEZ-1 for SAU campus, Dhaka, Rajbari district and Thakurgaon, respectively. Experiments were laid out in RCBD design with three replications. The results reveal that BARI Alu-25 showed highest yield at all locations and at Thakurgaon location the yield was 5.92% and 5.79% higher than Dhaka and Rajbari locations, respectively. Considering marketable yield and >75 g sized tuber yield, the highest (32.84 and 16.08 t ha^{-1}, respectively) was found with BARI Alu-25 (V_1) at Thakurgaon. In case of processing quality tuber, BARI Alu-29 (V_3) gave highest chips tuber yield (27.34 t ha^{-1}), chips tuber number (66.95). The highest tuber dry matter (23.32%) and specific gravity value (1.10) were also revealed with BARI Alu-29. But BARI Alu-25 gave highest french fry tuber yield (6.74, 6.38 and 6.20 t ha^{-1}) at Rajbari, Dhaka and Thakurgaon location, respectively. Application of poultry litter (O_2) showed the highest yield in Rajbari, Dhaka and Thakurgaon (39.13, 37.87 and 37.75 t ha^{-1}) which was 52.68, 43.67 and 39.87%, higher yield respectively over no manure treatment. Poultry litter (O_2) also gave the highest tuber number $hill^{-1}$ (7.78 no.) and tuber weight $hill^{-1}$ (0.39 kg), chips tuber yield (27.62 t ha^{-1}) and chips tuber number (58.40 %). Poultry litter gave the highest dry matter (24.49%) at Rajbari. The highest specific gravity, total soluble solid were contributed by (O_2) poultry litter which was similar with (O_1) cowdung. In case of mulching, water hyacinth (M_1), rice straw (M_2) and rice husk (M_3) gave non-significant yield but numerically rice straw (M_2) gave the highest yield (33.33 t ha^{-1}) and highest marketable yield (31.83 t ha^{-1}) at Dhaka. Rice straw gave highest chips tuber (56.91 %), higher dry matter (22.23%), specific gravity (1.079) and total soluble solid (6.58^{o}

Brix) than other two mulch materials. The performance of rice straw as mulch material seems superior than other mulches due to its wider availability throughout the country as well as in potato growing region. The interaction of V_1O_2 (BARI Alu-25 × poultry litter) contributed the highest tuber yield (42.46 t ha^{-1}), highest tuber weight $hill^{-1}$ (0.39 kg). Rajbari location gave highest chips tuber yield (31.09 t ha^{-1}) with V_3O_2 (BARI Alu-29 × poultry litter) interaction, french fry tuber yield (8.12 t ha^{-1}) with V_1O_1 (BARI Alu-25 × cowdung) interaction and dry matter weight (25.53%) with V_2O_1 (BARI Alu-28 × cowdung). On the other hand, the interaction of $V_1O_3M_1$ (BARI Alu-25 × ACI organic fertilizer × cowdung) and $V_1O_2M_2$ (BARI Alu-25 × poultry litter × rice straw) found promising for higher yield (42.36 and 40.95 t ha^{-1}, respectively) of potato tuber.

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LIST OF ACCRONYMS AND ABBREVIATIONS

ACCRONYM	ABBREVIATION
Abs	Absorbance
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Annu.	Annual
Appl.	Applied
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centi-meter
CV	Coefficient of Variance
DAP	Days After Planting
DAH	Days After Harvesting
Dev.	Development
df freedom	Degrees of freedom
DMC	Dry Matter Content
Environ.	Environmental
et al	and others
Exptl.	Experimental
FAO	Food and Agriculture Organization
g	Gram (s)
Hortc.	Horticulture
i.e.	*id est* (L), that is
J.	Journal
kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter square
mg	Milligram
Ph.D	Doctor of Philosophy
RCBD	Randomized Completely Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
Soc.	Society
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
TCRC	Tuber Crops Research Centre
TPS	True Potato Seed
TSS	Total Soluble Solid
UNDP	United Nations Development Programme
viz	*videlicet* (L.), Namely
V	*variety*
%	Percentage
@	At the rate of

CHAPTER 1

INTRODUCTION

Potato *(Solanum tuberosum L.)*, belonging to the family Solanaceae, in a leading staple food crops in the world. Potato is popularly known as 'The king of vegetables' in Bangladesh. Now-a-days potato being the third staple vegetable crop, could contribute in poverty alleviation and food security in Bangladesh. It is the 4th most important food crop in the world after leading rice, wheat and maize. Bangladesh is the 7th potato producing country in the world and it's rank second after rice in production (FAOSTAT, 2015). In Bangladesh, the cultivation of potato was started in the late 19th century but still average yield is very low compared to the leading potato growing countries (Hashem, 1990). It is a staple diet in European countries and its utilization both in processed and fresh food form is increasing considerably in Asian countries (Brown, 2005). In Bangladesh, potato is commercially grown in almost all over the country. The major potato growing districts in Bangladesh are; Rajshahi, Rangpur, Dinajpur and Munshigonj. However, the contribution of Munshigonj in potato production is prime (nearly 44%) in the country (Singh and Lal, 2003).

According to the Bangladesh Bureau of Statistics, the total area under potato crops, per ha yield and total production in Bangladesh are 500,000 hectares, 20.43 t ha^{-1} and 102,16,000 metric ton in 2017 (BBS, 2017), are 475,708.5 hectares, 20.15 t ha^{-1} and 94,74,000 metric ton in 2016 (BBS, 2016) , are 471,255 hectares , 19.64 t ha^{-1} and 92,54,000 metric ton in 2015 (BBS, 2015) respectively. The total production is increasing day by day as such consumption also rapidly increasing in Bangladesh. The national average yield of potato in Bangladesh is 20.43 t ha^{-1} (BBS, 2017) which is very low in comparison to that of the other leading potato growing countries of the world i.e. 40.16 t ha^{-1} in USA, 42.1 t ha^{-1} in Denmark, 40.0 t ha^{-1} in UK(FAO,2009) and 50.3 t ha^{-1} in New Zealand (FAOSTAT, 2008). The annual demand for potato in Bangladesh is 7-7.5 million tons against its production of 10.21 million tons (BBS, 2017). It was reported that, in 2009, both the fresh and processed potato consumption was 28.94 kg/capita/year that increased to 46.40 kg/capita/year in 2013 indicating the increasing demand of potato consumption in Bangladesh (BBS, 2014). Potato consumption as processed and fresh food is also increasing considerably in Bangladesh (Brown, 2005). The increasing demands of potato processed food specially chips have been gaining popularity indicating the demands of the varieties with good processing quality with the attributes beneficial for human health. A lot of research efforts have been made considering the yield potential of potato varieties but very few observations were made on the processing quality and health concern issue. Processing quality of potato tubers is determined by high dry matter, specific gravity, sugar content, low reducing sugar, flavonoids and phenol contents (Abong *et al.,* 2009).

In Bangladesh most of the potatoes consumed is unprocessed. Only 2% of the potatoes are processed mainly in the form of chips, French fry and crackers. Bangladesh Agriculture Research Institute (BARI) has so far developed 81 potato varieties. But the majority of Bangladesh's potato production is used for direct consumption called as table potato. The varieties used for table potatoes are not appropriate for processing (the dry matter content is too low) or export (foreign consumers have different tastes). Although the principal use of potatoes is to make potato curry along with fish, meat, and eggs, there exists a great diversity in the consumption of potatoes. Notable among potato-based food items are the boiled potato, fried potato, mashed potato, baked potato, potato chop, potato vegetable mix, potato singara, potato chips, french fry etc. In recent years, bakeries and fast food shops have started preparing a wide variety of potato-based food delicacies. Besides millions of tons of potatoes are processed annually in Europe into starch, alcohol, potato meal, flour, dextrose and other products. Some are processed into potato chips, dehydrated mashed potatoes, French fries and canned potatoes. Large quantities of potatoes in the Netherlands, Ireland, Germany and other countries of Europe are grown specifically for manufacture of alcohol, starch, potato meal or flour, and for livestock feeding. Europeans consume much larger quantities of potato than the North Americans. Asian countries consume more rice than potato for carbohydrate foods.

Nutritionally, potato is rich in carbohydrates or starch and is a good source of protein, vitamin C and B, potassium, phosphorus and iron. Most of the minerals and protein are concentrated in a thin layer beneath the skin, and skin itself is a source of food fiber. There are few foods, which are as versatile as potato. It is a favorite food throughout the world, both in its fresh and processed forms. Potato is unique in a sense that it can fit into any meal.

The record amount of potato is produced, the quantity of export is insignificant due to assure quality of potato. According to Bangladesh Bureau of Statistics, the revenue generated from exporting potato was $33.8 million in 2013-2014 (BBS, 2013) financial year whereas the amount came down to $13 million in 2016-2017 (BBS,16). Currently, there are only a few, around 8-10 established private companies that export fresh or processed potatoes, mostly to Singapore, Malaysia and the UAE and very recently to Russia, Vietnam and Sri Lanka.

The major constraints of such low yields viz. lack of quality and available seed tubers, high price of seed tubers, imbalanced fertilizations, no or less use of organic manures and sometimes low market value at the time of harvesting. Both chemical fertilizers and organic manures can play a major role to improve this situation (Ilin *et al.*, 1992). Moreover, mulch improves soil conditions, especially reduces water evaporation from soil and helps to maintain stable soil temperature (Ji and Unger, 2001; Kar and Kumar, 2007). Reduction of soil temperature has a great importance in countries with hot climate conditions, but now, as the climate is warming, temperature conditions for crops are becoming more unfavorable (Sinkeviciene *et al.,* 2009). For that reason, mulching becomes more important also in moderate climate conditions.

Fertilizer is one of the most important inputs of increasing the productivity of crops (Anon., 1997). The potato fertilization both dozes and ratio of nutrients is causing significant differences between varieties of different precocity (D. Nastase şi colab., 1996). The yield of potato is influenced by plant density, the cultural practices and environmental conditions such as temperature and day length. The goal of yield study is to attain the most profitable yields of quality potatoes, in order to obtain such a big goal it seems necessary to study the effect of cumulative yield factors such as the application of vermicompost. Growth, yield and quality of potato depend on nutrient availability in soil, which is directly related to the judicious application of manures and fertilizers. Use of optimum dose of fertilizers and vermicompost resulted in maximum yield in Potato (Patil, 1995; Saikia *et al*., 1998, Asumus, and Gorlitz, 1986). The technology of potato cultivation and fertilizers used are important in order to obtain maximum yield, economic and quality potato. Without the use of optimal doses of well-balanced fertilizers in terms of nutrients, the investment made for used with high varieties capacity has very low efficiency (Rusu M. *et al.*, 2005).

Ierna (2009) reported after a delay of the harvest date, nitrate contents in the investigated tuber samples significantly decreased in winter–spring crop, whereas they increased in summer–autumn crop in the three potato varieties, but to the greatest extent in the case of late Mondial variety. It is evident that uses of mulching, organic manure and appropriate harvesting time to different varieties in the crop field is very important variable in potato production and storage can affect potato in great extent also. However, in developing the cultivars, much emphasis was given to productivity and late blight tolerance while less emphasis was given to improve processing quality of potato. To meet the demand for suitable cultivars for processing, there is an urgent need to evaluate the suitability of the already released cultivars.

Depending on the above discussion, a research was undertaken to find out the individual as well as combined effect of mulching, organic manure and harvesting time on the yield and quality of some selected potato varieties. But the productivity, processing characteristics and quality are largely unknown, so that the productivity and quality improvement are the most important issue that can be increased by using different agronomic management. Accordingly, some agronomic practices such as organic manure, mulch materials were practiced in applying separately and combinedly, and effective harvesting period was selected for cultivating some released varieties of potato in different Agro Ecological Zones (AEZ) to meet up the urgent need for evaluation of quality of these potato varieties. This study will compose the productivity and examine processing quality attributes of some promising varieties of potato.

Objectives:

The main objectives of the study were :

i. To evaluate the growth performance , yield and tuber quality of different potato cultivars.

ii. To find out the suitable organic manure and mulch material for higher yield and better quality of potato.

iii. To evaluate the yield and quality of potato tubers in different locations of Bangladesh.

CHAPTER 2
REVIEW OF LITERATURE

Potato is the most important tuber food crops in the world but in Bangladesh it is mainly used as a vegetable. The average yield of potato in Bangladesh is very low compared to many potato growing countries of the world. In Bangladesh still there is a lack of industrial quality potato due to its low quantity of dry matter content. Numerous experiments have been conducted throughout the world on potato crop but information on response of potato varieties to various mulch materials, organic manures, harvesting time regarding growth, yield and quality parameters are still inadequate.

Brief reviews of available literatures pertinent to the present study have been reviewed in this chapter.

2.1 Influence of variety on yield and quality of potato

Kassim *et al.* (2014) ran an experiment and reported that reducing physiological functions of above ground part of potato plant (leaf area and total chlorophyll content), the number and the weight of tuber decreased, so the productivity of the plant decreased.

Rojoni *et al.* (2014) found on an experiment, which was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh that BARI TPS-1 produced gross tuber yield 27.67 t ha^{-1} that conducted during the period from November 2010 to March 2011.

Mihovilovich *et al.* (2014) found that the potential tuber number that can be successfully produced by a plant varies with the genotype and most cultivars having a consistent number of tubers on each stem.

Abebe (2013) carried out an experiment at three distinct locations in the Amhara region of Ethiopia for evaluation of the specific gravity of 25 potato varieties. The pooled specific gravity values ranged from 1.058 to 1.102. The specific gravity of tubers of the improved variety Belete was the highest while that of Menagesha was the lowest. Furthermore, the specific gravity values for varieties grown at Debretabor were higher than those for the corresponding varieties grown at Adet and Merawi. He mentioned that specific gravity is the measure of choice for estimating dry matter and ultimately for determining the processing quality of potato varieties.

Behjati *et al.* (2013) observed a field experiment to evaluate the yield and yield components on promising potato clones. Clone No. 397031-1, had the highest yield and Lady rosetta variety had the lowest yield compared with other varieties. The lowest and highest average number of main stems plant^{-1}, related to Lady rosetta and clone No. 397067-2. Lady rosetta variety had the highest number of tuber plant^{-1} and clone No. 397067-2 had 25 the lowest number of tubers per plant. The lowest and highest average tuber weight per plant related to clone No. 397067-2 and Lady rosetta variety respectively.

Jatav *et al.*(2013) conducted a study at Central Potato Research Station, Jalandhar during 2009-11 to evaluate potato cultivars*viz.* Kufri Jyoti, Kufri Jawahar, Kufri Bahar, Kufri Sutlej, Kufri Pukhraj, Kufri Pushkar, Kufri Surya and Kufri Gaurav. Results revealed that Kufri Gaurav recorded maximum yield, agronomic efficiency and net return at all the levels of nitrogen followed by Kufri Pushkar and Kufri Pukhraj. Kufri Surya yielded minimum with least agronomic efficiency. This variety can be useful for poor farmers as this produces higher yield compared to other released varieties .

Cota and Hadzic (2013) conducted a two-year experiment included four potato varieties (Desire, Romano, Bistra and Kis Sora). The aim was to select new varieties for cultivation. Productive characteristics of potato varieties (yield, weight and number of tubers per box) were examined. In the frame of qualitative properties, dry matter content and starch were examined. Higher average yield was achieved by Romano cultivar by 8% compared to Desire and Kis Sora. Dry matter content ranged from 21.80% in Romano to 22.20% in Desiree.

Sohail *et al.* (2013) reported that the local varieties consisted thick juice than HYV varieties like TPS which can be an indication of using the local varieties for ready to drink juice along with other materials like malt and flavours.

Ranjbar and Mirzakhan (2012) done an experiment with treatments included 11 cultivars of commercial and conventional potato that Ramous, Sante , Shepody, Marfona, Santana, Maradona, Milova, Boren ,Cosima,Granola, Agria. In this study growth indices such as: days to maturity, plant height, number of stems per plant, number of tubers per plant and mean weight of tubers were assessed. Results showed that all cultivars have significant different at 1% probability levels in all of growth traits. Results indicated that Cosima variety with mean weight of tubers (26.2 g) and Ramus variety with mean weight of tubers (14 g) were significantly superior to the other cultivars. The purpose of this study was to evaluate the phenology of potato cultivars in green house condition.

Schwarz and Geisel (2012) reported that storage problems most often occurred because of conditions in the field and not conditions in storage. Adverse weather, disease or improper harvesting and handling of tubers can cause problems in storage. Tubers that are rotting, frozen, chilled or diseased must be managed differently than mature, sound tubers. Good storage management will help to salvage problem tuber lots, but storage will never improve a poor-quality variety.

Karim *et al.* (2011) conducted an experiment with ten exotic potato varieties (var. All Blue, All Red, Cardinal, Diamant, Daisy, Granola, Green Mountain, Japanese Red, Pontiac and Summerset) to determine their yield potentiality. The highest total tuber weight per plant (344.60g) recorded in var. Diamant and total tuber weight plant^{-1}was the lowest (65.05 g) recorded in var. All red, all blue variety showed the most potential yield in this experiment.

Hossain (2011) ran three experiments with BARI released twelve potato varieties to determine the yield potentiality, natural storage behavior and degeneration rate for three consecutive years. He found that the highest emergence was observed in Granola at 34 DAP. At 50 DAP plant height (cm) of Diamant was (43.50 %), BARI TPS 1 (47.70 %), Felsina (52.00 %), Asterix (52.97 %), Granola (38.30 %), Cardinal (46.33 %).

Adhikari (2009) carried out a field experiment to assess the effect of NPK on vegetative growth and yield of potato cultivars; Kufri Sindhuri and Desiree. Plant height, number of stems, fresh weight of stem and leaves were recorded at 15 days interval during crop growth period and tuber yield at maturity stage. Kufri Sindhuri was taller than Desiree at all the stages of plant growth. The yield increase of potato tuber was associated with increase in the plant height, fresh weight of leaves and stems as a result of applied N.P.K.

Guler (2009) conducted an experiment and observed that first, second, third class tuber yields and total tuber yield, tuber number per plant, mean tuber weight and leaf chlorophyll were significantly influenced by potato cultivar. There were significant correlations between chlorophyll and yield and yield related characters. Total yield significantly correlated with leaf chlorophyll. Correlations between yield and total yield as well as total yield and tuber number plant^{-1} were highly significant.

Hamouz *et al.,* (2009) reported that vitamin C is the main vitamin in potatoes. Global dietary contribution of vitamin C from potatoes is important with an estimate of 40% of daily-recommended intake. Just the concentration of vitamin C is in most cases consequence of the reaction of potato varieties to climatic conditions and ways of agricultural crop management

Anonymous (2009a) conducted an experiment with three potato varieties to observe their performance on yield under different soil moisture levels. The highest plant height (50.75 cm) was found in Cardinal which was similar to Diamant (48.88 cm). The lowest plant height was observed in Granola (38.50 cm). The highest foliage coverage (93.25%) was observed in Diamant followed by Cardinal (92.75%) and the lowest in Granola (90.33%). The highest no. of stems hill^{-1} (6.25) was observed in Cardinal which was similar to Diamant (5.42) and the lowest in Granola (4.75). The highest no. of tubers hill^{-1} (13.83) was observed in Granola which was similar to Cardinal (13.33) and the lowest in Diamant (11.92).

Anonymous (2009b) conducted an experiment with twenty five varieties were evaluated at six locations. They found that, plant height (cm) was for Diamant (47.87), Sagitta (56.20), Quincy (95.40); no. of stem hill^{-1} was in Diamant (3.66), Sagitta (2.53), Quincy (2.26); Foliage coverage at 60 DAP (%) was in Diamant (73.33), Sagitta (93.67), Quincy (92.00); No of tuber hill^{-1} was in Diamant (6.72), Sagitta (3.94), Quincy (9.95); Weight of tuber hill^{-1} (kg) was in Diamant (0.30), Sagitta (0.34), Quincy (0.35); dry matter (%) in case of Diamant (19.54), Sagitta (20.10), Quincy (18.70).

Anonymous (2009c) conducted an experiment with twelve varieties were evaluated at six locations in their third generation. They found that, plant height (cm) in case of Diamant (50.93), Granola (69.10), Sagitta (41.33), Quincy (65.87); no. of stem hill^{-1} in Diamant (5.66), Granola (3.20), Sagitta (3.46), Quincy (4.86); Foliage coverage at 60 DAP (%) in Diamant (92.00), Granola (91.00), Sagitta (89.33), Quincy (96.00); no. of tuber hill^{-1} in Diamant (7.24), Granola (6.82), Sagitta (5.23), Quincy (5.76); Weight of tuber hill^{-1} (kg) in Diamant (0.38), Granola (0.26), Sagitta (0.33), Quincy (0.35); dry matter (%) in case of Diamant (20.80), Granola (20.45), Sagitta (19.80), Quincy (18.40).

Anonymous (2009d) conducted an experiment with twenty-eight varieties were evaluated at five locations. They found that, plant height at 60 DAP (cm) in case of Diamant (54.13), Sagitta (47.27), Quincy (80.93); no. of stem hill^{-1} in Diamant (4.66), Sagitta (5.40), Quincy (5.80); Foliage coverage at 60 DAP (%) in Diamant (93.67), Sagitta (90.67), Quincy (97.00); no. of tubers hill^{-1} in Diamant (8.11), Sagitta (5.41), Quincy (6.95); Weight of tubers hill^{-1} (kg) in Diamant (0.28), Sagitta (0.37), Quincy (0.45); dry matter (%) in case of Diamant (19.91), Sagitta (20.60), Quincy (18.34).

Anonymous (2009e) conducted an experiment with four exotic potato varieties along with check Diamant, Cardinal and Granola were evaluated at six locations in Regional Yield Trial. They found that plant height (cm) in case of Diamant (51.20), Cardinal (48.27), Meridian (48.33) and Laura (41.00); Felsina (82.22), Asterix (89.44), Granola (85.56), Cardinal (81.67). no. of stems hill^{-1} of Diamant was (4.06), BARI TPS 1 (3.21), Felsina (3.14), Asterix (4.03), Granola (3.30), Cardinal (3.89). Tuber yield hill^{-1} (g) of Diamant was (244.2), BARI TPS-1 (227.9), Felsina (300.1), Asterix (276.9), Granola (277.0), Cardinal (316.9). Under the grade 28-40mm, the highest number (48.63%) of seed tubers was produced by Granola which was statistically identical with Asterix (46.43%). Under the same grade (28-40 mm), the highest weight (43.46%) of seed tubers was produced by Patrone followed by Asterix (37.16%), Granola (36.64%) and Multa (35.39%) among which there was no significant variation. Cardinal (6.20), Meridian (5.67) and Laura (4.73); Foliage coverage (%) in Diamant (88.33), Cardinal (90.33), Meridian (95.67) and Laura (86.67); no. of tuber hill^{-1} in Diamant (9.48), Cardinal (9.81), Meridian (9.63) and Laura (7.50); weight of tuber hill^{-1} (kg) in case of Diamant (0.313), Cardinal (0.377), Meridian (0.490) and Laura (0.430); dry matter (%) in case of Diamant (22.69), Cardinal (21.03), Meridian (19.49) and Laura (20.22).

Anonymous (2009f) conducted an experiment with seven potato varieties were evaluated at MLT site. They found that plant height (cm) in case of Diamant (43.00), Lady rosetta (37.00), and Courage (44.47); no. of stem plant^{-1} in Diamant (3.57), Lady rosetta (2.80), and Courage (3.67); no. of tuber plant^{-1} in Diamant (8.07), Lady rosetta (5.67), and Courage (6.70).

Anonymous (2009g) conducted adaptive trails with new potato varieties at eleven districts. The mean yield of varieties over locations arranged in order of descending as BARI TPS-1 (23.87 t ha^{-1}), Granola (23.68 t ha^{-1}), Diamant (23.63 tha^{-1}), Asterix (20.83 tha^{-1}) and Raja (18.28 t ha^{-1}).

Haque (2007) ran a field experiment with 12 exotic potato germplasm to determine their suitability as a variety in Bangladesh. He found that all the varieties gave more than 90% emergence at 20-35 DAP. He also observed that plant height (cm) of Quincy was (87.8), Sagitta (65.8), Diamant (62.6); no. of stems hill^{-1} was counted in Diamant (7.2), Quincy (4.5), Sagitta (4.4); plant diameter (cm) of Sagitta was (4.0), Quincy (3.7), Diamant (2.6) at 60 DAP; foliage coverage (%) of Sagitta was (100.0), Diamant (98.3), Quincy (96.6); no. of tubers plant^{-1} of Diamant was (13.06), Sagitta (8.34), Quincy (6.71); wt. of tubers plant^{-1} (kg) of Quincy was (0.64), Sagitta (0.63), Diamant (0.49); dry matter (%) of Sagitta was (20.8), Diamant (20.1), Quincy (18.5).

Das (2006) carried out an experiment to study the physio-morphological characteristics and yield potentialities of potato varieties. He found that foliage coverage (%) of Diamant was (93.3), Asterix (71.7), Granola (66.7), Quincy (90.0), Courage (63.3), Felsina (83.3), Lady rosetta (83.3), Laura (78.3); no. of tubers hill^{-1} of Diamant (11.7), Asterix (8.00), Granola (11.3), Quincy (9.33), Courage (7.33), Felsina (8.00) Lady rosetta (10.3), Laura (8.33); tuber weight hill^{-1} (g) of Diamant (380), Asterix (285), Granola (275), Quincy (300), Courage (320), Felsina (333), Lady rosetta (348), Laura (258); dry matter (%) of Diamant (25), Asterix (17.5), Granola (23), Quincy (31), Courage (34.5), Felsina (22.5), Lady rosetta (22.0), Laura (27.0); Regarding size grade distribution of tubers the varieties Courage, Espirit, Granola, Lady rosetta, Laura were found superior.

Anonymous (2005) evaluated twenty-one varieties along with two standard checks Diamant and Granola at seven locations. The yields of the varieties varied from location to location as well as within location. Of all the stations, except Pahartoli, none crossed the check variety Diamant but comparatively higher yields were produced by the varieties Espirit, Courage, Innovator, Quincy, Matador, Markies, Laura and Lady rosetta.

Rainys and Rudokas (2005) studied with early (Goda and Voke), moderately early (Lady rosetta) and moderately late (Saturna and Heres) potato cultivars in Lithuania. Tuber yield was significantly affected by the fertilizers, genotype and weather conditions. The growing period and cultivar had significant effects on starch and dry matter contents of tubers. Averaged over the 3 years, the highest starch and dry matter contents were recorded for Lady rosetta (17.0-17.9 and 23.2-24.1%) and Saturna (17.1-17.4 and 23.5-23.8%). The cultivars had the highest starch and dry matter contents in 2002 (14.9-21.0 and 21.3-27.1%).

Mahmood (2005) was carried out an experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to investigate the effect of planting method and spacing on the yield of potato using Cv. BARI TPS-1. He found highest yield (32.5 t ha^{-1}) from BARI TPS-1.

Kumar *et al.* (2005) evaluated the result under water weight, specific gravity, dry matter and starch content of potatoes grown at Modipuram, Uttar Pradesh. He found that there was a positive correlation between under water weight and specific gravity (r = 0.99), under water weight and dry matter (r = 0.92).

Mondol (2004) conducted an experiment to evaluate the performance of seven exotic (Dutch) varieties of potato. He found that plant height (cm) of Diamant was (18.07), Granola (13.47); no. of main stem $hill^{-1}$ of Diamant (4.36), Granola (4.90); no. of tubers $hill^{-1}$ of Diamant (12.00), Granola (10.93); weight of tubers $plant^{-1}$ (kg) of Diamant (0.57), Granola (0.39); dry matter (%) of Diamant (17), Granola (16.30).

Alam *et al.* (2003) conducted a field experiment with fourteen exotic varieties of potato under Bangladesh condition. The highest emergence (91%) was observed from Cardinal which was statistically identical with most of the varieties except the variety Granola (63%). The highest number of stem $hill^{-1}$ was recorded in Ailsa (4.59) followed by Cardinal (4.50). Significantly maximum number of leaves $hill^{-1}$ was produced from the plants of the variety Ailsa (53.80), which was followed by Cardinal (49.75). The yields ranged of exotic varieties were 19.44 to 46.67 t ha^{-1} . Variety Ailsa produced the maximum yield (46.67 t ha^{-1}) which was followed by Cardinal (42.21 t ha^{-1}).

Omidi *et al*., (2003) storage problem is also a serious problem in Bangladesh. In tropical and subtropical areas like Bangladesh it is difficult to produce seed tubers of potato due to lack of appropriate storage facilities and transport, as well as the presence of viral diseases

Pandey *et al*. (2002) reported that the variety BARI TPS-1 attained higher yield due to its hybrid vigor in its first clonal generation.

Hossain (2000) conducted an experiment to study the effects of different levels of nitrogen on the yield of seed tubers in four potato varieties. He found that the tallest plants were produced by the seedling tubers of BARI TPS-1 (74.51 cm) and the shortest plants came from the variety Diamant (58.63 cm); foliage coverage (%) of Diamant at 75 DAP was (79.00), BARI TPS-1 (89.00); no. of stems $hill^{-1}$ of Diamant was (3.50), BARI TPS-1

(2.71); no. of tubers hill^{-1} of Diamant was (7.85), BARI TPS-1 (9.55); weight of tubers hill^{-1} of Diamant 30 was (416.67), BARI TPS-1 (491.33); dry matter of tuber (%) of Diamant was (19.71), BARI TPS-1 (18.18).

The Bangladesh Agricultural Research Institute (BARI) has released two hybrid TPS varieties, namely, BARI TPS-1 and BARI TPS-2. TPS seedling tubers produce higher or equivalent yield with that of standard potato varieties and can maintain better yield potential for at least 2-3 successive clonal generations of tuber production without much reduction in yield (Anonymous, 2001).

Madalageri (1999) studies on tuber uniformity and storage behaviour of 7 TPS progenies (hybrids and open pollinated progenies) in comparison with tuber planted cultivars revealed that the TPS progenies were as good as those of tuber planted crops in respect of physiological loss in weight, and frequency and weight of rotten and sprouted tubers after 3 months of storage under ambient conditions. However, only hybrid populations HPS I/13, HPS II/13 and TPS-C-3 had comparable scores with the tuber planted standard varieties in respect of tuber uniformity. The produce from open pollinated TPS families recorded significantly lower uniformity scores than their counterpart hybrid populations or the tuber planted standard varieties.

Rasul *et al.* (1997) studied storage behavior of some exotic, recommended and advanced lines of potato were studied in 1991 at RARS, Jessore by storing their tubers in netted wooden box under natural condition. Much variation was observed among the varieties/lines for all the characters studied. Percent weight loss was higher in exotic varieties (12.89-35.52%). Cent percent sprouting was earlier in recommended varieties/lines (96 days) than of exotic ones (118.7 days). On an average, tubers shrank earlier in existing varieties per lines than first generation materials. Rottage of tubers by bacterial soft rot (Erwinia sp) during storage varied from 31.3 to 36.8%. Recommended varieties Kufri, Sindhuri, Cardinal, Multa, advanced lines P-93 and first-generation varieties viz. Granoloa, Modial, Producent and Vital performed the best on the basis of studied storage characteristics.

Rabbani and Rahman (1995) studied the performance of 16 Dutch potato varieties in their third generation. They reported that the height of the plants significantly varied among the varieties. The highest foliage coverage at maximum vegetative growth stage was found in the variety Cardinal (93.3%) followed by Diamant. The highest yield of tubers per hectare was obtained from Cardinal (35.19 t ha^{-1}) followed by Romano (30.09 t ha^{-1}) and the lowest from Stroma (11.11 t ha^{-1}).

Hossain *et al.* (1992) reported that the maximum tuber weight loss was (31.15%) recorded in the check variety Cardinal. In case of indigenous varieties, Jalpai lost maximum weight (19.16%) and Shilbilati lost the minimum (9.15%). The authors also reported that sprouting of tubers was started after 83 days in indigenous cultivars, while Cardinal sprouted first after 54 days of storage. In case of indigenous varieties, Bograi sprouted first after 70 days and Hagrai was most delayed (97 days).

Hossain and Rashid (1991) studied storage quality of three sizes of tubers of eight TPS progenies against standard variety Cardinal for 120 days after harvest (April to July) under natural storage condition. Weight loss of tubers due to transpiration and respiration was 23.93% in TPS progenies and 11.95% in Cardinal with average monthly loss of 5.98% and 2.99%, respectively. Small size tubers were found to suffer most from dehydration. *Erwinia sp.* and *Fusarium sp.* have been identified to cause rotting of tubers in storage. The incidence of soft rot and dry rot were 33.40% and 34.15%, respectively. No rot was observed in Cardinal during the period of study. Maximum potato loss was recorded in large size tubers. Tubers of the TPS progenies sprouted earlier than Cardinal. Maximum number of sprouts per tubers and length of the longest sprout were recorded in TPS progenies. Tubers of TPS progenies shriveled earlier than Cardinal. Usually, in Bangladesh, storage of potato starts during the month of March when both temperature and humidity rise up sharply which accelerates both physiological activities of tubers responsible for its deterioration and activities of the organisms responsible for various storage diseases. It has been reported (Anon., 1989) that the local varieties have a long period of dormancy and both and seed potatoes cm be stored at home without much physiological deterioration until the next planting season.

Anonymous (1989) observed that during storage period sprouting of tubers is an important evaluator character of varieties. As soon as sprouting starts, the tubers rapidly loss its quality. Unfortunately, the potato tubers cannot store for more than 4 to 5 months without much deterioration of quality under ordinary storage conditions. Exotic varieties sprouted earlier than the local ones. Sprouting in local varieties was first to observed after 102 days. It was also observed that the average dormancy period was higher in local varies (95 days) than the exotic varieties (83 days).

Sowa and Kuzniewicz (1989) studied the causes of loss during potato storage and indicated that the main causes of storage losses were respiration, evaporation and storage rot. In that study, storability was largely a varietal trait, although environmental conditions during both growth and storage were also important. Storage losses were lowest in the clone Clamp (4.4%) which increased with increasing temperature in the store (about 9%). Overall storage losses ranged from 9.4% in Janka to 32.5% in Sasanka. Storage losses due to rots ranged from 0.8% in Azalia to 22.69% in Sasanka.

Lisinska and Leszezynski (1989) stated that all the losses observed during potato storage, in respective of storage methods could be divided into two groups. Quantitative losses included weight losses of tubers due to vital process of tubers (respiration, evaporation, sprouting) and those resulting from parasites and pathogenic micro flora. The extent of such losses, apart from varietal properties is affected by the maturity and wholesomeness of tubers as well as internal condition of storage house. Quantitative losses are more difficult to detect since they do not reveal any decrease in the weight of tubers. They include quantitative losses of specific components but total content of dry matter not change significantly. Obviously, the difference between two groups of losses has only theoretical significance.

Potato is a perishable commodity and three variables determine storage losses in potatoes: i) quality of the tuber at the beginning of the storage, ii) storage conditions and iii) duration of storage (Barton *et al*., 1989). Storage losses are often specified as weight losses and losses in the quality of potatoes which are caused by respiration (Basker 1975); sprouting (Amoros *et al*., 2000); evaporation of water from the tubers (Kabira and Berga 2003); changes in chemical composition and physical properties of the tuber (Cronk *et al*., 1974; Maga 1980) and damage by extreme temperatures (Linnemann *et al*., 1985).

Picha (1986) stated that no sprouting was found when cured sweet potatoes were stored at 15.6°C and 90% RH for up to a year. The total weight loss of six cultivars was estimated. Transpiration played vital role for weight loss. Respiration contributed more total weight loss during the later period of storage than first month in storage. In Korea Republic sweet potatoes cv. Hongi, Eunmi, Hwangi and Sinmi were stored in man-made cave (0-15°C, 15-75% RH) or a store house (15-18°C, 80-85% RH). After a period of three months in the cave storage, tuber decomposition was less for sweet potatoes stored in the middle of the cave than for those stored at the entrance.

Decomposition became the highest at cave than in the storehouse (Lee *et al.,* 1985). During the year 1980-81 the storage performance of some exotic and local cultivars of sweet potato was studied at the Bangladesh Agricultural University Farm. Among the cultivars studied, the storage ability of the cultivars ACC-6, TIS-3032, TIS-3247, AIS-230 and AIS-243-2 was quite good. New 10 and TIS 3032 showed the long dormancy period (Hossain *et al*., 1984).

The indigenous potato varieties showed a capability to store well and have a general popularity for taste (Ahmad and Kader, 1981). They observed that when stored under non-refrigerated conditions, the indigenous varieties showed a longer dormancy and stored better.

Storage life of potato tubers mainly depends on temperature and humidity which influence evaporation, respiration, sprout growth and ultimately weight loss of tubers. Low temperature and high humidity in storage results gave minimum loss. The local varieties are liked by the farmers, keep well under ordinary room condition and possess a high market value (Khan *et al.*, 1981).

Ahmad (1979) reported that the farmers of the north-west part of Bangladesh use local varieties of potato instead of high yielding exotic varieties only because they had a longer dormancy and keeping quality even under ordinary storage.

2.2 Influence of organic manures on yield and quality of potato

Akbasova *et al.* (2015) conducted an experiment and reported that the increase of root crops yields 1.2-1.5 times in making 8 t ha^{-1} vermicompost in gray soils was established. It was shown that the use vermicompost as a fertilizer was more expedient, as it contains more nutrients (N.P.K) and organic humic acids compared to conventional compost. Vermicompost has a direct physiological effect on plants; it stimulates the development of root systems and reduces the harmful effects of pollutants.

Shirzadi (2015) was done the study in order to evaluate the use of organic fertilizers (Vermicompost and Chicken manure) on the plant's height and number and weight of micro tuber Marfona cultivator potato (diameter of 25 to 35mm) with 2 factors of vermicompost in 4 levels (0,3,6 and 9 t ha^{-1}) and chicken manure in 4 levels (0,10,12 and 14 t ha^{-1}). The result showed that with increasing vermicompost fertilizer, plant's height was reduced. Also highest number and weight of tubers with a diameter of 25-35mm belonged to 12 tons chicken manure treatment without vermicompost.

Ramamurthy *et al*. (2015) was conducted an experiment to show the Influence of different percentages of vermicompost (25%, 50%, 75% and 100%) on the tuber length, width, circumference and weight of the radish plant (*Raphanus sativus* L.) was carried out at different period of exposures (30, 60 and 90 days). The maximum tuber length (20.67, 23.67 and 27.55cm) and weight (189.31, 215.31 and 244.64g) were noticed in 75% of vermicompost concentration at 30, 60 and 90 days respectively except tuber width and circumference. During 60 and 90 days of exposure the maximum width and circumference were noticed in 50% of vermicompost and thereafter both width and circumference decreased in commensurate with increasing vermicompost concentration. The study reveals the 75% concentration of the vermicompost influence the tuber yield status of Radish plant.

Kashem *et al.* (2015) conducted a study attempted to compare the effect of cow manure vermicompost and inorganic fertilizers on the vegetative growth and fruits of tomato plant (*Solanum lycopersicum* L.). An air dried sandy loam soil was mixed with five rates of vermicompost equivalent to 0 (control), 5, 10, 15 and 20 t ha^{-1} and three rates of NPK fertilizer equivalent to 50% (N-P-K = 69-16-35 kg t ha-1), 100% (N-P-K = 137-32-70 kg ha-1) and 200% (N-P-K = 274-64-140 kg ha^{-1}).The data revealed that stem length, number of leaves, dry matter content of stems and roots, fruit number and fruit weight were influenced significantly ($P < 0.05$) by the application of vermicompost and NPK fertilizer in the growth media. The highest dose of vermicompost of 20 t ha^{-1} increased dry weight of stem of 52 folds and root of 115 folds, number of fruit(s)/plant of 6folds and mean fruit weight of 29 folds while the highest rate of NPK fertilizer of 200% increased dry weight of stem of 35 folds and root of 80 folds, number of fruit(s)/plant of 4 folds and mean fruit weight of 18 folds over the control treatment. The growth performance of tomato was better in the vermicompost amended soil pots than the plants grown in the inorganic fertilizer amended soil pots.

Katar *et al*.(2014) conducted a field experiment at instructional Farm of N.D. University of agriculture and technology, Narandra Nagar (Kumarganj), Faizabad during two consecutive year of 2010-11 and 2011- 12. Potato cv. Kufri Ashoka was evaluated with seven treatment T_1 = Full recommended NPK (150:100:120) kg ha^{-1} through inorganic fertilizer, T_2 = FYM @ 20 t ha^{-1} , T_3 = FYM @ 10 t ha^{-1} + ½ NPK through inorganic fertilizer, T_4 = Vermicompost @ 5 t ha^{-1} , T_5 = Vermicompost @ 2.5 t ha^{-1} + 1/2 NPK through inorganic fertilizer, T_6 = Neem cake @ 3 t ha^{-1} , T_7 = Neem cake @ 1.5 t ha^{-1} + 1/2 NPK through inorganic fertilizer. Thus twenty seven treatment combinations were arranged in random block design with three replications. Results obtained after the successful conduct of the experiment and statistical analysis of data revealed that the height of plant, number of compound leaves $hill^{-1}$, number of haulms $hill^{-1}$, yield attributes and yield. Further number of A, B, C and D grade tubers $plot^{-1}$, percent of A, B, C and D grade tubers $plot^{-1}$, yield of A, B, C and D grade tubers $plot^{-1}$ (kg), total number of tubers $plot^{-1}$, total weight of tubers $plot^{-1}$ (kg) and tuber yield (t ha^{-1}) showed the beneficial response by the use of integrated levels of NPK, FYM, Vermicompost and Neem Cake. However, on the basis of pooled data it was also further observed that the application of 150:100:120 kg NPK, 20 ton FYM, 5 ton Vermicompost and 3 ton Neem Cake ha^{-1} brought paramount of improvement in growth and tuber yield of potato.

Chandresh *et al.* (2014) conducted a field experiment at Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G) during rabi 2010-11 and 2011-12. The experiment was laid out in split–split plot design with three replications. The treatments consisted of three irrigation schedule i.e. drip irrigation (125 % of OPE), drip irrigation (100 % of OPE) and control (furrow irrigation) as a main plot and four weed management i.e. weedy check, hand weeding (at 25 and 45 DAP) metribuzin (500 g a.i.ha^{-1} PE) and chlorimuron + quizalofop (6 + 50g a.i ha^{-1}) at 20 DAP as sub plot and four integrated nutrient management i.e. 100 % RDF, 100 % RDF + Micro nutrient (Zinc sulphate 25 kg ha^{-1}), 75 % N inorganic fertilizer + 25 % N poultry manure + PSB + Azatobactor and 50 % N inorganic fertilizer + 50 % N poultry manure + PSB + Azatobactor as sub sub plot. Kufri Chipsona-2 variety was used for experiment, the spacing of crop is 60cm×20cm. Application of 75% N inorganic fertilizer + 25 % N organic (Poultry manure) + PSB + Azotobactor) was found non significant to weed control while produced significantly highest yield attributes and total tuber yield.

Panwar and Wani (2014) a field experiment was done in the sweet potato filed with Nitrogen, Potash, and Phosphorus was applied in form of organic manure Farm yard Manure, Vermicompost, and Neemcake. (Vermicompost) recorded highest survival percent, length of vine, number of branches/vines, stem fresh weight, stem dry weight, tuber yield $plot^{-1}$, number of tuber $plot^{-1}$ under poplar trees. The maximum Gross return was noticed in with Rs. 99204.00. The maximum Benefit cost ratio was noticed in with 1:1.37.

Singh and Chauhan (2014) conducted an experiment and the results revealed that plant per meter row length, height of main stem, dry matter (g) and number of leaves/plant higher in treatment (1/3 N-FYM+1/3N-Vermicompost + 1/3N-Neem cake plus agronomic practices). On an average treatment (1/3 N-FYM + 1/3N-Vermicompost + 1/3N-Neem cake plus agronomic practices) for weed and pest control (without chemical) significantly maximum tuber yield and A grade B grade and C grade tuber of potato.

Singh *et al.(*2014) done a field experiment was conducted for two years to investigate the effect of vermicompost, organic mulching and irrigation level on growth, yield and quality attributes of tomato (*Solanum lycopersicum* L.). The vermicompost together with organic mulching increased plant height (106.5 cm), leaf area (40.6 cm^2), leaf weight (1301 mg/ leaf), fruit weight (92.9 g), fruit yield (4.013 kg $plant^{-1}$), fruit density (0.972 g cc^{-1}), post-harvest shelf-life (15.0 days) and TSS (5.2^o Brix) of tomato significantly. Application of vermicompost alone too increased the shelf-life of fruits by 25-106 % and TSS beyond 4.5%, both of which are traits highly desirable for production of summer tomato and the related processing industry. The application of vermicompost @ 5 t ha^{-1}, 5 cm thick mulching with dried crop residues, two-thirds dose of NPK fertilizer (80:40:40 kg ha^{-1}) and 30 % irrigation is optimum for obtaining better quality and productivity of field grown tomatoes during dry period of mild-tropical climate.

Narayan *et al.* (2014) conducted a field experiment during the rainy (kharif) seasons of 2008 and 2009 at Shalimar, Srinagar in a split plot design having 3 dates in the main plots and 6 sources of nutrients through the combinations of organic and inorganic fertilizers in the sub-plots with 3 replications, to find out their effect on productivity and profitability of potato (*Solanum tuberosum* L.). Among the dates, planting on 25 March recorded significantly higher tuber yield (35.7 t ha^{-1}) and benefit: cost ratio (1.89) than that sown on 10 March and 11 April during both the years. Plant height, number of stems, stem dry matter, leaf-area index (LAI) and number of tubers $hill^{-1}$ (11.48) were also the highest in 25 March planting as compared to the other planting dates. Application of 75% of full recommended dose of fertilizers (RDF) (120:75:75 NPKha-1) + 8 t ha^{-1} vermicompost + pre-sowing tuber treatment with Azotobacter and phosphorus- solubilizing bacteria proved significantly superior in terms of number of tubers $hill^{-1}$, harvest index, tuber yield (32.7 t ha^{-1}) and benefit: cost ratio (1.75) of potato over rest of the treatments during both years.

Mária *et al.* (2013) conducted an experiment with maize grown for grain were 4 treatments established – a control treatment and three treatments with dose increasing of granulated vermicompost (4.6; 9.2; 11.6 t ha^{-1}, respectively), which supplied 57, 114 and 142 kg ha^{-1} total nitrogen to the soil, respectively. The experiment was not irrigated. The experiment with potatoes included 7 treatments of fertilization. The first treatment was a control treatment, i.e., without the appliance of dry granulated vermicompost. In treatment 2 to 6 increasing doses of vermicompost (3.3; 6.6; 9.9; 13.2 and 19.8, respectively) were applied. Through the following doses of granulated vermicompost were applied to the soil 40, 80, 120, 160, 240 kg ha^{-1} N. Not only was the granular vermicompost applied in treatment 7, but also the industrial NPK fertilizer (150 kg urea + 200 kg ha^{-1} NPK 15-15-15. The grain yield was increased with the dose increasing of vermicompost. A thousand kernel weight, starch content and magnesium content parameters with the increasing dose of vermicompost were reduced. A dose of 4.6 t ha^{-1} vermicompost seems like the most appropriate for the parameters of a thousand kernel weight, starch and magnesium content. The increasing doses of vermicompost significantly increased the yield of potato tubers, starch content and dry matter content in tubers. The application of granulated vermicompost reduced vitamin C content in potato tubers. The use of fertilizers resulted to increasing the nitrate content in potato tubers however the application of granulated vermicompost has increased the contents of nitrates to a lesser extent than the joint application of NPK fertilizer and granulated vermicompost.

Mojtaba *et al.* (2013) conducted an experiment on which experimental factors included nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels 0 (control), 4.5, 9, and 12 t ha^{-1}). Results illustrated that the highest amount of plant height, leaf and stem dry weight, Leaf area (LA), fresh and dry weight of tuber, total tuber weight, total number of tubers, tuber diameter, nitrogen percent of tuber, potassium percent of tuber and phosphorous percent of tuber were found from application of 150 kg N ha^{-1}. Data also demonstrated that vermicompost application at the rate of 12 t ha^{-1} promoted all above traits except plant height in compared to control treatment. Furthermore, the interaction effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and N.P.K content of tuber compared with nitrogen and/or vermicompost alone treatments. To gain highest yield and avoidance of environments pollution use of 150 kg N ha^{-1} nitrogen fertilizer and vermicompost application of 12 t ha^{-1} are suggested.

Raja and Veerakumari (2013) conducted an experiment and find the impact of vermicomposts *viz.* Cowdung vermicompost, leaf ash vermicompost and poultry feather vermicompost on the yield and alkaloid content of medicinal plant, *Withania somnifera* were assessed and compared with the plants cultivated in the soil amended with chemical fertilizer and the plants cultivated without any fertilizer (control). The plant growth parameters such as stem length, root length, stem dry weight, root dry weight, stem wet weight, root wet weight, stem : root ratio and the alkaloid with aferin A and with anolide D were significantly increased in the plants cultivated in the soil amended with poultry feather vermicompost.

Meena *et al.* (2013) conducted a field experiment during 2008-09 and 2009-10 at New Delhi, to study the effect of organic sources of nutrients on growth, yield and yield attributes of pop corn (*Zea mays* averta Sturt)-potato (*Solanum tuberosum* L.) cropping system. The experiment consisted of 24 treatment combinations with 8 treatments in pop corn [control, recommended dose of fertilizers (RDF) (N 120 P 25 K 35 kg ha^{-1}), farmyard manure equivalent to 120 kg N ha^{-1} (FYM 120), leaf compost equivalent to 120 kg N ha^{-1} (LC 120), vermicompost equivalent to 120 kg N ha^{-1} (VC 120), farmyard manure equivalent to 90 kg N ha^{-1} (FYM 90), leaf compost equivalent to 90 kg N ha^{-1} (LC 90) and vermicompost equivalent to 90 kg N ha^{-1} (VC 90)] and 3 treatments in potato crop [control, farmyard manure equivalent to 60 kg N ha^{-1} (FYM 60) and farmyard manure equivalent to 90 kg N ha^{-1} (FYM 90)]. The application of RDF (N 120 P 25 K 35 kg ha^{-1}) recorded significantly highest plant height, leaf-area index and dry matter with higher values of yield attributes, viz. cob length and girth, cobs ha^{-1} over the control.

Application of vermicompost equivalent to 120 kg N ha^{-1} was the best source and remained at par with VC 90, FYM 120, FYM 90 and N 120 P 25 K 35 kg ha^{-1} for growth and yield attributes of pop corn. Similar trend in respect of grain and stover yield was also found. Due to residual fertility of FYM (equivalent to 120 kg N ha^{-1}) potato recorded the highest plant height, LAI, number of haulms and dry matter in haulms. Both FYM (equivalent to 90 kg ha^{-1}) and vermicompost (equivalent to 120 kg N ha^{-1}) exhibited the effects similar to FYM @ 120 kg N ha^{-1}. The yield and yield attributes of potato, viz. tubers $hill^{-1}$, fresh and dry weight of tubers, tuber yield and haulm yield also exhibited similar trend. Regarding direct effects of FYM, application of FYM equivalent to 90 kg N ha^{-1} in potato recorded the higher plant height, LAI, haulms $hill^{-1}$, dry matter in haulms; and yield and yield attributes compared to FYM equivalent 60 kg N ha^{-1} and control.

Mike *et al.* (2013) conducted a field experiment in North East England over six years (2004-2009) as part of a long-term factorial field trial about the effects of organic versus conventional crop management practices (fertilization, crop protection) and preceding crop on potato tuber yield (total, marketable, tuber size grade distribution) and quality (proportion of diseased, green and damaged tubers, tuber macro-nutrient concentrations) parameters. Inter-year variability (the effects of weather and preceding crop) was observed to have a profound effect on yields and quality parameters, and this variability was greater in organic fertility systems. Total and marketable yields were significantly reduced by the use of both organic crop protection and fertility management. However, the yield gap between organic and conventional fertilization regimes was greater and more variable than that between crop protection practices. This appears to be attributable mainly to lower land less predictable nitrogen supply in organically fertilized crops. Increased incidence of late blight inorganic crop protection systems only occurred when conventional fertilization was applied. In organically fertilized crops yield was significantly higher following grass red-1 clover leys than winter wheat, but there was no pre-crop effect in conventionally fertilized crops. The results highlight that nitrogen supply from organic fertilizers rather than inefficient pest and disease control may be the major limiting factor for yields in organic potato production systems.

Meena Kumari and Shekhar (2012) conducted an experiment to determine the effect of vermicompost and other fertilizers on growth, yield and fruit quality of tomato in the field condition. The field trails were conducted using different fertilizers having equal concentration of nutrients to determine their impact on different growth parameters of tomato plants. Six types of experimental plots were prepared where it was kept as control and five others were treated by different category of fertilizers Chemical fertilizers, Farm Yard Manure (FYM), Vermicompost, and FYM supplemented with chemical fertilizers and vermicompost supplemented with chemical fertilizer respectively). The treatment plots showed 73% better yield of fruits than control. Besides, vermicompost supplemented with N.P.K treated plots displayed better results with regard to fresh weight of leaves, dry weight of leaves, dry weight of fruits, number of branches and number of fruits per plant from other fertilizers treated plants.

Singh *et al.* (2013) conducted a field experiment during winter (rabi) season of 2007- 08 to Kharif season of 2009-10 to evaluate lower doses of FYM (2, 4 and 6 tonnes FYM ha^{-1}) in combination with three NPK levels (180:34.9:100, 270:52.4:150 and

360:69.8:200 kg ha^{-1}) for potato at CPRI Station, Gwalior, Madhya Pradesh . Sesame was grown on residual fertility in sequence. Integrated use of NPK 270:52.4:150 kg ha^{-1} along with 2 tonnes of FYM ha^{-1} recorded highest benefit :cost ratio (2.2). Increasing application of NPK (180:34.9:100 to 270:52.4:150 kg ha^{-1}) increased large-sized tuber yield (7.5 - 8.5 tonnes ha^{-1} and total tuber yield (28.4 - 32.4 tonnes ha^{-1}), however application of 2, 4 or 6 tonnes FYM ha^{-1} did not show any significant increase in total tuber yield. Increasing NPK levels increased potato equivalent yield from 32.2 to 37.3 tonnes ha^{-1} . Higher net return of 85.6 x 103 ha^{-1} was obtained with 2 tonnes FYM ha^{-1} compared to 4 and 6 tonnes FYM ha^{-1}. There was no significant effect of organic and inorganic nutrient doses on cutworm damage on potato crop.

Meena *et al.* (2012) conducted a research on to evaluate the growth, yield and economics of baby corn (*Zea mays* L.) potato (*Solanum tuberosum* L.) - mungbean (*Vigna radiata* L.) cropping system under different combinations of farm yard manure and bio-compost with chemical fertilizers at New Delhi during 2007-08 and 2008-09. The fertility level of N 90 P 20 K 25 + BC equivalent to 30 kg N ha^{-1} being at par with N 120 P 26 K 33 recorded the highest growth and yield parameters with 57.0 and 31.9 % more baby corn and green fodder yield compared to control, respectively. Similarly in potato application of N 60 P 17 K 42 + BC equivalent to 60 kg N ha^{-1} recorded the highest growth and yield attributes with the maximum tuber yield of 24.2 t ha^{-1}, which was 10.5 and 49.3 % higher as than 100% NPK and control , respectively. However, data of potato on residual fertility levels indicated that N 60 P 13 K 17 + FYM equivalent to 60 kg N ha^{-1} recorded the maximum growth and yield attributes; and tuber yield while, lowest values were recorded on 100 % NPK application as fertilizer. Similarly, the highest values of yield attributes, seed and stover yield of mungbean were recorded under 50% RDF + 50% N through FYM applied to both baby corn and potato, which was found at par with 50% RDF + 50% N through BC and remained significantly superior over other treatments. The net returns (91,164/ha) and B:C ratio (1.7) of baby corn- potato- mungbean cropping system were maximum with application of 75% NPK+25% N through FYM to baby corn and 50% NPK + 25% N through FYM , respectively.

Kumar *et al*. (2012) conducted a field experiments with farm yard manure (FYM), poultry manure (PM), vermicompost (VC) and solubilizing bacteria (PSB) and *Azotobacter* + PSB) in sub plots. The results showed that 50 % of the recommended dose of NPK through inorganic + 50% recommended dose of nitrogen (RDN) through organic manures

(FYM, PM or VC) or 100% recommended dose of NPK through inorganic fertilizers alone favorably influenced the tuber yield, nutrient uptake, soil fertility and paid higher returns compared to other treatments. Seed treatment with *Azotobacter* + PSB proved better in tuber yield, nutrient uptake and recorded higher returns as compared to sole treatment of either *Azotobacter* or PSB. Three years pooled result revealed that integrated application of 50 % of recommended NPK through inorganic and 50 % RDN through PM recorded significantly highest tuber yield (22.73 t ha^{-1}) closely followed by 100 % recommended NPK through inorganic (22.20 t ha^{-1}) which were 228 % and 223 % respectively, higher than control. Integrated application of inorganic and organic fertilizers and seed treatment with *Azotobacter* + PSB biofertilizers improved tuber yield, nutrient uptake, and gave higher return as compared to other treatment combinations. Total organic carbon (TOC), soil microbial biomass carbon (SMBC), available N, P, and K status of the soil after 3 years were maximum when 50% recommended dose of NPK were applied through inorganic and remaining 50 % RDN through PM.

Zandonadi and Busato (2012) reported that vermicomposting and its products represents a crucial ecofriendly technology capable of recycling organic wastes to be used as fertilizers. Through its hormone-like substances, vermicompost, liquid humus or worm bed leachate stimulates plant growth. Additionally, manipulation of microbial population presents in vermicompost and its products may increase both nutrient content and availability.

Goutam *et al.* (2011) was conducted field trials using different fertilizers having equal concentration of nutrients to determine their impact on different growth parameters of tomato plants. Six types of experimental plots were prepared where was kept as control and five others were treated by different category of fertilizers i.e. Chemical fertilizers, Farm Yard Manure (FYM), Vermicompost, and FYM supplemented with chemical fertilizers and vermicompost supplemented with chemical fertilizer respectively).The treatment plots showed 73% better yield of fruits than control, Besides, vermicompost supplemented with N.P.K treated plots displayed better results with regard to fresh weight of leaves, dry weight of leaves, dry weight of fruits, number of branches and number of fruits per plant from other fertilizers treated plants.

Sarker *et al*., (2011) conducted a field experiment during winter of 2005-06 and 2006-07 at Hooghly, West Bengal to investigate the effect of different organic and inorganic sources of nutrients on productivity and profitability of potato (*Solanum tuberosum* L.) cultivars. The treatments consisted 3 varieties, viz. Kufri Chipsona-1, Kufri Chipsona-2 and Kufri Jyoti in main-plots and 4 nutrient sources, viz. Farmyard manure (FYM) @ 35 t ha^{-1} (N1), FYM @ 30 t ha^{-1} + biofertilizers (N_2), FYM @ 25 t ha^{-1} + mustard cake @ 1 t ha^{-1} (N_3), recommended dose of NPK i.e. 180:66:125 kg ha^{-1} N, P, K (N_4) in sub-plots. Varieties had significant variations in growth and yield attributes, yield and nutrient uptake. Higher growth attributes were recorded under Kufri Chipsona-1 except plant height. Hence, Kufri Chipsona-1 gave maximum number of tubers, total tuber yield (28.18 and 28.39 t ha^{-1}), NPK uptake, net profit and B:C ratio (1.28, 1.22). Among sources of nutrient recommended dose of NPK showed better performance in all respects and registered 4.7 to 9.7% more tuber yield when compared with other nutrient sources. The highest B:C ratio (1.34, 1.29) was also recorded in recommended dose of NPK treatment. Higher dry weight of tubers (718.15, 722.40 g/m^2), number of tubers (680.21, 690.74 thousand ha^{-1}) and tuber yield (29.44, 29.89 t ha^{-1}) were obtained from Kufri Chipsona-1 potato treated with recommended dose of NPK.

Shweta and Sharma (2011) was conducted an experiment with application of organic manures along with chemical fertilizers had a significant effect on the tuber and haulm yield. Highest tuber (30.46t ha^{-1}) and haulm yield (9.04 t ha^{-1}) was recorded with application of 100 % NPK + 25 t ha^{-1} vermicompost and was significantly higher over sole use of chemical fertilizers. Tuber yield of potato recorded under 100% of recommended dose of NPK without organics (21.39 t ha^{-1}) was at par with 25 t FYM/ha or 12.5 t VC/ha applied along with 75% of recommended dose of NPK thereby, indicating a saving of 25% in NPK.

Baishya *et al.* (2010) conducted a field experiment during summer seasons of 2005 and 2006 at Shillong in split plot design having three potato varieties in the main plots and six organic-inorganic nutrient combinations in the sub-plots with four replications. Among the varieties, Kufri Megha recorded significantly higher tuber yield when compared with Kufri Giriraj and Kufri Jyoti. Number of tubers $plant^{-1}$, mean tuber weight, marketable and total tuber yield of potato increased significantly due to the use of recommended dose of fertilizers (RDF) i.e. 120-52.4-50 kg N-P-K ha^{-1} or 75% RDF + 25% recommended dose of N (RDN) through FYM. The yield components and tuber yield decreased gradually as the crop received higher proportion of plant nutrients through FYM. Accordingly, substitution of RDN by FYM resulted in lower tuber productivity which was significantly lower than those of other organic-inorganic combinations except control. Kufri Megha receiving RDF or 75% RDF + 25% RDN through FYM produced the highest tuber yield (27.11/26.98 t ha^{-1}) among all treatment combinations. High net return was obtained from the crop receiving 100% RDF or 25% RDN through FYM + 75% RDF. Kufri Megha at RDF or 75% RDF + 25% RDN through FYM may be recommended for better growth, higher tuber yield and greater net return from potato cultivation in the North Eastern Hill Region of Meghalaya.

Urkurkar *et al.* (2010) conducted field experiments at Raipur in Inceptisols between 2003-04 and 2007-08 to compare organic, integrated and chemical fertilizer nutrient inputs pakages in scented rice (*Oryza sativa* L.) – potato (*Solanum tuberosum* L.) a high value cropping system. Seven different nutrient treatments, 5 of them having use of organic inputs and 1 each having integrated (50% through fertilizers and 50% through organic nutrients) and 100%through fertilizers were studied in RBD with 3 replications. Organic transition effect in which decline in yield from 1to 3 years and again increase in yield was noticeable in rice under organic nutrient inputs packages. These treatments followed a steady increase and registered 20 to 50% more yield at the end of study compared to first year yield i.e. 2003-04. However, effect of different organic inputs packages on potato tuber yield was not stable over the years. Total productivity in terms of rice equivalent yield of the system (13.36 ton ha^{-1}) and total net return (Rs. 92, 634 kg^{-1}) was highest with chemical fertilizer treatment closely followed by integrated inputs use. 100% N (1/3 each from cowdung manure, neem cake and composed crop residue) appreciably increased the organic carbon (6.3 g kg^{-1}) over initial value (5.8 g kg^{-1}). However, availability of P and K did not show any perceptible change after completion of five cropping cycles under organic as well as integrated nutrient approaches.

Ansari (2008) study the effect of vermicompost application in reclaimed sodic soils on the productivity of potato (*Solanum tuberosum*), spinach (*Spinacia oleracea*) and turnip (*Brassica campestris*). The soil quality was monitored during the experiment followed by productivity. The treatments were 4, 5 and 6 t ha^{-1} of vermicompost as soil application in plots already reclaimed by Vermitechnology. Among the different dosages of vermicompost applied there has been a significant improvement in the soil quality of plots amended with vermicompost @ 6 t ha^{-1}. The overall productivity of vegetable crops during the two years of the trial was significantly greater in plots treated with vermicompost @ 6 t ha^{-1}. The present investigation showed that the requirement of vermicompost for leafy crops like spinach was lower (4 t ha^{-1}), whereas that for tuber crops like potato and turnip was higher (6 t ha^{-1}).

Alam *et al.*(2007) An experiment was conducted to study the effect of vermicompost and NPKS fertilizers on growth and yield of potato (cv. Cardinal) in Level Barind Tract (AEZ-25) soils of Bangladesh. The organic matter of the experimental field soil was very low and in case of N, P, K and S also low. 1 The land was medium fertile and P^H was 5.4. There were 12 treatments *viz*. control , vermicompost 2 3 4 5 (VC) 2.5 t ha^{-1}, VC 5.0 t ha^{-1}, VC 10.0 t ha^{-1}, VC 2.5 t ha^{-1} + 50% NPKS . VC 5 t ha^{-1} + 50% 6 7 8 9 NPKS , VC 10 t ha^{-1} + 50% NPKS , VC 2.5 t ha^{-1} + 100% NPKS , VC 5 t ha^{-1} +100% NPKS , 10 11 12 VC 10 t ha^{-1} + 100% NPKS 50% NPKS and 100% NPKS. The experiment was laid out in RCBD with three replications. The doses of N-P-K-S were 90-40-100-18 kg ha^{-1} for potato. Application of 10 vermicompost and NPKS significantly influenced the growth and yield of potato. The treatment produced the highest (25.56 t ha^{-1}) tuber yield of potato. The lowest yield and yield contributing parameters recorded in control. Application of various amounts of vermicompost (2.5, 5, 10 t ha^{-1}) with NPKS fertilizers (50% and 100%) increased the vegetative growth and yield potato. Vermicompost at 2.5 5 and 10 t ha^{-1} with 50% of NPKS increased tuber yield over control by 78.3, 96.9 and 119.5 t ha^{-1} respectively. And vermicompost at 2.5, 5 and 10 t ha^{-1} with 100% of NPKS increased tuber yield by 146.8, 163.1and 197.9 %, respectively. The results indicated that vermicompost (10 t ha^{-1}) with NPKS (100%) produced the highest growth and yield of potato.

Raghab *et al.* (2007) conducted a field experiment at Vegetable Research Centre, Pantnagar, Uttarakhand during 2003-04 and 2004-05 with potato cultivar K. Chipsona-2. The growth parameters and yield of potato was significantly influenced by the organic manures and chemical fertilizers. Maximum plant height (68.66 cm), number of haulms per hill (7.55), number of tubers per hill (8.33), weight of tuber per hill (626.66 g), dry matter content of tuber (26.30%), total soluble solids (5.03° B), specific gravity (0.975 g/cm3) and yield (245.60 g ha^{-1}) were recorded with the application of 100% recommended dose of NPK (160:100:120 kg ha^{-1}) + 10 t FYM followed by 100% of recommended dose of NPK alone. Maximum number and weight of A and B grade tubers were recorded in treatment T_4 and T_5, respectively. The highest net income as well as benefit: cost ratio (1:25) were obtained with the application of 100% NPK.

Zavalin (2005) reported that rational use of fertilizers, ameliorants is one of the most important measures for improving soil fertility and increase of agricultural crops productivity. Special prospects were presented by the innovative eco-friendly bio-organic fertilizer, enabling alternatively to implement the replacement of traditional fertilizers, including a certain amount of pollutants of various natures in its structure a certain. For example, the uncontrolled use of nitrogen fertilizers in large quantities (60 kg of active ingredient ha^{-1}) suppresses the natural biological process of nitrogen fixation in the soil, causing the accumulation of nitrates and nitrites in the plants.

Sood and Sharma (2001) was doing a field experiments during 2000 at Shimla for assessing the utility of growth promoting bacteria, *Azotobacter* & Vermicompost for potato production indicated 'that *Bacillus cerus* (A) and *Bacillus subtilis* (B) separately increased the tuber yield of potato from 115 to 268 q ha^{-1} par with 100% NPK treatment. Vermicompost @ 5 t ha^{-1} increased the tuber yield by 34 to 65 q ha^{-1}. The increase in yield was more when optimum NPK dose of fertilizer was applied. Inoculation of seed tubers with *Azotobacter* in the absence of N increased the tuber yield by 68 q ha^{-1} and the effect of *Azotobacter* decreased gradually as the dose of N was increased. Vermicompost can be a good substitute for chemical fertilizers to overcome their adverse effects. Vermicompost are finely divided peat-like materials with high porosity, aeration, drainage, water-holding capacity (Edwards and Burrows, 1988). They have greatly increased surface areas, providing more microsites for microbial decomposing organisms, and strong adsorption and retention of nutrients (Shi-wei and Fu-zhen, 1991).

In order to obtain good yield, modern varieties of different crops require relatively high quantity of fertilizer compared to the traditional cultivars. However, the economic condition of Bangladesh farmers often does not support them to use required quantity of fertilizers due to its high cost. On the other hand, the organic matter content of most of the soils of Bangladesh is very low (0.8-1.8%) as compared to desired (2.5% and above) levels (Hossain *et al.,* 1995). Therefore, it becomes an immense need to formulate an optimum fertilizer recommendation that would produce satisfactory yields and would maintain soil health to ensure sustainable crop production. One of the alternatives to economize the use of chemical fertilizer is to incorporate crop residues or farmyard manure in combination with chemical fertilizers (Sarker *et al.,* 1996).

The compost prepared through the application of earthworms is called vermicompost and the technology of using local species of earthworms for culture or composting has been called Vermitech (Ismail, 1997). The nutrient content of vermicompost greatly depends on most of the mineral elements, which are in available forms than the parent material (Edwards and Bohlen, 1996). Vermicompost improves the physical, chemical and biological properties of soil increased microbial activity and enzyme production, (Kale, 1998). There is good evidence that vermicompost which, in turn, increases the aggregate stability of soil promotes growth of plants (Krishnamoorthy and Vajranabhaiah, 1986) and it has been found that organic matter to have a favourable influence on all yield parameters of has a property of binding mineral particles like calcium, crops potato.

Islam and Hossain,(1992) reported that the use of organic manures improve texture, structure, humus, aeration, water holding capacity and microbial activity of soil. This is predominantly related to organic matter content, especially in the light textured soils. In drought prone areas, a massive effort to increase the organic matter status of soil is an important attempt to combat drought condition. In general, the OM content of Bangladesh soil is below 1% in about 60% cultivable land as compared to an ideal minimum value of 4%. In the areas of continuous cropping OM-supply to crop fields through cowdung, & oil cake, compost green manuring etc. are made only to a maximum extent

2.3 Influence of mulch materials on yield and quality of potato

Azad *et al.* (2015) conducted a research in order to determine the effect of mulch on some characteristics of potato. The experimental treatments consisted of mulch in five levels (clear mulch, white mulch, black mulch, double layer mulch and control, without mulch) and cultivar in two levels (Agria and Sante). The effect of mulch on the fresh and dry weight of weed was significant, so that the black and double layer mulches had greatest impact on reducing the fresh and dry weight of weed, respectively. As compared to control, clear mulch treatments could reduce the period of tuber formation by 6.33 days. Double layer mulches showed the highest number of stolons at 60-day after planting. In comparison to the control, mulch could reduce the days to harvest, while the clear (104.83 days), double layer (105 days), and white (105.16 days) mulches all had significant differences when compared to the control (108.16 days). Cultivar Sante and double layer mulch also had the greatest impact on early potato crop. Mulch was not, however, seen to have significant effect on yield per plant.

Begum and Saikia (2014) conducted a field experiment to find the effect of six levels of irrigation under mulch and no mulch condition. The results indicated that irrigation applied at critical stages significantly recorded highest tuber yield (18.03 t ha^{-1}). However, irrigation applied at 25 mm CPE recorded significantly the highest yield of both B grade (25-50 g) and C grade (50-75 g) tubers. Both B and C grades has higher market price and mostly preferred by people than A grade and D grade size tubers. Likewise, application of mulch significantly 24.04% higher yield over non-mulch condition. Besides this, mulching also significantly increased the yield of B grade and C grade tubers along with tuber numbers as compared to no mulch condition. But there was no significant increase in yield in both A grade and D grade tubers was observed due to application of irrigation and mulch.

Caruso *et al.* (2013) carried out a research on potato (*Solanum tuberosum* L.) growing in the field in order to evaluate the effects of two mulching treatments (black biodegradable film and bare soil) and six plant densities (12.5, 10.0, 8.3, 7.1, 6.2 and, as a control, 5.3 plants per m^2) on growth, yield and quality of "new potato" winter-spring and summer-autumn crops. Only in the case of the summer-autumn crop cycle, mulching resulted in a higher yield, plant dry matter and leaf area compared with the bare soil control, while in both crop cycles this latter treatment induced a delay in harvest. The winter-spring cycle gave a higher production of 40-70 mm tubers, while the summer-autumn cycle resulted in a higher vitamin C content.

Asghari-Zakaria *et al.,* (2009). Mulching can have an effect on the external quality of tubers (scab of tubers, mechanical damages, greening of potato tubers) and inner quality (chemical composition) as well. From inner quality point of view, potatoes are mainly valued for its starch, reducing sugar, non-reducing sugar, polyphenol, vitamin C content and specially for the high content of vitamin C.

Razzaquea and Alib (2009) carried out an experiment during rabi season of 1999-2000 to 2000-2001 with five recommended potato varieties viz. Heera, Dhera, Diamant, Chamak and Cardinal along with two types of mulching materials viz rice straw and water hyacinth to find out suitable variety and mulching material(s) for obtaining higher yield under no tillage condition. Heera produced highest yield under both rice straw (19.45 t ha^{-1}) and water hyacinth (23.15 t ha^{-1}) mulch. Rest of the variety performed more or less similar in both cases. Both Heera and Dhera seemed to be suitable for cultivation in no tillage condition.

Sometimes potato produced in Bangladesh is not of good quality enough in respect of dry matter content, starch content, non-reducing sugar content etc. which are not present at optimum level in produced product (Keijbets, 2008). So, using different mulch materials may put contribution for improving quality of potato in Bangladesh condition.

Mulch especially reduces water evaporation from the soil arid helps to maintain stable soil temperature' (Ji and Unger 2001; Kar and Kumar 2007). For that reason, the cover of mulch influences the soil moisture as well (Brant *et al*. 2006). Next, mulching has a positive effect on the weed density, which was documented by the results of some authors (Doring *et a*l. 2005; Sinkeviciene *et al.* 2009).

Mulching has become more popular for the last 10 years and it is an important way of soil protection in plant production. Mulching significantly decreases soil erosion (Doring *et al.,* 2005), virus vector in seed potatoes (Doring *et al*., 2006) and it may also act as a tool for the control of nitrogen losses by the imobilization of post-harvest nitrate (Doring *et al.,* 2005).

Chowdhury *et al.* (2000) conducted a field experiment in the rabi season of 1997-1998 on a clay terrace soil in Salna, Gazipur, Bangladesh, to study the effect of rice straw mulching and irrigation on the yield total water use and water use efficiency of an indigenous low yielding cultivar of potato, Lalpakri. Irrigation is indispensable in the rabi season of Bangladesh and the yield was significantly lowest in the treatment of no irrigation after seedlings establishment. Rice straw mulch conserved soil moisture and maintained a higher moisture regime in each irrigation level through the cropping period. The treatments of rice straw mulching and the single irrigation at 30 days after sowing were the best combination with a satisfactory high yield.

Bhuyan (2003) conducted a field experiment at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh during the period from November 2002 to March 2003 to investigate the effect of mulching, variety and crop management practices on growth and yield of potato. The experiment was conducted with four mulching treatments, (no mulch no irrigation, irrigation, saw dust and straw mulch); two varieties (Diamant and Cardinal) and use of organic manure without pesticides application). Mulching treatments showed significant effect on most of the yield and yield components. The highest yield (21.31 t ha^{-1}) was obtained from straw mulch followed by sawdust (19.47 t ha^{-1}), irrigation treatment (19.06 t ha^{-1}) and no mulch no irrigation treatment (15.29 t ha^{-1}). The variety also caused significant variations on most of the parameters. The variety Diamant gave the higher yields (19.07 t ha^{-1}) and compare to Cardinal (18.51 t ha^{-1}) yield.

Bwamiki *et al.,* (1998) reported that significant yield increases using mulches from coffee husks and increases in productivity using animal manures and hay residues have been reported. Their important roles in the soil and their potentially positive effect on crop yields have made organic amendments a valuable component of farm fertilization and management programs in alternative agriculture. Forms of organic matter used include crop residues as mulches, among others.

Collins (1997) reported that transparent black polythene and polythene coated black paper mulches increased soil temperature and advanced emergence of potato. He also reported that transparent black polythene and polythene coated black paper mulches non-significantly reduced the yield of potato from bare soil of 46.9 and 48.3 t ha^{-1} and clear polythene mulch.

Jalil (1995) conducted an experiment at the Horticulture farm, Bangladesh Agricultural University, Mymensingh in order to study effect of mulch on potato. Black polythene mulched potato took minimum time to reach 80% emergence, resulted maximum coverage of area. However, yield was higher with water hyacinth mulch.

Shelton *et al.,* (1995), Surface mulching is one of the most cost-effective means because of a range of positive effects on the soil fertility and other factors important for plant production.

Khalak and Kumaraswamy (1992) conducted a field trial in 1985-1987 on red sandy soil at Bangalore, Karantakca. Potatoes cv. Kufri jyoti was irrigated with 20 or 40 mm water and the crop was given no mulch, straw mulch or polythene mulch. Tuber yield and N uptake were the highest in both years with 20mm irrigation water. Mulching with straw and polythene gave average tuber yields of 18.2 and 16.7 t ha^{-1} respectively compared with 14.3 t ha^{-1} without mulching.

Siddique and Rashid (1990) conducted experiments for 3 seasons (1987/88) to study the effect of irrigation and mulching on the yield of 3 varieties of potato (Challisha, Lalpakri and Pakri Lalita). Water hyacinth was used for mulching. From the results they found that the varieties responded very well to both irrigation and mulching.

Wilhoit *et al.,* (1990) reported that to minimize the cultivation cost, mulching could be effectively used instead of irrigation. Different kinds of mulches play important role in conserving soil moisture. Soil temperature is important for potato production, which is influenced by mulch. Artificial mulch such as crop residues, plant species, or polyethylene sheet is generally practiced for production of horticultural crops.

Sarker and Hossain (1989) studied the effect of weeding and mulching on potato cv. Cardinal and reported that the percentage of foliage coverage, which ranged from 40.0 to 65.00, was significantly different among the treatments, the lowest coverage being obtained from the control (no weeding) treatment. Mulching also increased growth of leaf and stem (Kim *et al*. 1988).

Mulching has been reported as a means of improving production in many crops, especially vegetable crops like potato, sweet potato, carrot, cabbage, cauliflower etc. (Rashid *et al*., 1981; Sarker and Hosain, 1989;).

In an experiment conducted at Kore, Kim *et al*. (1988) observed that when white polythene sheet was used as much in potato cultivation; average soil temperature was increased by 2.4-2.6 ^{o}C and moisture content of the soil also increased. They observed that 80% emergence of the potato occurred in 29-39 days in mulched plot compare with 41-54 days in the control

Mangaser *et al.* (1986) stated that mulch in potato improved yield and proportion of marketable size tubers compared to no mulch plants. They also reported that potato planting with mulch should be done from the last week of November up to second week of December to obtain the best yield. Polythene mulch conserved more moisture in the soil than control (Harris, 1965). Mulching conserved the soil moisture better in potato cultivation (Prihar, 1986; Devaux and Haverkort, (1987) and Ifenkwe and Tong (1987).

According to Devaux (1984), mulching reduced the soil temperature due to better ground cover. Sutater (1987) found an increase in plant height and the number of potato leaf with different mulching treatments. Taja *et al.,* (1991) reported that mulching by rice straw with optimum inorganic fertilizer application of 50 kg N/ha were good for canopy coverage of potato.

Manrique and Meyer (1984) found in a study of black and white plastic and various qualities of barley straw as mulches for non-heat tolerant potato variety at Manilla Agricultural Experiment Station, Lima, Peru, that during winter, soil temperature in plastic mulched plots ranged from 18 to 26°C. The condition gave relatively higher tuber yields in most of the varieties. Rashid *et al.* (1981) conducted a trial at Joydebpur, Dhaka on potato cv. Cardinal cultivated with or without ridges, without mulching or mulching with water hyacinth, rice straw, or spike lets (Chitta). Tuber yield was the highest

(17.6 t ha^{-1}) when the plants ridged and mulched with water hyacinth. Emergence in the no mulched plots was significantly lower than that of mulched plots.

Lang (1984) reported that the percentage of potato tuber production >6 cm diameter was higher under polythene mulch. Polythene mulch conserved more moisture in the soil than control (Harris, 1965).

Challaiah and Kulkani (1979) conducted an experiment in potato with irrigation at 13 to 15 days interval in combination with polythene mulch. Polythene mulch gave higher yield (30.64 t ha^{-1}).

Bhattacharjee *et al.* (1979) demonstrated that potato yields were higher with straw mulch than that of without mulch on coarse textural soil in Patna, India. Burger and Nel (1984) reported that mulching by straw produced 30% more tubers than the no mulch potato crops. Similarly, Natheny *et al.* (1992) also found that white, pale blue and stripped straw mulch produced more than 15% marketable tubers of potato than the no much control plots. Mulching helps in checking evaporation and thus soil can retain sufficient amount of moisture. Polyethylene film mulches reduce evaporation in vegetable cultivation (Lamont, 1993). In a separate experiment, Bieoral (1970) found that polythene sheets caused a 2% increase in the moisture content of the top 30cm of the soil. Black polythene, sawdust and dried grass mulch in tomato production improved soil moisture retention but black polythene mulch had the best result (Patil and Basad, 1972).

Yamaguchi *et al.* (1964) also reported that average minimum temperature fall within the range in bare soil than from clear and black polythene, which delay mergence.

2.4 Influence of harvesting time on yield and quality of potato

Rymuza *et al.* (2015) set a field experiment to find out the effect of ridge height and harvest date, determined based on soil temperature, on edible potato tuber quality. Starch and dry matter contents were affected by the study years, cultivar and harvest date, the highest levels being found for cv Romula tubers as well as tubers harvested at the soil temperature of 12°C.

Bhattacharjee *et al.* (2014) set a laboratory experiment at the Agronomy Department, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during March to August 2013 to study the influence of variety and date of harvesting on post-harvest losses of potato derived from TPS at ambient storage condition. Due to the interaction effect of different variety and time of harvest at before storage and 20, 40, 60, 80, 100 days after storage (DAS), the maximum dry matter in flesh (13.99, 17.75, 18.80, 19.93, 21.71 and 22.57%) was observed from BARI TPS-1 and harvest at 110 days after planting and the lowest from BARI TPS-1 and harvest at 80 days after planting.

Elfnesh *et al*. (2011) reported that specific gravity and DM content increased with the maturity of tuber and crops grown usually have more time to mature those produce tubers with high specific gravity and DM content.

Mehta *et al*. (2011) studied on four Indian processing and one exotic potato variety harvested directly at 10 day interval between 70 and 100 days after planting and at 120 days after 20 days of tuber skin curing in the soil following dehaulming, were evaluated for french fry quality. Tuber dry matter increased with maturity and was >20% at 90 days after planting in Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Frysona and at 100 days in Kufri Surya. Reducing sugar content was low (<100 mg/100g fresh weight), except in Kennebec (172 mg/100 g fresh weight) harvested at 100 days after planting. Sucrose content decreased significantly towards crop maturity and curing.

Khan *et al.* (2011) studied on a field trial to optimize the sowing date and crop growth period of potato at the Agricultural Research Institute, Dera Ismail Khan, NWFP during 2004-05. The tubers were planted on four dates with one-week interval starting from September 24 in 2004 and found that total number of tubers, percent larger and medium sized tubers, tuber yield and plant dry bio-mass increased with the delay in harvesting. However, dry matter in tuber was found higher at earlier harvestings.

Muli and Agili (2010) demonstrated that the number of marketable roots per plant, percentage of marketable roots and percent dry matter increased as more time was allowed for tuber development, before harvesting.

Abong *et al.* (2009) experimented on Kenyan cultivars to observe the influence of potato cultivar and stage of maturity on chips and french fries. Dry matter content ranged from 19.50 to 24.07% and 20.56 to 24.66% in clone 393385.39 and variety Dutch Robyjn for tubers harvested 90 and 120 days after planting, respectively.

Kushwah and Singh (2008) conducted an experiment during 2004-05, in Madhya Pradesh, India, to evaluate the effects of intra-row spacing (10.0, 12.5, 15.0, 17.5, 20, 22.5 and

25.0 cm) and haulm cutting date (60, 65, 70, 75 and 80 days after planting (DAP)) on the production of small-sized tubers of potato. Data were recorded for plant height, stems plant^{-1}, fresh haulm weight, tuber yield per hectare and NPK content of soil after potato harvest. Intra-row spacing of 25 cm and haulm cutting at 80 DAP recorded the highest values for plant height, stems per plant, fresh haulm weight, tuber yield ha^{-1} and NPK content of soil as well as the highest net returns and benefit: cost ratio.

To improve the production of seed-size potato tubers, 31 experiments were conducted in India, from 1999 to 2003 at 9 centers, situated in different agro-climatic regions of the country by Dua *et al.* (2008). Two levels each of spacing (60 × 15 and 60 × 10 cm), fertilizer rates (100 + 35 + 66 and 150 + 52 + 66 kg of N + P + K ha^{-1} , respectively) and dates of haulm cutting (70 and 80 days after planting) were imposed on popular potato cultivars of the regions. The authors reported that yield of seed-size tuber at closer spacing (13.9 t ha^{-1}) increased by a 15.7% compared to that at wider spacing. Economics of potato cultivation for production of seed size tubers also favoured planting at wider spacing (60 × 15 cm), with higher fertilizer rate (150 + 52 + 66 kg of N + P + K ha^{-1}, respectively) and dehaulming at 80 days after planting.

Lisinska (2006) reported that the delayed harvest results in increased dry matter contents of potato.

According to Rytel (2004) delayed harvest results in increased dry matter contents of potato but the rate of their accumulation depends on cultivar and growing conditions.

Ali *et al.* (2003) reported that dry matter content and specific gravity increased when harvesting was delayed to the optimum time. The variety '9620' was at the top by producing maximum number of marketable tubers. The varieties like Hateema, Adora and 9619 were also close to 9620 in producing higher number of marketable tubers.

Mehta and Kaul (2003) evaluated the storability and processing quality of two potato cultivars cv. Kufri Chandramukhi and Kufri Lauvkar in India and found that the respiration rate one day after harvest was highest in immature tubers harvested at 60 DAP, and the rates decreased as the harvest was delayed. The weight loss in stored potatoes was affected by harvest date with more physiologically immature tubers.

Trials were conducted in 2000, 2001 and 2002 in Tamil Nadu, India by Ravichandran and Singh (2003) to investigate suitable agro-techniques for obtaining the maximum number of seed size tubers from potato cultivars Kufri Swarna and Kufri Jyoti. Treatments included: tuber weights of 10-20, 20-30, 30-40 and 40-50 g; intra-row spacing of 10, 15 and 20 cm; and 2 dates of haulm killing (75 and 90 days after planting). The authors observed that in both cultivars, 30-50 and 20-50 g tubers, may be used at an intra-row spacing of 10 cm, and with haulm killing at 90 days after planting to obtain the maximum number of seed size tubers.

Waterer (2002) studied the influence of planting and harvest dates on yields and grade-out due to tuber damage by common scab (*Streptomyces* spp.) over three cropping seasons using two cultivars of potato grown on land heavily infested with pathogenic *Streptomyces* species. Early planting and delaying the harvest enhanced yields in both cultivars, but also increased tuber grade-out due to excessive levels of scab. Delaying the harvest reduced marketable yields more than did early planting. The longer harvest was delayed after top-kill, the greater was the grade out due to scab. He demonstrated that common scab of potato may be managed by minimizing the period of the crop in the ground, but this method of disease management is achieved at the expense of yields. Early planting coupled with timely harvesting after kill-down of the tops appears to be an effective compromise between the objectives of maximizing yields while avoiding excessive grade-out due to common scab.

Garayo and Moreira, (2002) found in there experiment that a higher L* value indicates a lighter color, which is desirable in potato chips.

According to Okwuowulu and Asiegbu (2000) the harvesting age significantly ($p<0.05$) affected the storability of potato; tubers harvested early (3 months after planting) exhibited the greatest deterioration as a result of sprouting and weight loss, but were characterized by lowest rot incidence.

A study conducted on low and high sugar potato cultivars for processing quality as influenced by storage temperature by Marwaha *et al.* (2005) in Punjab. The dry matter content of exotic cultivars was higher than the Indian cultivars and free amino acids and total phenols were significantly lower in the exotic cultivars than the Indian cultivars at the time of storage. The reducing sugar content of the exotic cultivars was very low (64 to 80 mg 100 g^{-1} fresh wt basis) as compared to the Indian cultivars (158 to 285 mg 100 g^{-1} fresh wt basis).

Peschin (2000) studied the influence of storage temperature and reconditioning on the biochemical composition of potato tubers in Himachal. There was no significant varietal difference among genotypes in their biochemical constituents at the time of storage and during storage. Among these Kufri Kuber, Kufri Chandramukhi and Kufri Lauvkar contained low reducing sugars of 1.8, 5.8 and 5.0 mg 100 g^{-1} fresh weight basis respectively. On storage at 5-7°C, all the cultivars showed accumulation of large quantities of reducing sugars and phenols and produced dark brown colored chips. All the genotypes reflected an accumulation of phenols, which was more predominant after 90 days of storage. Post-harvest reconditioning of tubers for 10 days at ambient temperature (20±2°C) caused decline in reducing sugar in all the cultivars.

Moreira *et al*. (1999) reported that low reducing sugar content (below 0.25% and preferably below 0.1% is desired for the production of potato chips.

Burke J.(1998) reported that in the literature there is a general consensus that early harvesting - before soil conditions deteriorate and soil temperature drops below 80^0c is essential to ensure that tubers attain appropriate fry colour following storage. For the grower, early desiccation and harvest may necessitate a yield penalty. A primary objective of the study is therefore to investigate agronomic factors which might offset any such yield penalty while ensuring that the crop had attained a sufficient degree of "maturity" prior to desiccation. Since late planting is inimical with an early harvest, strategies to promote rapid crop establishment and early growth were investigated.

Marwaha (1998) also observed an increase in the specific gravity of tubers with the increase in harvesting time.

Ezekiel and Bhargava (1998) illustrated that the sprouting of potato cv. Kufri Candramukhi increased with the increase in age of seed tubers. Physiologically older tubers were reported to have higher sprouting. It was also reported that, endogenous content of IAA could be related to rate of sprout elongation in potato.

Walter *et al*. (1997) found a positive correlation between specific gravity and dry matter of tubers was observed earlier.

Jeong *et al*. (1996) reported gradual increase in specific gravity until 100 days after planting, and showed a decrease thereafter.

Chaurasia and Singh (1992) conducted an experiment at Uttar Prodesh of India on potato cv. Kufri Bahar and Kufri Lalmia. Haulms were cut 80, 90, 100, 110 and 120 days after planting. Tubers were harvested 10 days after stem cutting, and stored for 30, 60 and 90 days. They observed that the percentage of tuber weight loss, sprouting and rotting decreased with the delay in haulm cutting date.

Sinha *et al.* (1992) grew potato cvs. Atlantic, Eramosa, Kanona, Norchip, Onaway and Saginaw Gold, and selections MS 700-70, MS 700-83 (Spartan Pearl), MS 716-15 and W-855 (Snowden) on a sandy loam in Michigan. In year 1988, average yields were 46.9 t ha^{-1} at 98 days and 54.7 t ha^{-1} at 138 days; corresponding yields in 1989 were 43.1 and 52.3 t ha^{-1} . Increase in yield between the two harvest dates ranged from 0-19.6 t ha^{-1}. Tuber yield after 138 days was highest for 'MS-700-83' (62.3 t ha^{-1}) in 1988 and 'MS-700-70' (59.4 t ha^{-1}) in 1989 and lowest in 'Eramosa' in both years (41.2 and 43.0 t ha^{-1} in 1988 and 1989, respectively). Two of the selections ‘Onaway’ and ‘Eramosa’ were the earliest maturing, contained low specific gravities, high concentrations of glucose, and resulted into dark colored chips. Specific gravities of the tubers were 1.079-1.088 in Atlantic, MS 700-70, MS 716-15 and W-855, 1.071-1.076 in Norchip, Kanona and Saginaw Gold and 1.056-1.068 in Eramosa and Onaway; harvest dates did not affect specific gravity.

De-Buchananne and Lawson (1991) studied the effect of plant population and harvest timing on potato yield and chipping quality at Muscatine and Whiting. They planted cultivars: Atlantic and Nor Chip at in-row spacing of 15, 31, and 46 cm and harvested approximately 12, 14 and 16 week after planting. They obtained greater yield and greater specific gravity for both cultivars at final harvesting at both the locations. But chip color was not significantly affected at Muscatine by harvest date while each successive date of harvest resulted in lighter colored chips at Whiting. They further reported that higher plant population increased the yield but smaller increase in specific gravity was noted for both the cultivars. However chip color was not significantly influenced by the plant population. Cultivar 'Atlantic' produced lower yield having lower specific gravity as compared to ‘Nor-Chip’ throughout the season in the final harvest.

Simon and Richard (1989) conducted an experiment to find the effect of four dates of defoliation (0, +10, +20, +30 days) and three days intervals to harvest (0, +10, +20 days) on yield, tuber size, dry matter, reducing sugar, fry test color and finish fried sensory quality for two cultivars (Pentland Dell, Maris Piper). Dry matter content and yield of tuber were influenced by all factors in the trail. Later date of defoliation gave lowest reducing sugar levels. Increase the interval from defoliation to harvest reduced dry matter and raised yield.

Santerre *et al*. (1986) studied the influence of cultivars, harvest dates and soil nitrogen on sucrose, specific gravity and storage stability of potatoes grown in Michigan. They planted potato cultivars: Atlantic, Belchip, Denali, Monona, Nor chip, and Russet Burbank and harvested them at weekly intervals from early August to early October. They obtained sucrose rating (mg sucrose/g of fresh tuber) below 1 by 145 days of growth. Higher nitrogen levels reduced the total yield for early harvests, but had no significant effect for later harvest. Changes in sucrose levels as tubers matured were helpful in evaluating the chemical maturity of more recently developed cultivars in relation to established chipping varieties.

Kundzicz (1985) stated that the influence of harvest date on the storage loss was considerable. The highest losses occurred at late harvest dates during the storage of cv. Sokol and Sowa. At early harvest dates the differences in the amount of damage were remarkable.

Workman and Harrison (1982) studied the influence of harvest date on yield, early blight tuber infection and chipping characteristics of potatoes grown with sprinkler irrigation. Potato tuber yield was increased by late harvesting. Decreased tuber infection by *Alternaria solani* was attributed to maturation of the tuber periderm.

Peterson *et al.* (1981) observed that respiration rates of Potato tubers were high immediately after harvest, and declined to an equilibrium level after about 7 days. Weight loss during storage ranged from 8.3 to 3.7% in the early and late harvested samples.

2.5 Influence of temperature on yield and quality of potato

Krystyna Rykaczewska (2013), reported that Potato crop is characterized by specific temperature requirements and develops best at about 20˚C. The impact of high temperature on the development of potato confirm the view that its productivity is greatly reduced at higher temperatures than the optimum temperatures.

Pulane Charity Modisane (2007), discovered that lowering the temperature (22/14^{o}C) and low humidity (35%) had beneficial effects on the tuber yield. Maintaining plants at low temperature (22/14^{o}C) and high humidity (85%) could improve the tuber quality.

However, high humidity (85 %) and high temperature (27/17^{o}C) improved tubers quality in calcium uptake by the tubers.

Temperature and humidity do not only affect the quality of the tubers, but also the general growth of the potato crop and tuber yield (Cao & Tibbitts, 1992). Potatoes can be grown in many areas under various climatic conditions, but the crop prefers a specific environment to grow successfully with good yield and quality.

An extreme environment, for example high/low temperature, as well as high/low humidity, on the potato crop, may result in a decrease in the crop growth and tuber yield (Struik *et al*., 1989b; Adams & Ho, 1993; EL-Beltagy *et al.*, 2002).

Potato is categorized as a cool season crop, which requires temperatures between 15oC and 22^{o}C for optimum growth, production and quality El-Beltagy *et al*. (2002) and Tawfik *et al*. (1996) report that high temperatures (>28/18 ^{o}C day/night) affect the potato crop growth and production negatively.

Higher temperatures and long days promote vegetative growth and stimulate stem elongation (Tadesse *et al*., 2001; El-Beltagy *et al*., 2002). Increase in temperatures to the optimum range of 20-25^{o}C enhances stem growth (Tadesse *et al*., 2001). High temperatures (more than 25-30^{o}C) tend to increase stem length and branching while reducing leaf size and leaf area (Palta, 1996; El-Beltagy *et al*., 2002). Tawfik *et al*. (1996) have found the reduction in potato leaf size to be due to the reduction in cell division, altered cell membrane permeability or reduced stomatal conductance as well as reduced CO_2 supply for assimilate production.

Subhash *et.al.* (2000), found that the effect of temperature (15, 25, 30^{o}C and glasshouse as control) at different growth stages (stage-I: vegetative to tuber initiation, stage-II: tuber initiation to initial tuber bulking and stage-III: tuber bulking to maturity) on leaf nitrate reductase (NR) activity, carbohydrate contents and tuber yield were investigated in potatoes (*Solanum tuberosum* L. cvs. May Queen and Normn 1) as pot experiment in naturally lit glasshouse and phytotron. The high temperature treatment decreased the total dry matter production as well as tuber yield and degraded the tuber quality by reducing the specific gravity. NR activity of leaves was also decreased by high temperature treatment, whereas low temperature increased the activity. Water soluble carbohydrate (WSC) and starch content in leaves were sequentially decreased and as a result total nonstructural carbohydrates (TNC) were also decreased by high temperature. The inhibition of tuber yield by high temperature was due to the limited translocation of carbohydrates from leaves to the tubers, following the reduction of NR activity and the expense of carbohydrates for dark respiration. The maximum yield reduction was observed at high temperature treatment at stage-I which was most critical for tuber yield, and low temperature at stage-II produced the highest yield which was considered as more advantageous step towards yield improvement.

High air temperatures promote development and branching of stolons, even though some reports indicate that number of stolons and stolon yield are decreased by high soil temperatures. Some reports also indicate that the number of stolons or stolon yields are reduced by high soil temperature, while stolon development is delayed (Struik *et al.*, 1989a). To the contrary, some reports indicate that high temperatures tend to delay stolon development, while the final number of stolons and final stolon yields are increased (Struik *et al*., 1989b).

Balamani *et al*. (1986) report tuberization to be promoted by short days and low temperatures (<25^{o}C) whereas long days and high temperatures delay or inhibit the process. The optimum temperature for tuber initiation and growth ranges from 15-19^{o}C (Tadesse *et al*., 2001). Cool temperatures as well as short photoperiods favour partitioning of photosynthates to the tubers (Ewing, 1981). Cao & Tibbitts, (1992) established the highest production of plant dry mass and tuber yield at 20^{o}C.

High temperatures lower tuber yields. This is due to reduced partitioning of photosynthates to the tubers (Tadesse *et al*., 2001; El-Beltagy *et al*., 2002; Kleinhenz and Palta, 2002). According to Basu & Minhas (1991) high temperatures lower tuber yields because they inhibit starch synthesis in tubers and the partitioning of the photosynthates to the tubers. Soil temperatures also affect the number of tubers formed as well as the rate and period of tuber growth as reported by Struik *et al*. (1989c).

According to Struik *et al*. (1989a, 1989b), high temperature (> 28/18^{o}C day/night) impedes the production of dry matter and its distribution between tubers and haulm, as well as the net amount of photosynthates available for the entire plant (night temperatures are more crucial). High temperatures also affect photosynthesis, respiration and membrane permeability (Tawfik e*t al.*, 1996).

Wheeler *et al*. (1989) reported that lowering the humidity results in greater leaf sizes with dark green colour. The investigation highlights the fact that humidity can also affect potato growth and tuber yield. Through this experiment on three potato cultivars grown for 56 days in controlled environment rooms under continuous light at 20^{o}C and 50 or 85% relative humidity. The results indicated that reducing humidity (50%) benefits foliage and stem growth; while increasing humidity (85%) favours increase in tuber yield. This is evidenced by the data obtained which shows higher leaf and stem dry mass, total dry mass as well as leaf area values at 50% humidity and higher tuber yield values at 85% humidity. Wheeler *et al*, (1989) relates the reason for high tuber yields at high (85%) humidity to the increase in photosynthate allocation to the tubers. There is a possible benefit in raising humidity levels to increase tuber yields of potatoes. The elevated relative humidity appears to shift the allocation pattern of photosynthates to favour allocation to the tubers over allocation to leaves and the stems.

CHAPTER 3
MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of the experimental materials and methods are described below:

3.1 Experimental period

The experiment was conducted in three consecutive years from 2014 to 2017 covering three potato growing seasons during the period from November to March for field experimental data in Rabi season and up to June for storage quality data in ambient temperature. The periods of experimentation cover in each year.

3.2 Site description

3.2.1 Geographical location

The selected experimental areas covered three different geographical locations; first at $23^{0}77$'N latitude and $90^{0}33$'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004), second at 23° 16' 0" North and 89° 53' 0" East and third at 25° 57′ 0″ N latitude and 88° 15′ 0″ East longitude.

3.2.2 Description of the experimental sites

The experimental sites covered three agro ecological zones in Bangladesh. It's first site belongs to the agro-ecological zone of "Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b).

The landscape comprises level upland closely or broadly dissected terraces associated with either shallow or broad, deep valleys. Eleven general soil types exist in the area of which deep red brown terrace, shallow red brown terrace soil and acid basin clays are the major ones. Soil of the experimental site belongs to the general soil type, shallow red brown terrace soils under Tejgaon Series. Top soils are clay loam in texture, olive-grey with common fine to medium distinct dark yellowish-brown mottles. Soil pH ranged from 6.0 to 6.6 and had organic matter 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level.

The second site belongs to the agro-ecological zone of “Low Ganges River Floodplain”, AEZ-12. The zone comprises the eastern half of the Ganges river floodplain which is low lying. The area has a typical meander flood plain landscape of broad ridges and basins. Soil of this region are silt loams and silt clay-loams on the ridges and silty clay loam to heavy clays on lower sites. General soil types predominantly include calcareous dark grey and calcareous brown floodplain soils. Organic matter content is low in ridges and moderate in the basins. General fertility level is medium. Soil texture is medium high to medium low land type.

The third site also belongs to the agro-ecological zone of “Old Himalayan Piedmont Plain”, AEZ-1. This distinctive region is developed in an Old Tista alluvial fan extending from the foot of the Himalayas. It has a complex relief pattern. Deep, rapidly permeable sandy loams and sandy clay loams are predominant in this region. They are strongly acidic in topsoil and moderately acidic in subsoil; low in weatherable K minerals. Seven general soil types occur in the region, of which non calcareous brown floodplain soils, black terrain soils and non-calcareous dark grey floodplain soils predominate. The natural fertility of the soil is moderate but well sustained. Soil fertility problem include rapid leaching of N, K, S, Ca, Mg and B. The experimental sites were shown in the map of AEZ of Bangladesh in Appendix I.

3.2.3 Climate of the experimental site

Experimental sites were located under the sub-tropical monsoon climatic zone, which are characteristics by heavy rainfall, high humidity, high temperature and relatively long days during kharif season, and scanty rainfall, low humidity, low temperature and relatively short days during rabi season covering the months from October 15 to March 15. The rabi season is suitable for potato cultivation in Bangladesh. The field experiment was conducted from November 01 to March 15 (2014-2017). Plenty of sunshine and moderately low temperature prevails during experimental period which is appropriate for potato cultivation in Bangladesh. Details of the meteorological data in respect of temperature, rainfall, relative humidity and total sunshine time during the study period (2014-2017) at the experimental sites in the locations for SAU, Dhaka, Baliakandi in Rajbari district and Sadar in Thakurgaon district are shown in Appendix III, IV and V.

3.3 Details of the Experiment

3.3.1 Treatments and experimental design

Details of treatments and design of all experiments during the period of study (2014-15, 2015-16 and 2016-17) were furnished in below:

Experiment of first year (2014-15)

3.3.2 Expt. 1. Effect of various mulch materials on growth yield and quality of potato varieties

3.3.2.1 Objective

i) To observe the varietal performance under different mulch materials,

ii) To find out suitable mulch materials that contributing the highest yield and good quality potato.

3.3.2.2 Experimental procedure

There were two factors in the experiment as

Factor A: Variety -5

i) V_1 = BARI Alu-25 (Asterix)

ii) V_2 = BARI Alu-28 (Lady rosetta)

iii) V_3 = BARI Alu-29 (Courage)

iv) V_4 = BARI Alu-29 (Diamant)

v) V_5 = BARI TPS-1

Factor B: Mulch materials (4)

i) M_0 = Control (without mulch)

ii) M_1 = Water Hyacinth

iii) M_2 = Rice Straw

iv) M_3 = Rice Husk

Treatment combinations were (20) as:

V_1M_0, V_1M_1, V_1M_2, V_1M_3, V_2M_0 V_2M_1, V_2M_2, V_2M_3, V_3M_0, V_3M_1, V_3M_2, V_3M_3, $V_{14}M_0$, V_4M_1, V_4M_2, V_4M_3, V_5M_0, V_5M_1, V_5M_2, V_5M_3.

A total of 60-unit plots measuring 2.5m × 4m = 10m^2 were used to set-up the experiment.

The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. The layout was completed one day before planting on 15th Novemebr,2014. Spacing of 40cm, 50cm and 25cm were maintained in between replicated plot to plots, line to line and plant to plant, respectively. The unit plot size was 2.5m x 4m. All the potato varieties (certified seed) were collected from Bangladesh Agricultural Development Corporation (BADC) except BARI TPS-1. BARI TPS-1 was collected from Tuber Crop Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur. Before planting of potato tuber, land was well prepared with tractor drawn rotavator and subsequently ploughed 4 times with a country plough followed by laddering. Land preparation was completed two days before planting. Furadan 5G @ 2 kg/ha and Dursban 20 EC @ 1.5 kg/ha was applied after sowing the seedling tubers to control ants and cutworm. The plots were fertilized with 250, 150, 250, 120, 10, 10 and 100 kg ha^{-1} of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate, boric acid and magnesium carbonate, respectively BARI (2014). All the fertilizers except urea were applied in the plot as basal dose. The urea was applied in three equal splits – one third as basal, second one third at 30 days after planting (DAP) followed by first pouring the soil and rest one third at 45 DAP followed by pouring the soil. Planting of potato tuber was done on 15th November. The sprouted healthy and uniform sized tubers were planted within 4-5 cm soil depth. Individual weight of seed potato was 50-60 g and single seed potato was planted in each point. Mulching was done in cover the whole planting area with 1-2 inches thick layers . When potato plants became 3-4 leaves then first top dressed and first earthing up were done. Second earthing up & top dressing of urea were completed within 45 DAP. Dithane M-45@ 2kg/ha and Antracol 70 WP @ 2kg/ha was applied one after another commencing from 30 DAP to 15 days interval continuing up to 80 DAP as a preventive measure for controlling fungal infected diseases like late blight, early blight and scab of potato. Weeding, watering and other intercultural operations were done as and when necessary. Harvesting was done on 100 days after planting. Haulm cutting was done at 7 days before harvesting, when 80-90% plants showed senescence and tops became started drying. Harvesting was done manually by using spade and hand. It was done so carefully that the potatoes were free from any injury. Harvesting area was measured 3m^2 from each of the plot. The harvested tubers were bagged and tagged separately and brought to the laboratory for recording further data.

3.3.3 Expt. 2. Effect of organic manure on growth yield and quality of potato varieties

3.3.3.1 Objective:

i) To assess the varietal performance with different organic manures,

ii) To find out the best organic manure for maximum yield and quality potato tubers.

3.3.3.2 Experimental procedure

The experiment consisted of two factors having variety and organic manure. The factors and treatments were as follows:

Factor A: Variety - 5

i) V_1 = BARI Alu-25 (Asterix)

ii) V_2 = BARI Alu-28 (Lady rosetta)

iii) V_3 = BARI Alu-29 (Courage)

iv) V_4 = BARI Alu- 7 (Diamant)

v) V_5 = BARI TPS-1

Factor B: Organic manure - 4

i) O_0 = Control / (without manure)

ii) O_1 = Cowdung @ 10 tha^{-1}

iii) O_2 = Poultry litter @ 10 tha^{-1}

iv) O_3 = ACI organic fertilizer @ 10 tha^{-1}

Treatment combinations were (20) as:

V_1O_0, V_1O_1, V_1O_2, V_1O_3, V_2O_0, V_2O_1, V_2O_2, V_2O_3, V_3O_0, V_3O_1, V_3O_2, V_3O_3, $V_{14}O_0$, V_4O_1, V_4O_2, V_4O_3, V_5O_0, V_5O_1, V_5O_2, V_5O_3

A total of 60-unit plots measuring 2.5m × 4m = $10m^2$ were used to set-up the experiment.

The experiment was laid out in the experimental field of Sher-e-Bangla Agricultural University research farm following Randomized Complete Block Design (RCBD) with three replications. Same variety (as used in expt-1) and same sources of potato seed tuber was used in this experiment. Well decomposed cowdung and poultry litter and ACI organic fertilizer were used @ 10 t ha^{-1} in each of the experiment field as per treatment. Chemical fertilizers were used as BARI (2014) recommended dose (mentioned in expt-1). Single seed potato tuber having 50-60 g sized were planted in each point on the furrow of the experiment plot. Land preparation, irrigation, weeding and other intercultural operation were the same as in expt-1. Harvest of potato was done on 100 days after planting.

3.3.4 Expt. 3. Effect of harvesting time on growth yield and quality of potato varieties

3.3.4.1 Objective

i) To find out an appropriate harvesting time for achieving higher yield and quality of potato

3.3.4.2 Experimental procedure

The experiment consisted of two factors which were as follows:

Factor A: Variety -5

i) V_1 = BARI Alu-25 (Asterix)
ii) V_2 = BARI Alu-28 (Lady rosetta)
iii) V_3 = BARI Alu-29 (Courage)
iv) V_4 = BARI Alu – 7 (Diamant)
v) V_5 = BARI TPS-1

Factor B: Harvesting time - 4

i) H_1 = harvesting at 80 DAP
ii) H_2 = harvesting at 90 DAP
iii) H_3 = harvesting at 100 DAP
iv) H_4 = harvesting at 110 DAP

Treatment combinations were (20) as:

V_1H_1, V_1H_2, V_1H_3, V_1H_4, V_2H_1, V_2H_2, V_2H_3, V_2H_4, V_3H_1, V_3H_2,
V_3H_3, V_3H_4, V_4H_1, V_4H_2, V_4H_3, V_4H_4, V_5H_1, V_5H_2, V_5H_3, V_5H_4.

A total of 60-unit plots measuring $2.5m \times 4m = 10m^2$ were used to set-up the experiment.

The experiment was laid out in the experimental field of Sher-e-Bangla Agricultural University research farm following Randomized Complete Block Design (RCBD) with three replications. Same variety and same sources of potato seed tuber (as used in expt-1), distance of line to line, plant to plant and plot to plot (as used in expt-1) were followed in this experiment. Chemical fertilizers were used as BARI (2014) recommended dose (mentioned in expt-1). Single seed potato tuber having 50-60 g sized were planted in each point on the furrow of the experiment plot. Land preparation, irrigation, weeding and other intercultural operation were the same as in expt-1. Haulm cutting was conducted at 7 days before harvesting. Harvest of potato was done on 80, 90, 100 and 110 days after planting as per treatment.

Experiment of second year (2015-16)

3.3.5 Expt. 4. Response of organic manures and various mulch materials on growth yield and quality of selected potato varieties

3.3.5.1 Objective

i) To find out the suitable organic manure and mulch material along with their combination effects that contributes the highest yield and quality of potato.

3.3.5.2 Experimental procedure

The experiment consisted of three factors *viz;* variety, organic manures and mulch materials. The treatments were selected on the basis of the findings of first year's experiments (Expt-1, 2 and 3).

The treatments were as follows:

Factor A: Variety -3

V_1 = BARI Alu-25 (Asterix)

V_2 = BARI Alu-28 (Lady rosetta)

V_3 = BARI Alu-29 (Courage)

Factor B: Organic manure -3

O_1 = Cowdung @ 10 tha^{-1}

O_2 = Poultry litter @ 10 tha^{-1}

O_3 = ACI organic fertilizer @ 10 tha^{-1}

Factor C: Mulch materials -3

M_1 = Water hyacinth

M_2 = Rice straw

M_3 = Rice husk

Treatment combinations were (27) as:

$V_1O_1M_1$, $V_1O_1M_2$, $V_1O_1M_3$, $V_1O_2M_1$, $V_1O_2M_2$, $V_1O_2M_3$, $V_1O_3M_1$, $V_1O_3M_2$, $V_1O_3M_3$, $V_2O_1M_1$, $V_2O_1M_2$, $V_2O_1M_3$, $V_2O_2M_1$, $V_2O_2M_2$, $V_2O_2M_3$, $V_2O_3M_1$, $V_3O_3M_2$, $V_2O_3M_3$, $V_3O_1M_1$, $V_3O_1M_2$, $V_3O_1M_3$, $V_3O_2M_1$, $V_3O_2M_2$, $V_3O_2M_3$, $V_3O_3M_1$, $V_3O_3M_2$, $V_3O_3M_3$.

A total of 81-unit plots measuring 2.5m × 4m = $10m^2$ were used to set-up the experiment.
The experiment was laid out in the experimental field of Sher-e-Bangla Agricultural University research farm following Randomized Complete Block Design (RCBD) with three replications. Same variety and same sources of potato seed tuber (as used in expt-1), distance of line to line, plant to plant and plot to plot (as used in expt-1) were followed in this experiment. Well decomposed cowdung, poultry litter and ACI organic fertilizer were used @ 10 t ha^{-1} at each in the experiment field as per treatment. Chemical fertilizers were used as BARI (2014) recommended dose (mentioned in expt-1). Mulches materials i.e. water hyacinth, rice straw and rice husk were used according to the treatment (mentioned in expt.-1). Single seed potato tuber having 50-60 g sized were planted in each point on the furrow of the experiment plot. Land preparation, irrigation, weeding and other intercultural operation were the same as in expt-1. Haulm cutting was done at 7 days before harvesting. Harvest of potato was done on 100 days after planting as per treatment

Experiment of third year (2016-17)

3.3.6 Expt. 5. Response of organic manures on growth yield and quality of selected potato varieties at three districts of Bangladesh.

3.3.6.1 Objective

i) To observe the varietal performance in different locations,

ii) To find out suitable organic manure that contributes the highest yield and quality of potato

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3.3.6.2 Experimental procedure

In this year, the experiment no. 5 was conducted for validation and refinement of the results of the second year's experiment (expt. no 4). In the previous experiments, it was observed that there were no significant variations among the three mulch materials, so rice straw was used as mulch material in expt.5 as it is available all over the country. Besides, in organic manure, cowdung and poultry litter were used due to its availability. For examining wider validation of the results, this experiment was conducted in the three potato growing regions of the country including SAU research farm, Dhaka (AEZ-28). Other two regions were – Baliakandi in Rajbari district (AEZ-12) and Sadar in Thakurgaon district (AEZ-1). The experiment consisted of three factors *viz.*,variety, organic manures and mulch materials. So, the treatments of the experiments were as follows:

Factor A: Variety -3

V_1 = BARI Alu-25 (Asterix)

V_2 = BARI Alu-28 (Lady rosetta)

V_3 = BARI Alu-29 (Courage)

Factor B: Organic manure -3

O_1 = Control (No manure)

O_2 = Cowdung @ 10 tha^{-1}

O_3 = Poultry litter @ 10 tha^{-1}

Treatment combinations at three locations were as follows:

V_1O_1, V_1O_2, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_1, V_3O_2, V_3O_3.

A total of 27-unit plots measuring 2.5m × 4m = $10m^2$ were used to set-up the experiment in each of the experimental location.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Same variety and same sources of potato seed tuber (as used in expt.-1), distance of line to line, plant to plant and plot to plot (as used in expt-1) were followed in this experiment. Well decomposed cowdung and poultry litter were used @ 10 t ha^{-1} in each of the experiment field of three locations as per treatment. Chemical fertilizers were used as BARI (2014) recommended dose (mentioned in expt-1). Mulch material i.e. rice straw was used except control as per to the treatment (mentioned in expt.-1). Single seed potato tuber having 50-60 g sized were planted in each point on the furrow of the experiment plot. Land preparation, irrigation, weeding and other intercultural operation were the same as in expt-1.

Haulm cutting was done at 7 days before harvesting. Harvest of potato was done on 100 days after planting.

3.4 Planting material

The planting materials comprised the certified seed tubers of five potato varieties. The varieties were (V_1) BARI Alu-25 (Asterix), (V_2) BARI Alu-28 (Lady rosetta), (V_3) BARI Alu-29, (Courage) , (V_4) BARI Alu-7 (Diamant) and (V_5) BARI TPS-1 tuberlets.

3.4.1 BARI Alu-25 (Asterix):

Asterix is a high yielding variety of long oval uniform red tubers with yellow flesh, with high dry matters and pale fry colour well suited to production of french fries and processed products. It’s susceptible to late blight on foliage, powdery scab, silver scurf, potato leaf roll virus, potato virus Yo and potato cyst nematode *Globodera pallida* Pa2/3,1. Resistance to Blackleg, Bruising, Splitting, Dry rot *Fusarium coeruleum* and potato cyst nematode *Globodera rostochiensis* Ro1

3.4.2 BARI Alu-28 (Lady rosetta):

Lady rosetta is a specialist crisping variety, with high dry matters and low reducing sugars. It has early crop maturity and is suitable to quality crisp production either fresh or from short term storage. Moderate to high yields of uniform, round tubers with low out grades, with good all-round and disease resistance. Susceptible to Powdery scab, Bolackleg and potato cyst nematode *Globoder apallida* Pa2/3,1. shows resistance to splitting and resistant to potato cyst nematode *Globodera rostochiensis* Ro1.

3.4.3 BARI Alu-29 (Courage):

This high yielding, rapidly bulking HZPC variety produces early yields of high dry matter and uniform red skinned, round tubers. It is suitable for ex field and short-term storage use. Resistant to potato cyst nematode *Globodera rostochiensis* Ro1.

3.4.4 BARI Alu-7 (Diamant):

Tuber: white, oval, medium to large size, skin smooth, light yellow, shallow eye, at first sprout initiation round shape, later it will taller, color reddish violet and slight hairy. Plant strong and rapid growing, number of stems is lower but tall and hard, leaf slight large and deep green, seed dormancy 50-60 days in general temperature, crop duration 90-95 days. This variety is cultivated throughout the Bangladesh. Farmer themselves can grow seed.

3.4.5 BARI TPS-1:

The variety is produced by true seed. Its stem is very long and shallow. It produced the tuber that are round in shape and yellow in color. Its water percentage is very high. True potato seeds are the seeds harvested from potato fruits. These seeds are also called "botanical potato seed" or "True Potato Seed", or "TPS" to differentiate them from "seed potatoes" which are genetically identical clones produced in large numbers by planting pieces of a potato stem or tuber or through tissue culture.

3.5 Recording of data

Experimental data were recorded from 25 days after planting and continued until harvest at field level. Dry weights of potato plant above ground and tuber dry matter were collected after harvesting.

The following data were collected during the experimentation:

A. Crop growth parameter

i. Plant height at 25, 40, 55, 70 and 85 DAP
ii. Number of stems hill^{-1} at 25, 40, 55, 70 and 85 DAP
iii. Leaf area (LA) at 25, 40, 55, 70 and 85 DAP
iv. SPAD value of leaves at 25, 40, 55, 70 and 85 DAP
v. Dry matter percentage of plant at 25, 40, 55, 70 and 85 DAP

B. Yield and yield parameter

i. Number of tubers hill^{-1}
ii. Weight of tubers hill^{-1}
iii. Yield (t ha^{-1})
iv. Marketable yield (t ha^{-1})
v. Non- marketable yield (t ha^{-1})
vi. Marketable tuber grading (>75g, 50-70g, 20-50g) (% by number)
vii. Non Marketable tuber (< 20 g) (% by number)
viii. Chips tuber (45-75 mm) (yield t ha^{-1} and % by number)
ix. French fry tuber (> 75 mm) (yield t ha^{-1} and % by number)
x. Canned tuber (20-30 mm) (yield t ha^{-1} and % by number)
xi. Dehydrated tuber (30-45mm) (yield t ha^{-1} and % by number)

C. Quality and post-harvest parameter

i. Dry matter content of tuber (%) at (at harvest, 15, 30, 45, 60 and 75 DAS)
ii. Specific gravity of tuber at (at harvest, 15, 30, 45, 60 and 75 DAS)
iii. Total Soluble Solid (TSS) (^{o}Brix) of tuber at (at harvest, 15, 30, 45, 60 and 75 DAS)

3.5.1 Experimental measurements

A brief outline of the data recording procedure followed during the study is given below:

3.5.1.1 Crop growth parameter

3.5.1.1.1 Plant height (cm)

Plant height refers to the length of the plant from ground level to the tip of the growing point. It was measured at an interval of 15 days starting from 25 DAP to till 85 DAP. The height of 5 plant of each plot was measured in centimeter (cm) with the help of a meter scale and mean was calculated.

3.5.1.1.2 Number of stems hill^{-1}

Number of stems hill^{-1} was counted at an interval of 15 days starting from 25 DAP to till 85 DAP. Stem number hill^{-1} was recorded by counting all stems from each plot.

3.5.1.1.3 Dry matter content of plant & tuber (%)

The samples of stems and tuber were collected from each treatment. For stems, after collecting the stems of above ground from each treatment, initially it was dried in sun for 2 days and then the samples were dried in an oven at 72^{0}C for 72 hours. For tuber, after slicing off the tubers, the samples were initially dried in sun for 1 day and after that dried in an oven at 72^{0}C for 72 hours. Dry matter content was calculated as the ratio between dry and fresh weight and expressed as a percentage. Dry matter percentage of above ground harvested plants and tubers were calculated with the following formula (Elfinesh *et al.* 2011)

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.5.1.1.4 Leaf Area (cm^2)

Three hills were selected from each plot for taking leaf area. In each hill three leaves were selected from top, middle and bottom position and measured length and width by measuring scale, then after the leaf area was measured. The average value was termed as leaf area and it is expressed in cm^2 .

3.5.1.1.5 SPAD value of leaves

SPAD values of leaves was measured at an interval of 15 days starting from 25 DAP till 85 DAP. Mature leaf (fourth leaves from top) were measured all time. Three mature plant of each plot were measured by using portable Chlorophyll Meter (SPAD-502, Minolta, Japan) and then calculated an average SPAD value for each plot at each sampling time.

The chlorophyll meter Soil Plant Analysis Development (SPAD-502) is a simple and portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves (Kariya *et al.,* 1982; Torres-netto *et al.,* 2005). It provides instantaneous and non-destructive readings on plants based on the quantification of the intensity of absorbed light by the tissue sample using a red LED (wavelength peak is ~650 nm) as a source. An infrared LED, with a central wavelength emission of approximately 940 nm, acts simultaneously with the red LED to compensate for the leaf thickness (Minolta camera Co. Ltd., 1989).

3.5.1.2 Yield and yield components

3.5.1.2.1 Yield of tubers (ton ha^{-1})

Tubers of each plot were collected separately from which yield of tuber per plot was recorded in kililogram (kg) and then converted into tons per hectare.

3.5.1.2.2 Average number of tuber hill^{-1}

Average number of tuber was measured by using the following formula-

$$\text{Average number of tuber hill}^{-1} = \frac{\text{Total no. of tuber/plot}}{\text{Total hills /plot}}$$

3.5.1.2.3 Average weight of tuber hill^{-1}

Average weight of tuber hill^{-1} was measured by using the following formula-

$$\text{Average weight of tuber hill}^{-1} = \frac{\text{Total weight of tuber/plot}}{\text{Total hills /plot}}$$

3.5.1.2.4 Marketable tuber and non-marketable tuber

On the basis of weight, the tubers have been graded into marketable tuber (>20g) and non-marketable tuber (<20g). The marketable tuber was also graded in three grades i.e. A-grade (>75g), B-grade (50-75g) and C-grade (20-50g). The non-marketable tuber (<20 g) was again graded into canned size potato measured between (20-30mm) (Marwaha *et al*. 2010). Marketable and non-marketable yield of tubers was recorded in ton per hectare. The percentage of each graded tubers was calculated by number and by weight basis.

3.5.1.2.5 Grading of tubers on industrial quality

Grading of tubers was emphasized on industrial quality of potato which were graded into three size as chips (45-75mm), french fry (>75mm) and dehydrated (>30-45mm) (Marwaha *et al*. 2010). Yield of graded potato tubers was calculated in ton per hectare The percentage of different grades of tubers was estimated as by number and by weight basis.

3.5.1.3 Quality and post-harvest characteristics

3.5.1.3.1 Dry matter content (%) of potato tuber

The samples of tuber were collected from each treatment. Samples fresh weights were determined with the aid of the electronic weighing balance after which they were sliced and oven-dried at 72^0C for 72 hours. The dry samples were then weighed. The percentage of dry matter was calculated as follows:

$$\text{Dry matter percentage} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times 100$$

3.5.1.3.2 Specific gravity

Specific gravity is the weight of the tuber compared to the weight of the same volume of water. The reference substance for liquids is nearly always water at its densest (at 4 °C or 39.2 °F). It is a measurement of density. The tubers used for the determination of specific gravity were washed and air-dried to remove soil particles and to obtain accurate values. The specific gravity (SG) was calculated using the formula: (Namo *et al.* 2016) (

$$\text{Specific gravity} = \frac{\text{Weight of tuber in air}}{\text{Weight of equal volume of water}}$$

3.5.1.3.3 Total soluble solids (TSS) °BRIX

TSS of harvested tubers was determined in a drop of potato juice by using Hand Sugar Refractometers "ERMA"Japan, Range : 0-32% according to (AOAC, 1990) and expressed as °Brix value.

3.5.1.4 Statistical Analysis

Mean data of the characters were subjected to multivariate analysis. Univariate analysis of the individual characters was done for all characters under study using the mean values (Singh and Chaudhury, 1985). The data collected on various parameters under different experiments conducted during 2014-15 to 2016-17 seasons were statistically analyzed by using MSTAT-C computer package programme to find out the statistical significance of the treatment effect, mean, range and co-efficient of variation (CV%). The significance difference among the treatment means and between pair of treatment means were evaluated by Least Significance Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULT AND DISCUSSION

The experiment was conducted in three consecutive years (2014-2017) covering three potato growing seasons during the period from November to March for field experiment in Rabi season and up to June for post-harvest quality in ambient temperature. All experiments were conducted at Sher-e-Bangla Agricultural University experimental field except third year's experments, which were conducted at SAU campus, Baliakandi Upazilla in Rajbari district and Sadar Upazilla in Thakurgaon district. The results of the experiments have been presented and discussion and possible interpretations are given in this chapter.

Experiment No. 1. Effect of various mulch materials on growth yield and quality of potato varieties

The experiment was conducted to study the effect of various mulch materials on growth, yield and quality of potato. Data on different growth, yield and quality of potato were recorded and discussed with possible interpretations under the following headings.

4.1 Growth parameter

4.1.1 Plant height

4.1.1.1 Effect of variety

Potato variety exhibited significant difference on plant height of potato at different growth stages (Figure 1). The results of the experiment revealed that, among the varieties, V_1 (BARI Alu-25) showed the tallest plant (22.37 cm, 46.68 cm, 68.49 cm, 76.82 cm and 81.06 cm at 25, 40, 55, 70 and 85 DAP, respectively), which were statistically similar with V_2 (BARI Alu-28) and V_3 (BARI Alu-29) at 25 DAP; with V_2 (BARI Alu-28) at 40 and 55 DAP. V_5 (BARI TPS-1) tuberlets showed the shortest plant (18.79 cm, 31.18 cm, 56.64 and 61.36 cm at 25, 40, 55 and 85 DAP, respectively), which were statistically similar with V_3 at 55 DAP and with V_4 (BARI Alu-7) at 85 DAP. At 70 DAP, the shortest plant (62.93 cm) showed by V_3 which was statistically similar with V_5. The varietal difference might be due to genetic variation of the potato variety because genetic potentiality varied with varietal variation. Mirdad (2010), Swaminathan *et al.* (1999), Marwaha (1998) and

El-Nashar *et al.* (1995). Since, they showed that potato cultivars differed significantly from each other in plant height of potato plants.

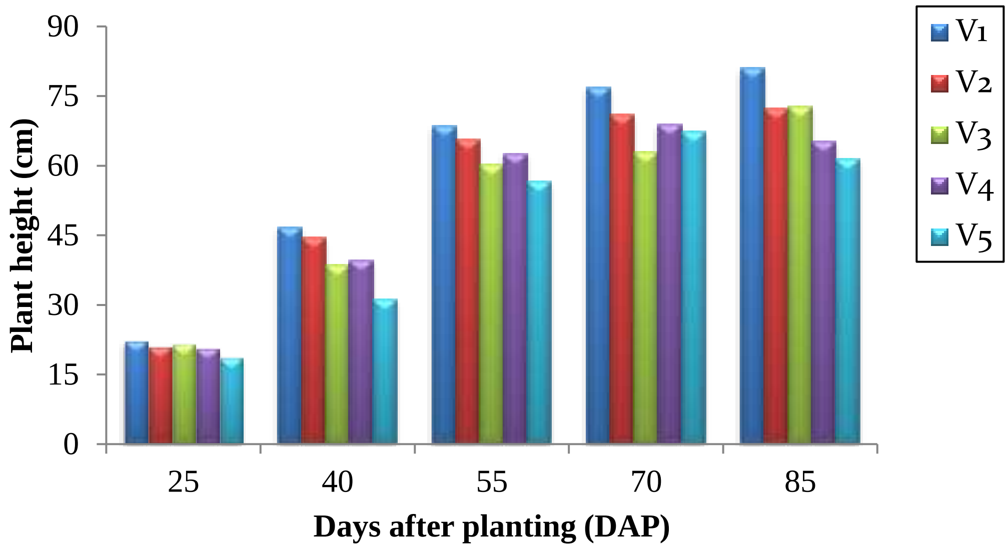


Figure 1. Effect of variety on the plant height of potato at different days after planting (LSD $_{0.05}$= 1.63, 3.20, 4.79, 5.69 and 5.51 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.1.2 Effect of mulch materials

Mulch materials showed a significant variation on plant height for all growth stages of potato (Figure 2). The result revealed that plant height increases with the advancement growth stages irrespective of mulch materials. The increasing trend was higher up to 55 DAP thereafter it was much slower. Treatment without mulch showed the lowest plant height for all samplaing dates. Rice straw (M_2) treatment showed the highest plant height at 55 and 70 DAP, but at 85 DAP the tallest plant was observed with rice husk (M_3) treatment. Plant height of a crop depends on the plant vigor, cultural practices, growing environment and agronomic management. Mulching is an effective method to control top-soil's temperature. Because of the favorable changes in soil temperature caused by mulching which favor boosting of plant height. Mulching changed other soil fertility associated properties (Li *et al.*, 2018). Ilyas and Ayub (2017) and Opara-Nadi (1993) reported that mulching is an effective method of manipulating crop growth environment to increase yield and improve product quality by controlling weed growth, regulate soil temperature, conserving soil moisture, improving soil structure and enhancing organic matter content of the soil. The contents of available phosphorus and potassium significantly increased under mulching compared with non-mulching which subsequently promoted the plant growth and development of plant. Singh and Ahmed (2008) and Asandhi and Suryadhi (1982) reported that potato plant height was markedly increased by rice straw mulching. Farrag *et al*. (2016) reported that plastic film mulches increased plant height of potatoes. The findings of the experiment was also similar with the findings of Pulok *et al*. (2016), Azad *et al*. (2015) and Zhao *et al*. (2012) who reported that plant height of potato significantly increased using mulch.

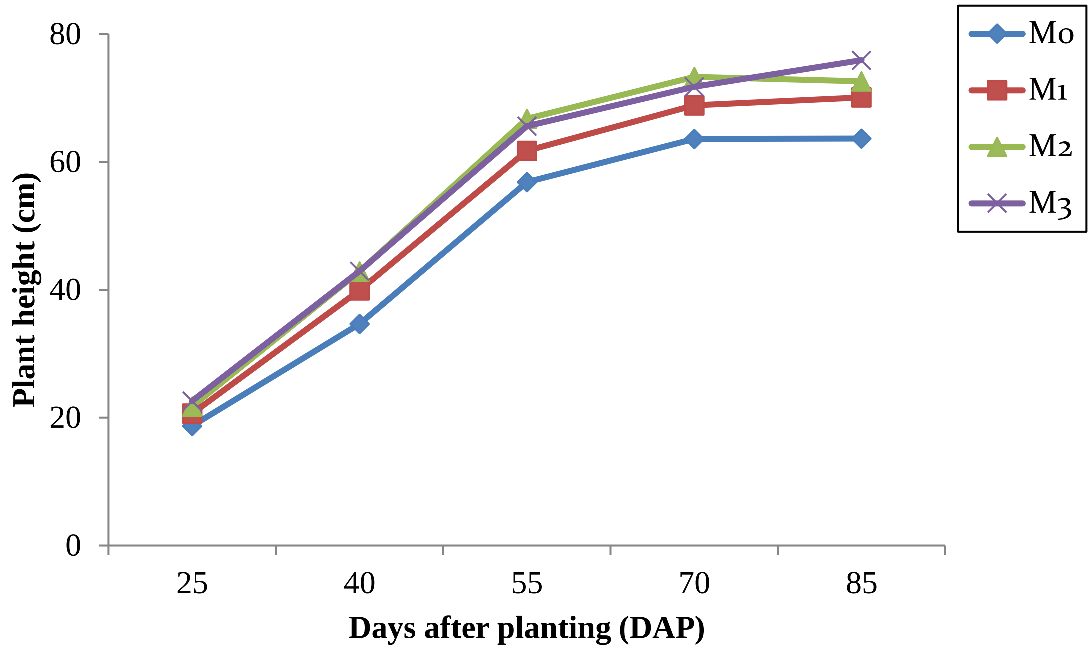


Figure 2. Effect of mulch materials on the plant height of potato at different days after planting (LSD $_{0.05}$= 1.46, 2.87, 4.29, 5.09 and 4.93 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, M_0 = Control(no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.1.3 Interaction effect of variety and mulch materials

Interaction of variety and mulch materials showed significant variation in potato plant height (Table 1). However, the tallest plant (24.20 cm, 51.76 cm, 74.56 cm and 84.18 cm at 25, 40, 55 and 85 DAP, respectively) were recorded from treatment combination V_1M_3, which were statistically similar with V_1M_2, V_3M_3, V_3M_2, V_4M_3, V_4M_1, V_3M_1, V_2M_3, V_2M_2 and V_1M_1 at 25 DAP; with V_1M_2, V_2M_2 and V_2M_3 at 40 DAP; with V_2M_2, V_1M_1, V_1M_2 and V_2M_1 at 55 DAP; with V_1M_1, V_1M_2, V_1M_0, V_2M_2, V_2M_3 and V_3M_3 at 85 DAP. At 70 DAP the tallest plant (79.82 cm) was recorded from treatment combination V_1M_1 which were statistically similar with V_1M_2, V_1M_0, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_3M_3, V_4M_2, V_4M_3

and V_5M_2. On the other hand, the shortest plant (17.77 cm, 27.57 cm, 50.11 cm and 53.18 cm) were recorded from treatment combination V_5M_0 which was statistically similar with V_5M_1, V_5M_2, V_5M_3, V_4M_2, V_4M_0, V_3M_1, V_3M_0, V_2M_1, V_2M_0 and V_1M_0 at 25 DAP; with V_5M_1, V_5M_3 and V_3M_0 at 40 DAP; with V_5M_1, V_5M_3, V_3M_0 and V_4M_0 at 55 DAP and with V_5M_1 and V_4M_0 at 85 DAP. At 70 DAP the shortest plant (56.04 cm) was recorded from treatment combination V_3M_0 which was statistically similar withV_3M_1, V_3M_2, V_4M_0, V_4M_1, V_5M_0, V_5M_1 and V_2M_0.

Table 1. Interaction effect of variety and mulch materials on the plant height of potato at different days after planting

Interaction (variety × mulch material)	Plant height (cm) at different days after planting (DAP)				
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**	**85 DAP**
V_1M_0	19.83 c-f	40.96 d-h	64.83 b-e	71.75 a-e	74.48 a-e
V_1M_1	21.88 a-e	44.89 b-e	65.45 a-e	79.82 a	83.94 a
V_1M_2	23.58 ab	49.11 ab	69.11 a-c	79.37 a	81.63 ab
V_1M_3	24.20 a	51.76 a	74.56 a	76.36 a-c	84.18 a
V_2M_0	18.78 ef	38.45 f-h	60.56 c-g	66.06 b-f	64.85 e-g
V_2M_1	20.27 c-f	44.55 b-f	65.56 a-e	70.11 a-e	71.97 b-e
V_2M_2	22.63 a-c	46.00 a-d	73.00 ab	77.03 ab	74.43 a-e
V_2M_3	22.61 a-c	48.86 a-c	63.67 b-f	70.78 a-e	78.22 a-d
V_3M_0	19.16 d-f	31.42 ij	52.44 gh	56.04 f	67.05 e-g
V_3M_1	20.98 a-f	38.93 e-h	60.71 c-g	61.67 ef	70.22 c-f
V_3M_2	22.93 a-c	41.46 d-g	64.44 b-e	64.89 d-f	72.72 b-e
V_3M_3	23.66 ab	42.73 b-f	63.55 b-f	69.11 a-e	81.17 a-c
V_4M_0	17.99 f	35.01 hi	56.22 e-h	62.55 ef	58.72 gh
V_4M_1	21.92 a-e	41.42 d-g	62.56 c-f	67.22 b-f	64.87 e-g
V_4M_2	20.73 b-f	42.62 c-f	64.56 b-e	70.33 a-e	68.02 d-g
V_4M_3	22.27 a-d	39.31 e-h	66.89 a-d	75.22 a-d	69.34 d-g
V_5M_0	17.77 f	27.57 j	50.11 h	61.55 ef	53.18 h
V_5M_1	18.14 f	29.97 ij	54.44 f-h	65.55 c-f	59.43 f-h
V_5M_2	18.94 ef	35.22 g-i	62.67 c-f	74.86 a-d	66.12 e-g
V_5M_3	20.29 c-f	31.95 ij	59.33 d-h	67.44 b-e	66.70 e-g
LSD $_{(0.05)}$	**3.27**	**6.41**	**9.58**	**11.38**	**11.02**
CV (%)	**9.44**	**9.67**	**9.24**	**9.92**	**9.45**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control(no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.2 Number of stems hill^{-1}

4.1.2.1 Effect on variety

Significant difference was observed on number of stem hill^{-1} at different growth stages among potato varieties (Figure 3). At 25 DAP the maximum number of stem hill^{-1} (2.25) was attained by V_2 which was statistically similar with V_1 and V_3. Again the maximum number of stem hill^{-1} (3.98, 3.95, 3.86 and 3.73) were attained by V_1 at 40, 55, 70 and 85 DAP, respectively which was statistically differed from other treatment. Whereas the minimum number of stem hill^{-1} (1.92, 2.50, 2.42 and 2.45) were attained by V_5 at 25, 40, 55 and 70 DAP, respectively which was statistically similar with V_4 and V_3 at 25, 40 and 70 DAP; with V_3 at 55. At 85 DAP the minimum number of stem hill^{-1} (2.36) was attained by V_3 which was statistically similar with V_5.

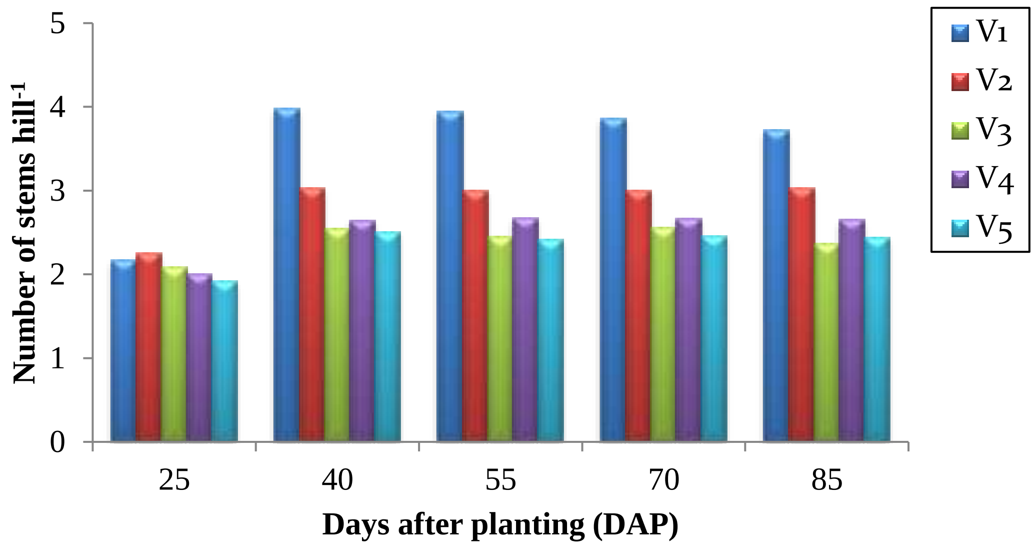


Figure 3. Effect of variety on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.17, 0.26, 0.25, 0.24 and 0.26 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.2.2 Effect of mulch materials

Mulch materials had a significant variation on number of stem hill^{-1} for all growth stages of potato (Figure 4). The figure indicated that number of stems plant^{-1} increased rapidly from 25 to 40 DAP after that the rate of increase was much slower and this trend was continued up 85 DAP irrespective of mulch materials except no mulch (control) treatment (M_0). No mulch treatament showed the lowest number of stems plant for all sampling dates, which indicates that mulch application increased the branches plant^{-1} over control.

However, M_2 and M_1 treatment produced the higher level of stems plant^{-1} from 40 DAP to 85 DAP. Mulching changed soil fertility associated properties. The content of available nitrogen was significantly increased by using organic mulch (rice straw) which was beneficial to increase soil nitrogen helped to increase other nutrient available to the plant consequently boosting the proliferate stem production of potato. Li *et al.* (2018) reported that the contents of available phosphorus and potassium significantly increased under mulching compared with non-mulching plot. Pulok *et al.* (2016) found that rice straw produced maximum number of stems hill^{-1} compare to other mulch materials in all growing stage. Ilyas and Ayub (2017) concluded that mulching produced maximum number of stems hill^{-1} (3.70) as compared to (3.40) in control treatment (no mulch). Similar findings were reported by Farrag *et al*. (2016) and Farhadi and Kashi (2003).

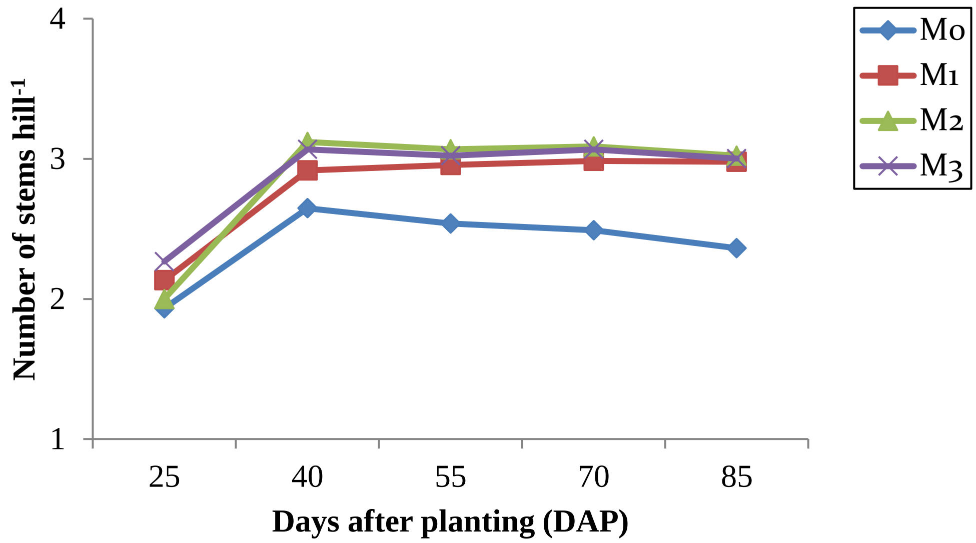


Figure 4. Effect of mulch materials on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.15, 0.23, 0.22, 0.22 and 0.23 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.2.3 Interaction effect of variety and mulch material

Interaction of variety and mulch material had significant variation on the number of stem hill^{-1} of potato with all growth stages (Table 2). At 25 DAP the highest number of stem hill^{-1} (2.67) was attained by both treatment combinations V_1M_1 and V_2M_3 which were statistically similar with V_1M_2, V_2M_2, V_3M_3 and V_4M_3 and the lowest number of stem hill^{-1} (1.67) was attained by treatment combinations V_1M_0, V_4M_2 and V_5M_2 which were statistically similar with all the treatment combinations except V_1M_1, V_1M_2, V_2M_2, V_2M, V_3M_3 and V_4M_3. At 40, 55, 70 and 85 DAP the highest number of stem hill^{-1} (4.33, 4.33, 4.22 and 4.11, respectively) were attained by treatment combination V_1M_2 which was statistically similar with V_1M_3 and V_1M_1 at 40, 55, 70 and 85 DAP. At 40, 55 and 70 DAP the lowest number of stem hill^{-1} (2.11, 1.89 and 2.11, respectively) were attained by treatment combination V_5M_0 which was statistically similar withV_4M_0, V_3M_0, V_2M_1, V_3M_1, V_3M_2 and V_5M_2 at 40 DAP; with V_3M_2 and V_3M_0 at 55 DAP; with V_4M_0, V_3M_0, V_2M_0, V_3M_1, V_3M_2, V_5M_1 and V_5M_2 at 70 DAP. At 85 DAP the lowest number of stem hill^{-1} (2.00) was attained by treatment combination V_3M_0 which was statistically similar with V_5M_0, V_4M_0, V_3M_3, V_3M_2, V_2M_0 and V_5M_2.

Table 2. Interaction effect of variety and mulch materials on the number of stems hill^{-1} of potato at different days after planting

Interaction (variety × mulch material)	Number of stems hill^{-1} at different days after planting				
	25 DAP	40 DAP	55 DAP	70 DAP	85 DAP
V_1M_0	1.67 c	3.46 cd	3.46 b	3.23 bc	3.12 cd
V_1M_1	2.67 a	4.00 ab	4.11 a	4.00 a	3.89 ab
V_1M_2	2.33 ab	4.33 a	4.33 a	4.22 a	4.11 a
V_1M_3	2.00 bc	4.11 a	3.89 ab	4.00 a	3.78 ab
V_2M_0	2.00 bc	3.11 c-e	2.67 cd	2.55 e-h	2.44 e-i
V_2M_1	2.00 bc	2.44 f-i	2.89 c	2.89 c-e	3.11 cd
V_2M_2	2.33 ab	3.55 bc	3.56 b	3.44 b	3.44 bc
V_2M_3	2.67 a	3.00 de	2.89 c	3.11 b-d	3.11 cd
V_3M_0	2.00 bc	2.33 g-i	2.23 de	2.33 f-h	2.00 i
V_3M_1	2.00 bc	2.48 f-i	2.44 cd	2.55 e-h	2.44 e-i
V_3M_2	2.00 bc	2.60 e-i	2.22 de	2.56 e-h	2.33 f-i
V_3M_3	2.33 ab	2.78 e-g	2.89 c	2.78 c-f	2.67 d-g
V_4M_0	2.00 bc	2.22 hi	2.45 cd	2.22 gh	2.16 g-i
V_4M_1	2.00 bc	2.89 ef	2.89 c	2.89 c-e	2.89 de
V_4M_2	1.67 c	2.67 e-h	2.56 cd	2.78 c-f	2.78 d-f
V_4M_3	2.33 ab	2.78 e-g	2.78 c	2.78 c-f	2.78 d-f
V_5M_0	2.00 bc	2.11 i	1.89 e	2.11 h	2.09 hi
V_5M_1	2.00 bc	2.78 e-g	2.44 cd	2.59 e-h	2.56 e-h
V_5M_2	1.67 c	2.45 f-i	2.67 cd	2.45 e-h	2.445 e-i
V_5M_3	2.00 bc	2.67 e-h	2.67 cd	2.67 d-g	2.67 d-g
LSD $_{(0.05)}$	**0.34**	**0.51**	**0.50**	**0.48**	**0.51**
CV (%)	**9.94**	**10.58**	**10.36**	**10.03**	**10.88**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control (no mulch), M_1 = water hyacinth, M_2 = rice straw and M_3 = rice husk

4.1.3 SPAD value in leaf

4.1.3.1 Effect of variety

Significant difference was observed on SPAD value for chlorophyll in leaves of potato due to varietal variation at all growth stages (Figure 5). The maximum SPAD value for chlorophyll in leaf (41.33, 51.97, 50.79 and 50.00) was observed in V_3 which was statistically at par with V_4 and V_1 at 25 DAP; with V_2 and V_4 at 55 DAP; with V_4 at 70 DAP. At 85 DAP the maximum SPAD value for chlorophyll in leaf (46.8) was observed in V_1. The minimum SPAD value for chlorophyll in leaf (36.08, 46.47, 43.42 and 36.39) was observed in V_5 at 25, 40, 70 and 85 DAP, respectively which was statistically at par with V_2 and V_1 at 25 and 70 DAP; with V_1 at 40 DAP; with V_2 at 85 DAP. At 55 DAP the minimum SPAD value for chlorophyll in leaf (45.89) was observed in V_2 which was statistically at par with V_1 and V_5.

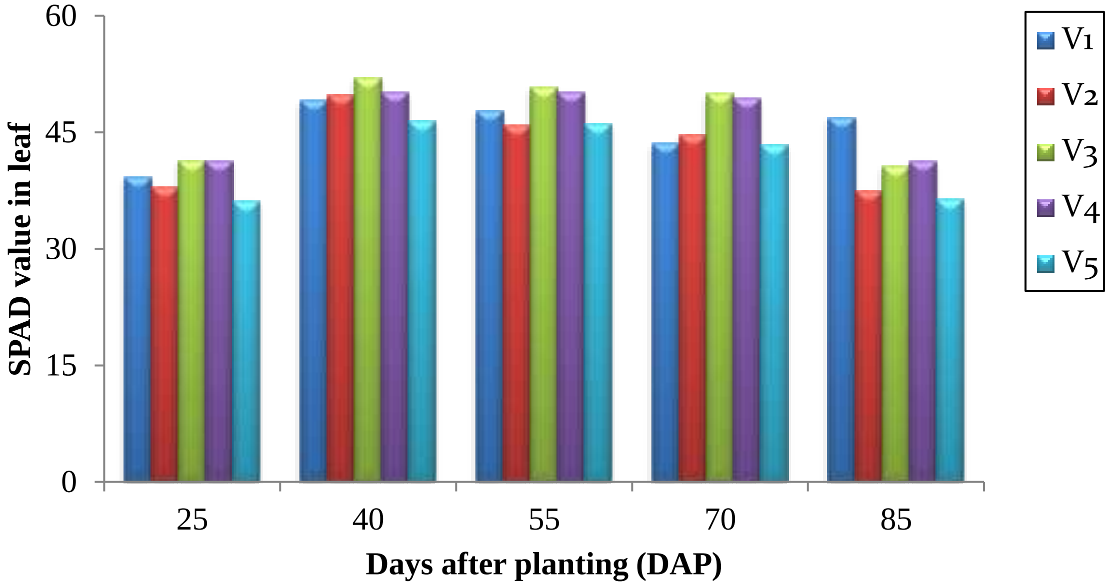


Figure 5. Effect of variety on the SPAD value in leaf of potato at different days after planting (LSD $_{0.05}$= 3.41, 2.79, 3.02, 2.73 and 3.51 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.3.2 Effect of mulch materials

Significant difference was observed on SPAD value for chlorophyll content in leaf of potato due to different mulch materials at all growth stages (Figure 6). The figure revealed that SPAD value for chlorophyll content in leaf showed an increasing trend with the early stages of growth up to 55 DAP after that it reduces gradually up to 85 DAP, irrespective of mulch materials. Rice straw mulch (M_2) showed its superiority over other mulch materials by producing higher SPAD value for chlorophyll content in leaf for all stages of growth. On the other hand, no mulch (control) treatment showed the lowest values of SPAD value for chlorophyll content in leaf for all sampling dates. Li *et al.* (2018) reported that addition of mulch materials changed the soil fertility and add soil nitrogen. Nitrogen is the core component of chlorophyll molecule and thus, its content in leaf is directly correlated with chlorophyll content. It is expected that additional nitrogen added by the organic mulch thus increasing the nitrogen content in potato plant which may also cause the increase of chlorophyll content. The result of the present study was agreed with those findings of Pulok *et al.* (2016), El-Zohiri and Samy (2013b) and Panchal *et al.* (2001) who found that mulch had significant effect on total chlorophyll contents in chili.

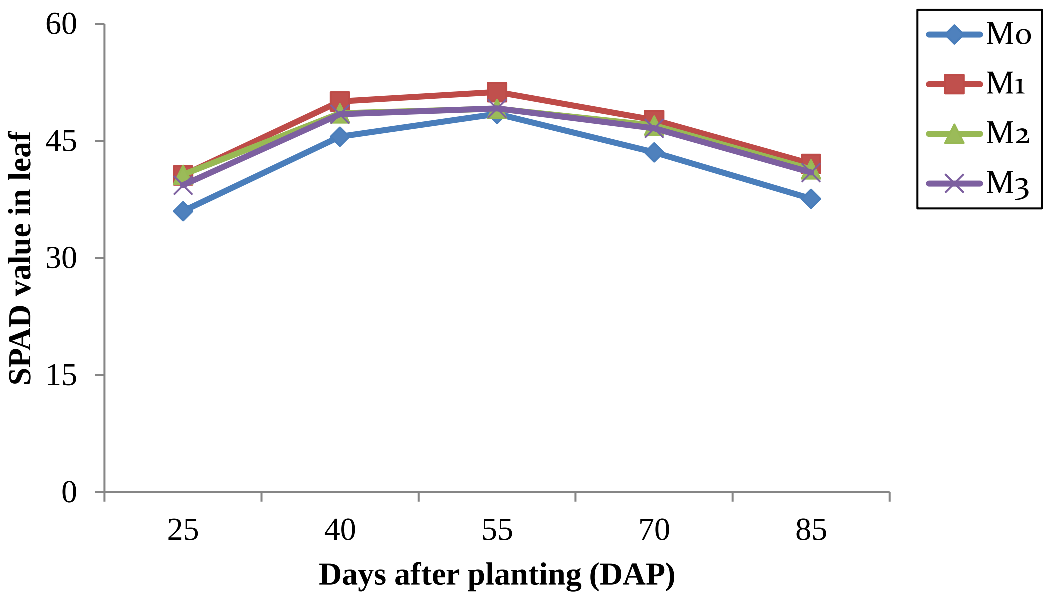


Figure 6. Effect of mulch materials on the SPAD value in leaf of potato at different days after planting (LSD $_{0.05}$= 3.05, 2.49, 2.70, 2.44 and 3.14 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, M_0 = Control(no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.3.3 Interaction effect of variety and mulch material

Significant difference was observed on SPAD value for chlorophyll content in leaf of potato due to interaction of variety and mulch materials at all growth stages (Table 3). At 25 DAP the maximum SPAD value for chlorophyll content in leaf (44.67) was observed in V_4M_1 which was statistically at par with rest of the treatment combinations except V_1M_0, V_1M_3, V_2M_0, V_2M_1, V_5M_0 and V_5M_2. At 40 DAP the maximum SPAD value for chlorophyll content in leaf (53.81) was observed in V_3M_2 which was statistically at par with rest of the treatment combinations except V_1M_0, V_5M_0, V_5M_3 and V_5M_2. At 55 DAP the maximum SPAD value for chlorophyll content in leaf (54.31) was observed in V_3M_1 which was statistically at par with V_4M_1, V_4M_3, V_4M_2, V_5M_2, V_3M_3, V_3M_2, V_3M_0, V_1M_1 and V_1M_2. At 70 DAP the maximum SPAD value for chlorophyll content in leaf (53.00) was observed in V_3M_0 which was statistically at par with V_4M_1, V_3M_0, V_3M_1, V_3M_2, V_3M_3, V_4M_0, V_4M_2 and V_4M_3.

Table 3. Interaction effect of variety and mulch materials on the SPAD value for chlorophyll content in leaf of potato at different days after planting

Interation (variety × mulch material)	SPAD value for Chlorophyll content in leaf of potato at different days after planting				
	25 DAP	40 DAP	55 DAP	70 DAP	85 DAP
V_1M_0	36.33 c-e	44.69 d	45.38 cd	36.67 f	42.33 b-e
V_1M_1	39.33 a-d	51.31 ab	49.21 a-c	45.00 de	46.05 a-c
V_1M_2	43.33 ab	48.24 a-d	48.38 a-c	46.67 b-e	51.93 a
V_1M_3	37.67 b-e	52.18 a	47.98 bc	46.00 c-e	47.10 ab
V_2M_0	35.33 de	50.90 a-c	44.83 cd	43.00 e	34.53 fg
V_2M_1	36.33 c-e	50.01 a-d	45.83 b-d	47.33 b-e	40.14 b-f
V_2M_2	40.67 a-d	48.38 a-d	45.33 cd	44.00 de	39.25 c-f
V_2M_3	39.33 a-d	50.00 a-d	47.55 b-d	44.33 de	35.77 e-g
V_3M_0	38.67 a-d	52.67 a	48.39 a-c	53.00 a	40.23 b-f
V_3M_1	44.00 ab	52.19 a	54.31 a	48.00 a-e	41.54 b-f
V_3M_2	42.33 a-c	53.81 a	51.43 ab	50.67 a-c	37.62 d-g
V_3M_3	40.33 a-d	49.23 a-d	49.04 a-c	48.33 a-e	43.01 b-d
V_4M_0	38.00 a-e	49.27 a-d	47.65 bc	48.67 a-d	39.90 c-f
V_4M_1	44.67 a	53.68 a	54.11 a	52.00 ab	42.24 b-e
V_4M_2	41.33 a-d	48.88 a-d	48.47 a-c	48.33 a-e	40.70 b-f
V_4M_3	41.00 a-d	48.68 a-d	50.42 a-c	48.33 a-e	41.99 b-e
V_5M_0	31.67 e	44.79 d	41.52 d	36.33 f	30.93 g
V_5M_1	38.67 ad	49.09 a-d	46.74 b-d	46.00 c-e	40.36 b-f
V_5M_2	35.67 c-e	46.29 b-d	49.03 a-c	45.33 c-e	37.29 d-g
V_5M_3	38.33 a-e	45.71 cd	47.01 b-d	46.00 c-e	36.98 d-g
LSD $_{(0.05)}$	**6.82**	**5.58**	**6.04**	**5.45**	**7.03**
CV (%)	**10.53**	**6.82**	**7.59**	**7.14**	**10.5**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

Finally at 85 DAP the maximum SPAD value for chlorophyll content in leaf (51.93) was observed in V_1M_2 which was statistically at par with V_1M_3 and V_1M_1. While at 25, 55, 70 and 85 DAP the minimum SPAD value for chlorophyll content in leaf (31.67, 41.52, 36.33 and 30.93, respectively) were observed in V_5M_0 which was statistically at par with V_2M_0,

V_1M_0, V_2M_1, V_4M_0, V_5M_2 and V_5M_3 at 25 DAP; with V_5M_3, V_5M_1, V_2M_3, V_2M_2, V_2M_1, V_2M_0 and V_1M_0 at 55 DAP; with V_1M_0 at 70 DAP and V_2M_0, V_2M_3, V_3M_2, V_5M_2 and V_5M_3 at 85 DAP. At 40 DAP the minimum SPAD value for chlorophyll content in leaf (44.69) was observed in V_1M_0 which was statistically at par with rest of the treatment combinations except V_1M_1, V_1M_3, V_2M_0, V_3M_0, V_3M_1, V_3M_2 and V_4M_1.

4.1.4 Leaf area (cm^2)

4.1.4.1 Effect of variety

Leaf area of potato significantly differed due to varietal difference at all growth stages (Figure 7). The result revealed that maximum leaf area was found in V_2 (Lady rosetta) for all sampling dates except 25 DAP which was closely followed by V_3 (BARI Alu-29) and V_4 (BARI Alu-7) and V_1 (BARI Alu-25). On the other hand lowest values of leaf area was observed in V_5 (BARI TPS-1). At 25 DAP, V_1 (BARI Alu-25) showed the highest leaf area.

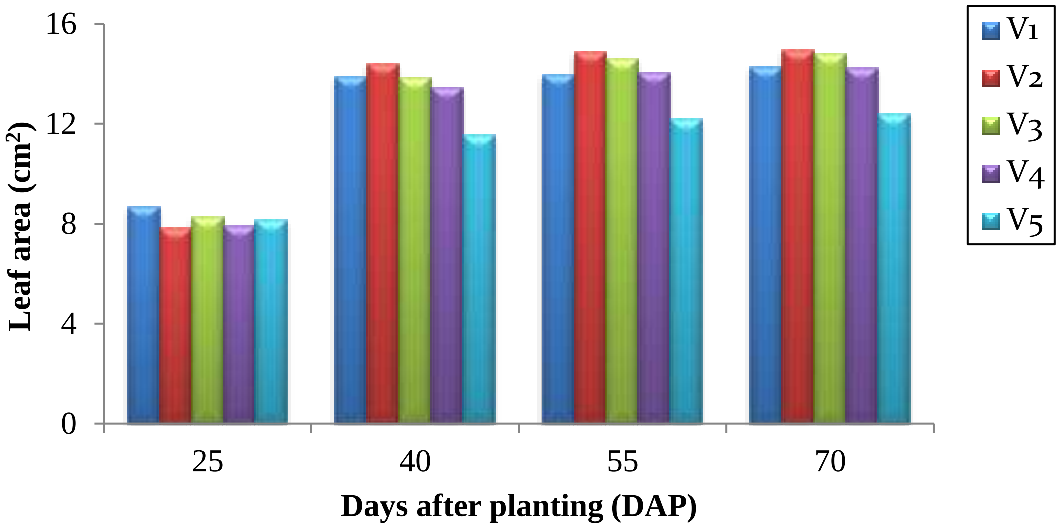


Figure7. Effect of variety on the leaf area of potato plant at different days after planting (LSD $_{0.05}$= 0.62, 1.09, 1.12 and 1.24 at 25, 40, 55 and 70 DAP, respectively.)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.4.2 Effect of mulch materials

Leaf area of potato significantly differed due to different mulch materials at all growth stages (Figure 8). The figure indicated that the leaf area showed an increasing trend from 25 DAP to 70 DAP, irrespective of mulch materials. It is interesting that the rate of increase was much higher from 25 DAP to 40 DAP after that the rate of increase was much slower irrespective of mulch materials. On the other hand, the figure revealed that mulch material application increased the leaf area over no mulch (control) treatment for all sampling dates. However, M_2 (rice straw) was superior in producing leaf area than other mulch materials including control for all sampling dates. Leaf area depends on how vigor the leaf and its number. Organic mulch helps to add additional nitrogen and increase the availability of other essential nutrients to plant. Thus the plant grown under organic mulching became healthy and vigorous and produced vigorous leaf. Beside this organic mulch helps to improve soil chemical, physical and biological properties and increase water holding capacity which favor the producing of vigorous plant and also leaf and attained the maximum leaf area compare to that of no mulch plot. Farrag *et al*. (2016) and Coling (1997) reported that plastic film mulches increased leaf area of potato plant. Kumari (2012) and Lamont *et al*. (2000) reported that black plastic mulch stimulated proliferate and vigorous leaf production

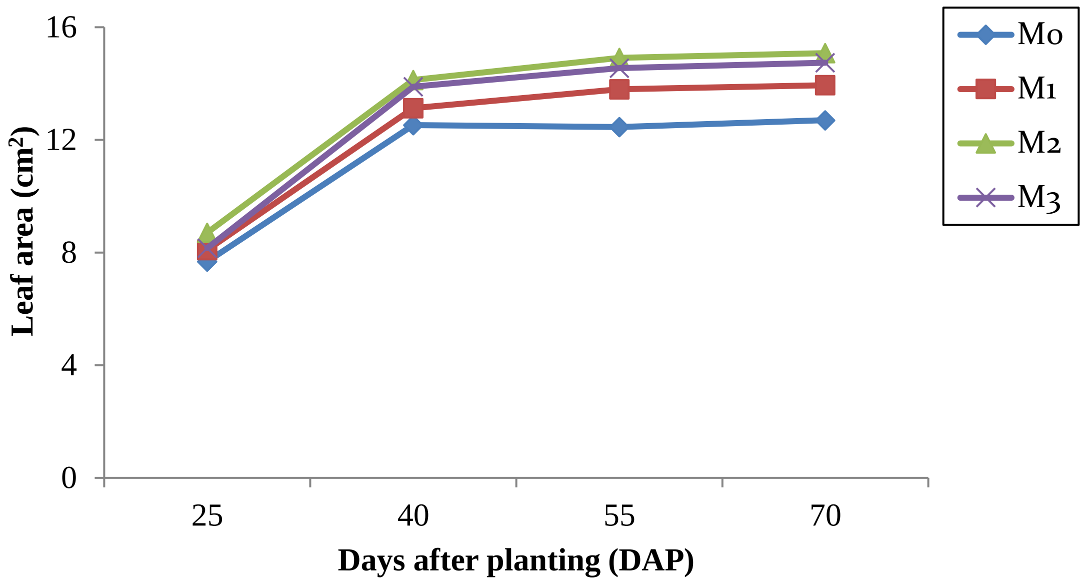


Figure 8. Effect of mulch materials on the leaf area of potato plant at different days after planting (LSD $_{0.05}$= 0.55, 0.97, 1.00 and 1.11 at 25, 40, 55 and 70 DAP, respectively)

Here, M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.4.3 Interaction effect of variety and mulch materials

Leaf area of potato significantly differed due to the interaction of variety and mulch materials at all the growth stages (Table 4). Result revealed that, the maximum leaf area (9.17 cm^2)) was found from V_1M_1 at 25 DAP which was statistically similar with rest of the treatment combinations except V_2M_0, V_2M_1, V_2M_3, V_4M_0, V_4M_1 and V_5M_0 and the minimum leaf area (7.21 cm^2) was found from V_2M_0 at 25 DAP which was statistically similar with rest of the treatment combinations except V_1M_2, V_1M_3, V_2M_2, V_4M_2 and V_5M_2. At 40, 55 and 70 DAP the maximum leaf area (15.45, 16.05 and 16.18 cm^2, respectively) were found from V_1M_2 which was statistically similar with V_4M_2, V_2M_3, V_1M_1, V_2M_0, V_2M_1, V_2M_2, V_3M_1, V_3M_2, V_3M_3 and V_4M_3 at 40 DAP; with V_1M_1, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_3M_1, V_3M_2, V_3M_3, V_4M_1, V_4M_2 and V_4M_3 at 55 DAP and with V_1M_1, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_3M_1, V_3M_2, V_3M_3, V_4M_2, V_4M_3 and V_5M_3 at 85 DAP. At 40 DAP the minimum leaf area (11.00 cm^2) was found from V_5M_2 which was statistically similar with V_5M_1, V_5M_0, V_5M_3, V_4M_1, V_4M_0 and V_3M_0. At 55 and 70 DAP the minimum leaf area (10.95 and 11.14 cm^2, respectively) were found from V_5M_0 which was statistically similar withV_5M_1, V_5M_2, V_4M_0 and V_1M_0 at 55 DAP; with V_5M_1, V_5M_2, V_4M_0, V_1M_0, V_4M_1 and V_2M_0 at 70 DAP.

Table 4. Interaction effect of variety and mulch materials on the leaf area of potato plant at different days after planting

Interaction (variety × mulch material)	Leaf area (cm^2) at different days after planting			
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**
V_1M_0	7.973 a-e	13.26 b-g	11.58 gh	12.40 e-g
V_1M_1	9.170 a	13.61 a-f	14.30 a-e	14.45 a-e
V_1M_2	9.083 a	15.45 a	16.05 a	16.18 a
V_1M_3	8.510 a-d	13.22 b-h	13.88 a-f	14.02 a-f
V_2M_0	7.207 e	13.64 a-f	13.63 b-g	13.43 b-g
V_2M_1	7.550 c-e	14.34 a-e	15.01 a-d	15.13 a-d
V_2M_2	8.700 a-c	14.58 a-d	15.28 a-d	15.39 ab
V_2M_3	7.833 b-e	15.01 a-c	15.60 a-c	15.75 ab
V_3M_0	8.180 a-e	12.35 e-i	13.40 c-g	13.64 b-f
V_3M_1	8.283 a-e	13.95 a-f	14.63 a-e	14.79 a-e
V_3M_2	8.380 a-e	14.55 a-d	15.13 a-d	15.29 a-c
V_3M_3	8.197 a-e	14.53 a-d	15.20 a-d	15.44 ab
V_4M_0	7.317 de	12.15 f-i	12.73 e-h	12.91 c-g
V_4M_1	7.353 de	12.69 d-i	13.29 d-g	13.41 b-g
V_4M_2	8.907 ab	15.07 ab	15.66 ab	15.87 ab
V_4M_3	8.007 a-e	13.84 a-f	14.51 a-e	14.70 a-e
V_5M_0	7.717 b-e	11.21 g-i	10.95 h	11.14 g
V_5M_1	8.110 a-e	11.05 hi	11.78 f-h	11.90 fg
V_5M_2	8.453 a-d	11.00 i	12.43 e-h	12.67 d-g
V_5M_3	8.227 a-e	12.87 c-i	13.57 b-g	13.76 a-f
LSD $_{(0.05)}$	**1.24**	**2.18**	**2.25**	**2.48**
CV (%)	**9.19**	**9.82**	**9.75**	**10.63**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.5 Above ground dry matter content (%) of plant hill^{-1}

4.1.5.1 Effect of variety

Above ground dry weight of plant hill^{-1} of potato was significantly varied due to varietal difference shown in the figure 9. It can be inferred from the figure that V_1 (BARI Alu-25) was superior than other varieties in producing dry weight hill^{-1} of potato plant for all sampling dates. Although V_3 (BARI Alu-29) produced higher dry weight hill^{-1} at 55 DAP and 75 DAP but it was statistically at par with V_1 (BARI Alu-25). The result also indicated that V_3 (BARI Alu-29) and V_1 (BARI Alu-25) variety were statistically similar in producing dry matter (%) of plant hill^{-1} for all sampling dates. On the other hand, lowest dry weight of plant hill^{-1} was found with V_5 (BARI TPS-1) for all sampling dates except 25 DAP.

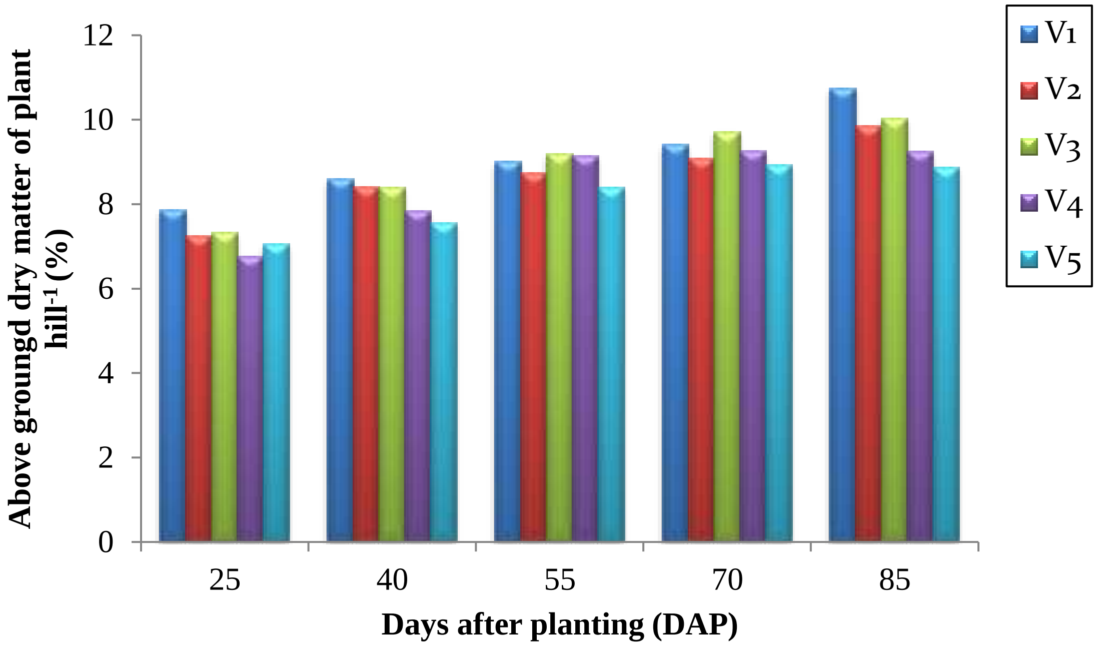


Figure 9. Effect of variety on the above ground dry matter of potato plant hill^{-1} (%) at different days after planting (LSD $_{0.05}$= 0.55, 0.64, 0.69, 0.67 and 0.84 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.5.2 Effect of mulch materials

Above ground dry matter (%) hill^{-1} of potato plant was significantly varied due to different mulching shown in the figure 10. The figure indicates that dry matter production due to use of mulching material increased over control. Among the mulch materials M_2 (rice straw) produced the highest dry matter for all sampling dates. The lowest dry matter was recorded with the M_0 (no mulch) treatment for all sampling dates. Li *et al.* (2018) reported that the content of available nitrogen, phosphorous and potassium was significantly increased by rice straw mulch which triggered the dry matter accumulation of plant. Pulok *et al.* (2016) concluded that stem dry matter content (gm) of potato was significantly affected due to rice straw mulch compare to control treatment. Similar findings were also reported by Roy *et al.* (2007), Moinuddin and Shahid (2004), Farhadi and Kashi (2003), Chettri and Thapa (2002) and Lamont *et al.* (2000) who reported that mulching increased the above ground dry weight of potato plant.

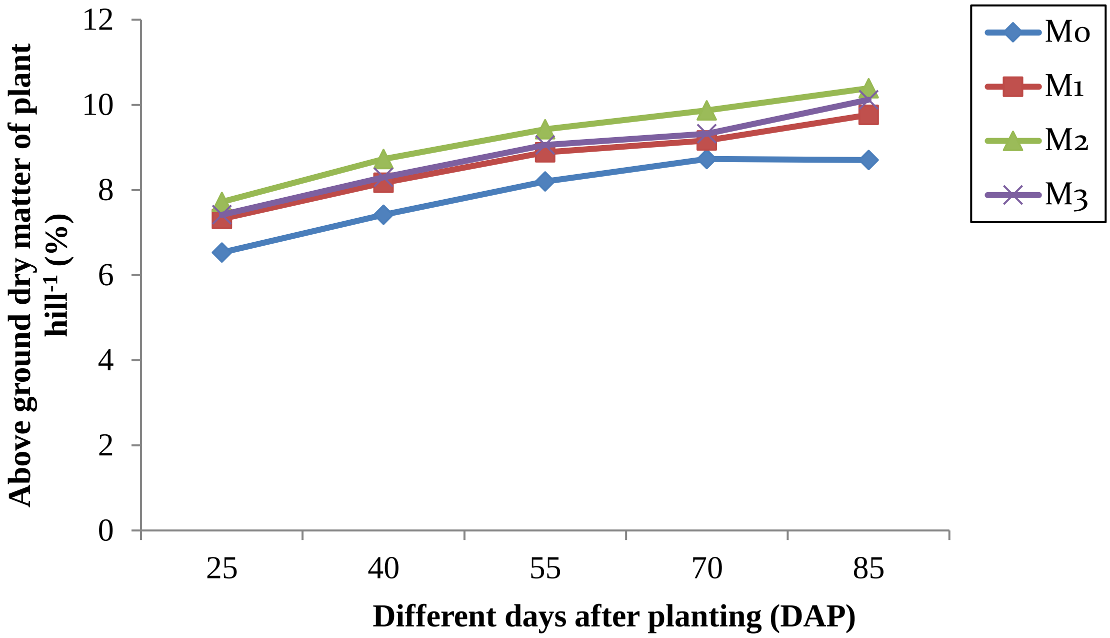


Figure 10. Effect of mulch materials on the above ground dry matter of potato plant hill^{-1} (%) at different days after planting (LSD $_{0.05}$= 0.49, 0.57, 0.62, 0.60 and 0.75 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, M_0 = Control(no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.1.5.3 Interaction effect of variety and mulch materials

Above ground dry weight content hill^{-1} of potato was significantly varied due to different variety and mulching shown in the table 5. The result exposed that, the highest above ground dry weight content hill^{-1} (8.44, 9.58 and 11.67 %) were produced by V_1M_2 at 25, 40 and 85 DAP, respectively which was statistically similar with V_1M_3, V_1M_1, V_2M_1, V_2M_2, V_2M_3 and V_3M_2 at 25 DAP; with V_1M_3, V_1M_1, V_2M_1, V_2M_2, V_2M_3, V_3M_2, V_3M_1 and V_3M_3 at 40 DAP and with V_1M_1, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_3M_1, V_3M_2, V_3M_3 and V_4M_2 at 85 DAP. The highest above ground dry weight content hill^{-1} (10.14 and 10.39 %) were produced by V_3M_2 at 55 and 70 DAP, respectively which was statistically similar with V_1M_2, V_1M_1, V_1M_3, V_2M, V_2M_3, V_3M_1, V_3M_3, V_4M_0, V_4M_1, V_4M_2 and V_4M_3

at 55 DAP and with V_1M_2, V_1M_1, V_1M_3, V_2M, V_2M_3, V_3M_1, V_3M_3, V_4M_2, V_4M_3 and V_5M_2 at 70 DAP. At 25 DAP the lowest above ground dry matter content hill^{-1} (5.80 %.) was produced by V_4M_0 which was statistically similar with V_5M_0, V_4M_1 and V_2M_0. At 40, 55, 70 and 85 DAP the lowest above ground dry matter content hill^{-1} (7.19, 7.75, 8.22 and 7.74 %.) were produced by V_5M_0 which was statistically similar with all the treatment combinations except V_1M_1, V_1M_2, V_1M_3, V_2M_2, V_2M_3, V_3M_2 and V_3M_3 at 40 DAP; with V_1M_2, V_1M_3, V_2M_2, V_3M_2, V_3M_1, V_3M_3, V_4M_1 and V_4M_2 at 55 DAP; with V_1M_2, V_3M_2, V_3M_1, V_3M_3 and V_4M_2 at 70 DAP and with V_1M_2, V_3M_2, V_3M_1, V_3M_3, V_4M_2, V_1M_1, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_4M_3 and V_5M_2 at 85 DAP.

Table 5. Interaction effect of variety and mulch materials on the above ground dry matter of potato plant hill^{-1} (%) at different days after planting

Interaction (variety × mulch material)	Above ground dry matter hill^{-1} (%) of plant at different days after planting				
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**	**85 DAP**
V_1M_0	6.917 c-e	7.513 c-e	8.357 b-e	9.037 b-e	9.227 c-f
V_1M_1	8.003 a-c	8.540 a-c	8.890 a-e	9.503 a-e	10.82 a-c
V_1M_2	8.443 a	9.580 a	9.557 ab	9.990 a-c	11.67 a
V_1M_3	8.040 ab	8.750 a-c	9.247 a-d	9.097 a-e	11.25 ab
V_2M_0	6.510 ef	7.537 c-e	8.090 c-e	9.053 b-e	9.040 d-f
V_2M_1	7.407 a-e	8.407 a-e	8.673 b-e	8.703 c-e	10.09 a-d
V_2M_2	7.633 a-d	9.010 ab	9.270 a-d	9.423 a-e	10.11 a-d
V_2M_3	7.443 a-e	8.650 a-c	8.893 a-e	9.103 a-e	10.15 a-d
V_3M_0	6.930 c-e	7.607 c-e	7.977 de	8.677 c-e	9.313 c-f
V_3M_1	7.173 b-e	8.447 a-e	9.213 a-d	9.630 a-d	10.04 a-d
V_3M_2	8.013 a-c	9.017 ab	10.14 a	10.39 a	10.39 a-d
V_3M_3	7.203 b-e	8.497 a-d	9.427 a-c	10.12 ab	10.35 a-d
V_4M_0	5.797 f	7.243 de	8.837 a-e	8.650 de	8.197 ef
V_4M_1	6.777 d-f	7.943 b-e	9.147 a-d	8.933 b-e	8.797 d-f
V_4M_2	7.253 b-e	8.113 b-e	9.437 a-c	10.09 ab	10.20 a-d
V_4M_3	7.210 b-e	8.000 b-e	9.107 a-e	9.333 a-e	9.803 b-e
V_5M_0	6.500 ef	7.187 e	7.753 e	8.223 e	7.743 f
V_5M_1	7.243 b-e	7.513 c-e	8.487 b-e	9.040 b-e	9.073 d-f
V_5M_2	7.257 b-e	7.920 b-e	8.723 b-e	9.460 a-e	9.577 c-e
V_5M_3	7.190 b-e	7.573 c-e	8.607 b-e	8.957 b-e	9.057 d-f
LSD (0.05)	**1.10**	**1.28**	**1.38**	**1.34**	**1.67**
CV (%)	**9.21**	**9.46**	**9.41**	**8.73**	**10.39**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0 = Control(no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.2 Potato yield and yield parameter

4.2.1 Tuber number hill^{-1}

4.2.1.1 Effect of variety

Potato variety exerted significant difference on the tuber number hill^{-1} (Table 6). Results showed that the maximum tuber number hill^{-1} (7.11) was found in V_1 and the minimum tuber number hill^{-1} (6.08) was found in V_5 which was statistically similar with V_2, V_3 and V_4. Tuber number varied among the varieties and this trend may perhaps due to the genetic make up of the varieties. These findings agreed with Hoque *et al*, (2004).

4.2.1.2 Effect of mulch material

Mulch materials had a significant difference on the tuber number hill^{-1} (Table 6). Results showed that the maximum tuber number hill^{-1} (7.23) was found in M_2 and the minimum tuber number hill^{-1} (5.69) was found in M_0 which was statistically similar with M_1. Pulok *et al.* (2016), Petr *et al.* (2010) concluded that straw mulch influenced and increased the number of tubers. Farrag *et al*. (2016), the combined treatments of irrigation and mulching, showed higher increase in plant fresh and dry weight, main stems number, yield and tuber weight per plant (Farhadi and Kashi, 2003). Thus the result corroborates with the findings of above mention scientists.

4.2.1.3 Interaction effect of variety and mulch material

Interaction between variety and mulch material exerted a significant difference on the tuber number hill^{-1} (Table 7). Results showed that the maximum tuber number hill^{-1} (8.21) was found in V_1M_2 which was statistically similar with V_1M_3, V_2M_2 and V_3M_2 and the minimum tuber number hill^{-1} (5.07) was found in V_5M_0 which was statistically similar with V_5M_1, V_4M_0, V_3M_1, V_3M_0, V_2M_3 and V_2M_1.

4.2.2 Tuber weight hill^{-1}

4.2.2.1 Effect of variety

Potato variety had a significant difference on the tuber weight hill^{-1} (Table 6). Results showed that the maximum tuber weight hill^{-1} (0.31 kg) was found in V_1 which was statistically at par with V_3 and V_4 and the minimum tuber weight hill^{-1} (0.23 kg) was found in V_5 which was statistically similar with V_2. The result indicates that tuber weight varied among the varieties which was supported with the findings of Azad *et al.* (2015) who observed that highest yield was seen in the Sante cultivar with the weight of 959.97 gm per plant, while the least yield belonged to the Agria cultivar with the weight of 676.69 gm per plant.

4.2.2.2 Effect of mulch material

Mulch material had a significant difference on the tuber weight hill^{-1} of potato (Table 6). Results showed that the maximum tuber weight hill^{-1} (0.32 kg) was found in M_2 and the minimum tuber weight hill^{-1} (0.23 kg) was found in M_0. The result is consistent with the findings of Pulok *et al.* (2016) and Petr *et al.* (2010) that straw mulch increasing the weight of tubers.

Table 6. Effect of variety and mulch material on the yield and tuber characteristics of potato

Treatment	Tuber number hill^{-1} (no.)	Tuber weight hill^{-1} (kg)	Yield of potato (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})
Effect of variety					
V_1	7.11 a	0.31 a	28.64 a	25.48 a	2.30 a
V_2	6.09 b	0.25 b	27.58 a	25.48 a	1.34 c
V_3	6.53 b	0.30 a	25.84 bc	21.54 b	2.14 a
V_4	6.43 b	0.29 a	26.74 ab	24.49 a	2.12 a
V_5	6.08 b	0.23 b	22.43 d	20.49 b	1.94 b
LSD (0.05)	**0.58**	**0.03**	**2.11**	**1.91**	**0.18**
CV (%)	**10.85**	**9.83**	**9.98**	**9.77**	**11.23**
Effect of mulch material					
M_0	5.69 c	0.23 c	20.77 c	18.94 c	1.84 b
M_1	6.19 bc	0.30 b	25.30 b	25.26 ab	1.89 b
M_2	7.23 a	0.32 a	29.13 a	26.66 a	2.09 a
M_3	6.68 b	0.28 b	27.26 a	23.73 b	2.07 a
LSD (0.05)	**0.52**	**0.02**	**1.89**	**1.71**	**0.16**
CV (%)	**10.85**	**9.83**	**9.98**	**9.77**	**11.23**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.2.2.3 Interaction effect of variety and mulch material

Interaction between variety and mulch material exerted a significant difference on the tuber weight hill^{-1} (Table 7). Results showed that the maximum tuber weight hill^{-1} (0.35 kg) was found in V_1M_2 and V_3M_2 which were statistically similar with V_1M_3, V_1M_1, V_2M_2, V_3M_1, V_4M_2 and V_4M_3 and the minimum tuber weight hill^{-1} (0.18 kg) was found in V_5M_0 which was statistically similar with V_2M_0.

4.2.3 Yield of potato

4.2.3.1 Effect of variety

Yield of potato significantly affected by potato variety (Table 6). Results revealed that, the highest potato yield (28.64 t ha^{-1}) was found from V_1 which was statistically similar with V_2 and V_4 and the lowest potato yield (22.43 t ha^{-1}) was recorded from V_5 .The findings of the study was in line with the findings of Razzaque and Ali (2009) who reported that among the varieties tuber yield was ranged from 21.302-17.638 t ha^{-1}. The variety Heera produced higher tuber yield (21.30 t ha^{-1}) which was statistically different from other tested varieties.

4.2.3.2 Effect of mulch material

Yield of potato was significantly affected by different mulch material (Table 6). Result revealed that, the highest potato yield (29.13 t ha^{-1}) was recorded when the plot provided with rice straw mulch (M_2) followed by when the plot provided with rice husk (M_3) mulch (27.26 t ha^{-1}) and the lowest potato yield (20.77 t ha^{-1}) was recorded when the plot provided with no mulch (M_0). Potato is grown during the winter season when rainfall is scarce and irrigation become essential for providing sufficient moisture to the growing crop. Water-saving becomes the most critical factor in enhancing potato yield and quality under this situation. So, to minimize the cultivation cost mulching could be effectively used instead of irrigation. Mulching improves water conservation by reducing soil evaporation rates and increasing the water-use efficiency (Li *et al.*, 2018). Straw mulch as an organic mulching has improved environmentally and economically important aspects of growing crops such as potato and massively reduced soil erosion (Döring *et al.*, 2005 and Edwards *et al.*, 2000). Soil mulching with organic material is one method of soil water conservation and also helps in maintaining a constant soil temperature within the crops root system (Samaila *et al.*, 2011 and Awal and Khan, 2000). Li *et al.* (2018) reported that the tuber yield in rice straw mulch was 9.4% and 8.0% greater than that of bare soil in 2013 to 2014 and 2014 to 2015, respectively. The findings of the present investigation were in agreement with various researchers (Liu *et al.*, 2017, Zhang et *al.*, 2017a, Pulok *et al.*, 2016).

4.2.3.3 Interaction effect of variety and mulch material

Yield of potato was significantly influenced by interaction of different variety and mulch material (Table 8). Result revealed that, the highest potato yield (31.26 t ha^{-1}) was recorded from V_1M_2 which was statistically similar with V_1M_3, V_1M_1, V_2M_2, V_3M_2, V_3M_3, V_4M_2

and V_4M_3 and the lowest potato yield (16.27 t ha^{-1}) was recorded from V_5M_0 which was statistically similar with V_4M_0. The results were also coincided with the findings of Razzaque and Ali (2009) who reported that potato variety 'Chamak' produced higher yield (17.76 t ha^{-1}) in rice straw mulching compare than water hyacinth mulching (17.5 t ha^{-1}).

Table 7. Interaction effect of variety and mulch material on the yield and tuber characteristics of potato

Interaction (variety × mulch material)	Tuber number $hill^{-1}$ (no.)	Tuber weight $hill^{-1}$ (kg)	Yield of potato (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})
V_1M_0	6.28 b-e	0.27 c-e	24.47 d-f	22.36 e-h	2.11 b-d
V_1M_1	6.61 b-e	0.31 a-c	28.95 a-c	28.69 a	2.22 b-d
V_1M_2	8.21 a	0.35 a	31.26 a	26.31 a-d	2.65 a
V_1M_3	7.36 ab	0.33 ab	29.85 ab	27.62 a-c	2.23 b-d
V_2M_0	5.46 ef	0.20 fg	22.41 e-g	19.93 hi	1.44 f
V_2M_1	5.77 d-f	0.26 c-e	22.81 e-g	28.07 ab	1.17 f
V_2M_2	7.08 a-c	0.30 a-d	28.04 a-d	29.74 a	1.52 ef
V_2M_3	6.07 c-f	0.24 ef	24.54 d-f	24.19 c-g	1.24 f
V_3M_0	6.10 c-f	0.24 ef	21.37 fg	17.09 ij	2.24 b-d
V_3M_1	6.10 c-f	0.33 ab	25.43 c-f	22.59 d-h	1.96 b-d
V_3M_2	7.30 ab	0.35 a	30.90 a	25.95 a-e	2.09 b-d
V_3M_3	6.60 b-e	0.29 b-e	29.24 a-c	20.53 f-i	2.29 ab
V_4M_0	5.56 d-f	0.25 d-f	19.33 gh	20.53 f-i	1.88 de
V_4M_1	6.48 b-e	0.29 b-e	26.62 b-e	24.44 b-e	2.19 b-d
V_4M_2	6.98 bc	0.32 ab	29.19 a-c	27.04 a-c	2.14 b-d
V_4M_3	6.71 b-d	0.31 a-c	28.21 a-d	25.93 a-e	2.28 bc
V_5M_0	5.07 f	0.18 g	16.27 h	14.77 j	1.50 f
V_5M_1	5.99 c-f	0.27 c-e	22.70 e-g	22.54 d-h	1.92 cd
V_5M_2	6.60 b-e	0.29 b-e	26.28 b-e	24.25 c-f	2.03 b-d
V_5M_3	6.66 b-d	0.25 ef	24.46 d-f	20.40 g-i	2.30 ab
LSD $_{(0.05)}$	**1.16**	**0.05**	**4.23**	**3.82**	**0.37**
CV (%)	**10.85**	**9.83**	**9.98**	**9.77**	**11.23**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control(no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.2.4 Marketable yield of potato

4.2.4.1 Effect of variety

Marketable yield of potato was significantly varied by potato variety (Table 6). Results of the investigation revealed that, the highest marketable potato yield (25.48 t ha^{-1}) was produced by V_1 and V_2 , which was statistically similar with V_4 and the lowest marketable potato yield (20.49 t ha^{-1}) was produced by V_5 which was statistically similar with V_3. Yield difference among the varieties was also reported by Razzaque and Ali (2009).

4.2.4.2 Effect of mulch material

Marketable yield of potato was significantly affected by different mulch material (Table 6). Result revealed that, the highest marketable potato yield (26.66 t ha^{-1}) was produced by M_2 which was statistically similar with M_3 and the lowest marketable potato yield (18.94 t ha^{-1}) was produced by M_0 which was statistically differed from other treatments. Potato is reported to increase marketable tuber yield when plants are mulched with organic residues (Ibarra-Jimenez *et al*., 2008 and Lamont, 2005) and straw (Doring *et al*., 2005) compared with plants grown in bare soil. The mulching materials, organic in particular, modify the root zone temperature that regulate biomass accumulation and growth of potato tubers (Kumari, 2012 and Baghour *et al*., 2002) thus quality potato was produced. The findings of the experiment was agreement with the findings of Azad *et al.* (2015), El-Zohiri and Samy (2013a), El-Zohiri and Samy (2013b) and Amer and Al-Juborri (2011) who reported that the marketable yield was significantly increased with mulch comparative with non-mulching.

4.2.4.3 Interaction effect of variety and mulch material

Marketable yield of potato was significantly differed by interaction of different variety and mulch material (Table 7). Result showed that, the highest marketable potato yield (29.74 t ha^{-1}) was produced by treatment combination V_2M_2 which was statistically similar with V_1M_1, V_1M_2, V_1M_3, V_2M_1, V_2M_2, V_4M_2 and V_4M_3 , and the lowest marketable potato yield (14.77 t ha^{-1}) was produced by V_5M_0 which was statistically similar with V_3M_0.

4.2.5 Non-marketable potato yield

4.2.5.1 Effect of variety

Non-marketable potato yield was significantly differed by different potato varieties (Table 6). Results of the investigation revealed that, the highest non-marketable potato yield (2.30 t ha^{-1}) was produced by V_1 which was statistically similar with V_3 and V_4 variety and the lowest one (1.94 t ha^{-1}) was produced by V_5 which was statistically similar with V_2 .

4.2.5.2 Effect of mulch material

Non-marketable potato yield was significantly influenced by different mulch material (Table 6). Result revealed that, the highest non-marketable potato yield (2.09 t ha^{-1}) was produced by M_2 which was statistically at par with M_3 and the lowest non-marketable potato yield (1.84 t ha^{-1}) was produced by M_0 which showed similarity with M_1.

4.2.5.3 Interaction effect of variety and mulch material

Non-marketable potato yield was significantly influenced by interaction of different variety and mulching (Table 7). Result revealed that, the highest non-marketable potato yield (2.65 t ha^{-1}) was produced by V_1M_2 which was statistically similar with V_3M_3 and V_5M_3 and the lowest non-marketable potato yield (1.17 t ha^{-1}) was recorded from V_2M_1 which was statistically similar with V_2M_0, V_2M_2, V_2M_3 and V_5M_0.

4.2.6 Marketable tuber number by percent

4.2.6.1 Effect of variety

There was observed a mark difference on marketable tuber number of potato due to different potato varieties (Table 8). Results exposed that the maximum marketable tuber number (80.60 %) was gained from V_2 followed by V_5 (75.39 %) and the minimum marketable tuber number (71.97 %) was gained from V_1 which was similar with V_3 and V_4.

4.2.6.2 Effect of mulch material

Mulch material had a non-significant effect on marketable tuber number of potato (Table 8). Result showed that, numerically the highest and lowest marketable tuber number (76.28 and 73.90 %, respectively) was attained by M_1 and M_0, respectively. Similar results were also reported by Azad *et al.* (2015) and Farhadi and Kashi (2003) who stated that the percentage of very small tubers was considerably lower than potatoes without any mulch treatment. Ilyas and Ayub (2017) also found that using mulch material resulted in increased number of large size tubers $plant^{-1}$ (marketable tuber) (2.20) in relation to control (2.00).

4.2.6.3 Interaction effect of variety and mulch material

A marked difference was observed among marketable tuber number due to interaction of different varieties and mulch materials (Table 9). Result showed that, the highest marketable tuber number (84.09%) was attained by treatment combination V_2M_3 which was statistically similar with rest of the treatment combinations except V_1M_0, V_1M_1, V_1M_2, V_1M_3, V_3M_0, V_4M_0 and V_5M_3, and the lowest marketable tuber number (72.18 %) was attained by V_1M_0 which was statistically similar with rest of the treatment combinations except V_2M_1 and V_2M_3.

4.2.7 Marketable tuber weight by percent

4.2.7.1 Effect of variety

Potato variety exerted a non-significant difference on the marketable tuber weight of potato (Table 8). Results showed that numerically the maximum and minimum marketable tuber weight (93.97 and 91.40 %, respectively) was recorded from V_2 and V_5 respectively.

Table 8. Effect of variety and mulch material on the tuber characteristics of potato

Treatments	Marketable tuber number by (%)	Marketable tuber weight by (%)	Non-marketable tuber number by (%)	Non-marketable tuber weight by (%)
Effect of variety				
V_1	71.97 b	91.72	28.03 a	8.12 a
V_2	80.60 a	93.97	19.40 c	6.03 b
V_3	75.15 b	91.99	24.94 b	8.02 a
V_4	73.94 b	91.95	26.06 ab	8.05 a
V_5	75.39 ab	91.40	24.60 b	8.76 a
LSD $_{(0.05)}$	**5.45**	**NS**	**2.02**	**0.88**
CV (%)	**8.75**	**9.30**	**9.95**	**13.67**
Effect of mulch material				
M_0	73.90	91.16	26.17 a	8.84 a
M_1	76.28	93.05	23.72 b	7.08 b
M_2	75.90	92.80	24.10 b	7.20 b
M_3	75.57	91.81	24.43 ab	8.06 a
LSD $_{(0.05)}$	**NS**	**NS**	**1.81**	**0.79**
CV (%)	**8.75**	**9.30**	**9.95**	**13.67**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.2.7.2 Effect of mulch material

Mulch material exerted a non-significant difference on the marketable tuber weight of potato (Table 8). Results revealed that numerically the maximum and minimum Marketable tuber weight (93.05 and 91.16 %, respectively) was recorded from M_1 and M_0, respectively. Medium size tubers are very important because they have more market value. Razzaque and Ali (2009) expressed that during grading of tuber it was found that small sized tubers 40.0% by weight found under no mulching and large sized tubers ranged from 15.8% to 12% by weight. Maximum medium sized tubers were (50.2%) produced under water hyacinth mulching and minimum 45% of rice straw mulching. The findings of the present study were also similar with the findings of Azad *et al.* (2015).

4.2.7.3 Interaction effect of variety and mulch material

Interaction between variety and mulch material exerted a non-significant difference on the marketable tuber weight of potato (Table 9). Result showed that, numerically the highest and lowest marketable tuber weight (95.10 and 90.79 %, respectively) was attained by treatment combination V_2M_1 and V_3M_0, respectively.

4.2.8 Non-marketable tuber number by percent

4.2.8.1 Effect of variety

Potato variety had significant effect on non-marketable tuber number by percentage. (Table 8). Results showed that the maximum non-marketable tuber number (28.03 %) was gained by V_1 which was statistically similar with V_4 and the minimum non-marketable tuber number (19.40 %) was gained by V_2.

4.2.8.2 Effect of mulch material

Mulching had significant effect on non-marketable tuber number by percent of potato (Table 8). Result showed that, the highest non-marketable tuber number (26.17 %) was attained by M_0 treatment which was statistically similar with M_3 and the lowest non-Marketable tuber number (23.72 %) was attained by M_1 which was statistically similar with M_2 and M_3. Similar results were confirmed by Ilyas and Ayub (2017) who reported that mulching significantly reduced the number of small size tubers plant^{-1} and contributed to increase in size and weight of tubers. Kumar *et al*. (2015) and Dvorak *et al*. (2010) also reported that the application of gross mulch resulted in the increase of the number of tubers of over 56 mm as compared to the control treatment.

4.2.8.3 Interaction effect of variety and mulch material

There observed a marked difference among non-marketable tuber number by percent due to interaction of different varieties and mulches (Table 9). Result showed that, the highest non-marketable tuber number by percent (30.04%) was attained by treatment combination V_1M_2 which was statistically similar with V_1M_0, V_1M_1, V_1M_3, V_3M_0, V_3M_3, V_4M_0, V_4M_1 and V_5M_3 and the lowest non-marketable tuber number by percent (15.91 %) was attained by V_2M_3 which was statistically similar with V_2M_1.

4.2.9 Non-marketable tuber weight by percent

4.2.9.1 Effect of variety

Potato variety exerted a significant difference on the non-marketable tuber weight of potato (Table 8). Results showed that the maximum non-marketable tuber weight (8.76 %) was found in V_5 which was statistically similar with V_1, V_3, V_4 and the minimum non-marketable tuber weight (6.03 %) was found in V_2.

4.2.9.2 Effect of mulch material

Mulching exerted a significant difference on the non-marketable tuber weight of potato (Table 8). Results showed that the maximum non-marketable tuber weight (8.84 %) was found in M_0 which was statistically similar with M_3 and the minimum non-marketable tuber weight (7.08 %) was found in M_1 which was statistically similar with M_2.

Table 9. Interaction effect of variety and mulch material on the tuber characteristics of potato

Interaction (variety × mulch)	Marketable tuber number by (%)	Marketable tuber weight by (%)	Non-marketable tuber number by (%)	Non-marketable tuber weight by (%)
V_1M_0	72.18 c	91.37	27.82 ab	8.63 a-c
V_1M_1	73.00 bc	92.17	27.00 a-d	7.83 b-d
V_1M_2	69.96 c	91.43	30.04 a	8.57 a-c
V_1M_3	72.72 c	91.89	27.28 a-c	7.44 c-e
V_2M_0	75.57 a-c	92.12	24.43 b-f	7.88 b-d
V_2M_1	83.64 ab	95.10	16.36 g	4.90 f
V_2M_2	79.11 a-c	94.42	20.89 f	5.58 f
V_2M_3	84.09 a	94.26	15.91 g	5.74 ef
V_3M_0	72.30 c	89.74	28.03 ab	10.26 a
V_3M_1	76.94 a-c	93.42	23.06 d-f	6.58 d-f
V_3M_2	78.01 a-c	93.47	21.99 ef	6.53 d-f
V_3M_3	73.33 a-c	91.30	26.67 a-d	8.70 a-c
V_4M_0	72.54 c	91.76	27.47 a-c	8.24 b-d
V_4M_1	72.26 c	91.71	27.74 ab	8.29 b-d
V_4M_2	76.46 a-c	92.56	23.54 c-f	7.44 c-e
V_4M_3	74.51 a-c	91.76	25.49 b-e	8.24 b-d
V_5M_0	76.90 a-c	90.79	23.10 d-f	9.21 ab
V_5M_1	75.53 a-c	92.85	24.47 b-f	7.82 b-d
V_5M_2	75.97 a-c	92.14	24.03 b-f	7.86 b-d
V_5M_3	73.18 bc	89.84	26.82 a-d	10.16 a
LSD $_{(0.05)}$	**10.91**	**NS**	**4.05**	**1.76**
CV (%)	**8.75**	**9.30**	**9.95**	**13.67**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.2.9.3 Interaction effect of variety and mulch material

Interaction between variety and mulch material exerted a significant difference on the non-marketable tuber weight of potato (Table 9). Results showed that the maximum non-marketable tuber weight (10.26 %) was found in V_3M_0 which was statistically similar with V_1M_2, V_1M_0, V_3M_3, V_5M_0 and V_5M_3 and the minimum non-marketable tuber weight (4.90 %) was found in V_2M_1 which was statistically similar with V_2M_2, V_2M_3, V_3M_1 and V_3M_2.

4.3 Post-harvest quality of potato

4.3.1 Dry matter (%) of potato after storage

4.3.1.1 Effect of variety

Dry matter (%) of potato after storage was significantly influenced by potato varieties (Figure 11). The result revealed that, the highest dry matter (%) of potato after storage (22.19, 22.12, 22.03, 21.81 and 21.55 %) were obtained by V_3 (BARI Alu-29) at 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_2 (BARI Alu-28) at 15, 30, 45 DAS and the lowest dry matter (%) of potato after storage (17.84, 17.69, 17.19, 17.38 and 17.19 %) were produced by V_5 (BARI TPS-1) at 15, 30, 45, 60 and 75 DAS respectively, which was statistically similar with V_4 (BARI Alu-7) at 15, 30, 45, 60 and 75 DAS.

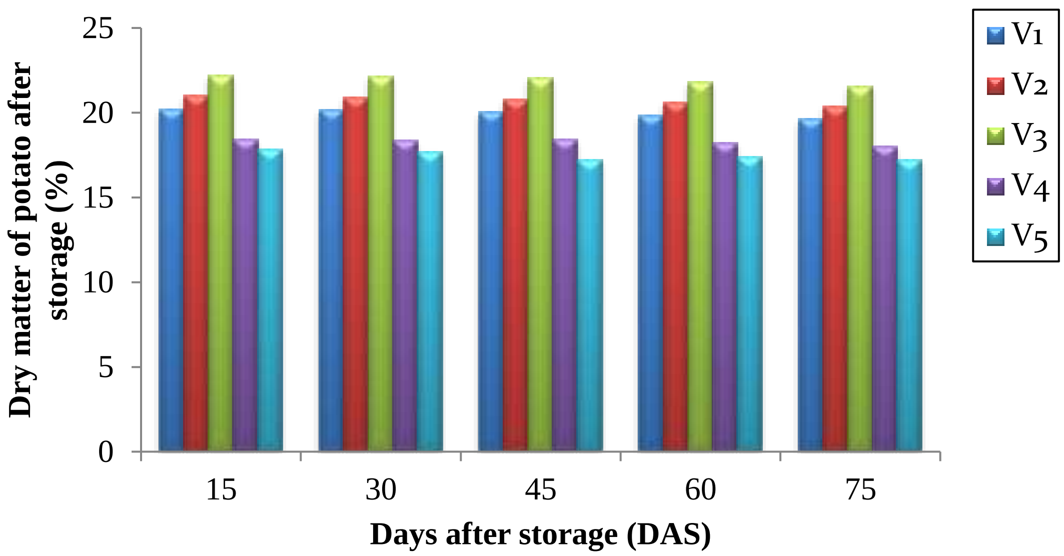
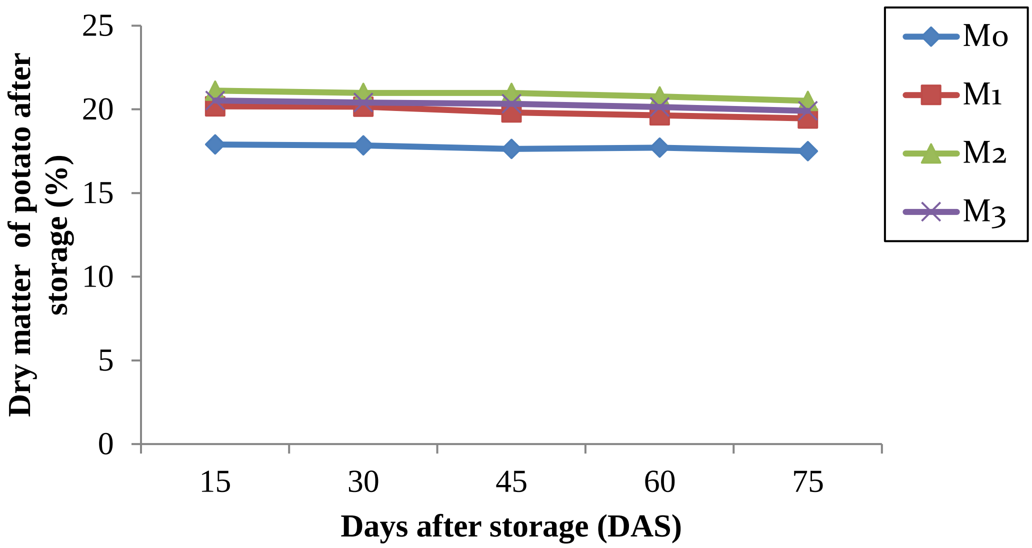


Figure 11. Effect of variety on the dry matter (%) of potato at different days after storage ($LSD_{0.05}$= 1.52, 1.57, 1.60, 1.00 and 0.97 at 15, 30, 45, 60 and 75 DAS, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.3.1.2 Effect of mulch material

Dry matter (%) of potato after storage was significantly varied due to different mulch material (Figure 12). It can be inferred from the figure that irrespective of mulch materials used dry matter reduction was marginal with the advancement of duration after harvest. M_2 (rice straw) mulch material used treatment showed higher dry matter (%) than other material used along with M_0 (no mulch) treatment. However, M_3 (rice husk) treatment produced statistically similar level of dry matter with M_2 (rice straw) treatment. The lowest dry matter (%) of potato after storaget (17.90, 17.85, 17.64, 17.72 and 17.51 %) were obtained by M_0 which was statistically differed from other mulching treatments. The findings of the study was also supported by Li *et al.* (2018), Farrag *et al.* (2016) and Farhadi and Kashi (2003) who reported that mulching increased the dry matter content of potato.



Here, M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

Figure 12. Effect of mulch material on the dry matter (%) of potato at different days after storage (LSD $_{0.05}$= 1.36, 1.40, 1.43, 0.89 and 0.87 at 15, 30, 45, 60 and 75 DAS, respectively)

4.3.1.3 Interaction effect of variety and mulch material

Dry matter (%) of potato after storage was significantly varied due to interaction of different variety and mulch material (Table 10). The result exerted that, the maximum dry matter content of potato after storage (23.89, 23.76, 23.89, 23.69 and 23.34 %) were obtained with V_3M_2 at 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_1M_2, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_3M_1 and V_3M_3 at 15, 30 and 45 DAS; with V_3M_1 and V_3M_3 at 60 and 75 DAS and the lowest dry matter content of potato after storage (16.68, 16.86, 15.73, 16.95 and 16.76 %) were obtained by V_5M_0 at 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_1M_0, V_1M_1, V_2M_0, V_3M_0, V_4M_0, V_4M_1, V_4M_2, V_4M_3, V_5M_1, V_5M_2 and V_5M_3 at 15 and 30 DAS; with V_1M_0, V_2M_0, V_3M_0, V_4M_0, V_4M_1, V_4M_3, V_5M_1, V_5M_2 and V_5M_3 at 45 DAS; with V_1M_0, V_1M_1, V_2M_0, V_3M_0, V_4M_0, V_4M_1, V_4M_3, V_5M_1, V_5M_2 and V_5M_3 at 60 DAS and finally with V_1M_0, V_2M_0, V_3M_0, V_4M_0, V_4M_1, V_4M_3, V_5M_1, V_5M_2 and V_5M_3 at 75 DAS.

Table 10. Interaction effect of variety and mulch material on the dry matter (%) of potato at different days after storage

Interaction (variety × mulch material)	Dry matter (%) of potato at different days after storage				
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
V_1M_0	18.21 d	18.19 e	18.11 e-g	17.91 cd	17.61 c-e
V_1M_1	19.25 b-d	19.08 b-e	19.05 b-f	18.90 cd	18.77 cd
V_1M_2	21.73 ab	21.76 ab	21.63 a-c	21.39 b	21.22 b
V_1M_3	21.59 a-c	21.65 a-c	21.39 a-d	21.19 b	20.94 b
V_2M_0	18.66 cd	18.43 de	18.41 d-g	18.26 cd	18.09 c-e
V_2M_1	21.72 ab	21.86 ab	21.66 a-c	21.42 b	21.26 b
V_2M_2	22.11 ab	21.84 ab	21.84 ab	21.61 b	21.31 b
V_2M_3	21.58 a-c	21.48 a-d	21.25 a-e	21.09 b	20.81 b
V_3M_0	18.59 cd	18.59 c-e	18.59 c-g	18.39 cd	18.14 c-e
V_3M_1	22.99 a	22.92 a	22.66 a	22.42 ab	22.17 ab
V_3M_2	23.89 a	23.76 a	23.89 a	23.69 a	23.34 a
V_3M_3	23.31 a	23.21 a	22.98 a	22.75 ab	22.54 ab
V_4M_0	17.34 d	17.20 e	17.34 fg	17.07 cd	16.93 c-e
V_4M_1	18.60 cd	18.60 c-e	18.60 c-g	18.40 cd	18.26 c-e
V_4M_2	19.26 b-d	19.23 b-e	19.26 b-f	19.06 c	18.81 c
V_4M_3	18.42 d	18.35 de	18.42 d-g	18.24 cd	18.01 c-e
V_5M_0	16.68 d	16.86 e	15.73 g	16.95 d	16.76 e
V_5M_1	18.33 d	18.26 e	17.10 fg	17.03 d	16.85 de
V_5M_2	18.60 cd	18.37 de	18.33 d-g	18.10 cd	17.86 c-e
V_5M_3	17.74 d	17.29 e	17.60 fg	17.43 cd	17.27 c-e
LSD $_{(0.05)}$	**3.04**	**3.13**	**3.19**	**2.00**	**1.94**
CV (%)	**9.22**	**9.55**	**9.8**	**6.19**	**6.05**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk
DAS = Days after storage

4.3.2 Specific gravity

4.3.2.1 Effect of variety

Specific gravity of potato was significantly influenced by potato varieties (Figure 13). Result revealed that, the maximum specific gravity (1.086, 1.086, 1.084, 1.085, 1.082 and 1.082) were scored by V_3 at harvest, 15, 30, 45, 60 and 75 DAS respectively, which was showed similarity with V_2 at harvest, 15, 30, 45, 60 and 75 DAS and the minimum specific gravity (1.061, 1.063, 1.062, 1.061, 1.060 and 1.057) were scored by V_5 at harvest, 15, 30, 45, 60 and 75 DAS respectively, which showed similarity with V_4 at harvest, 15, 30, 45 and 60 DAS.

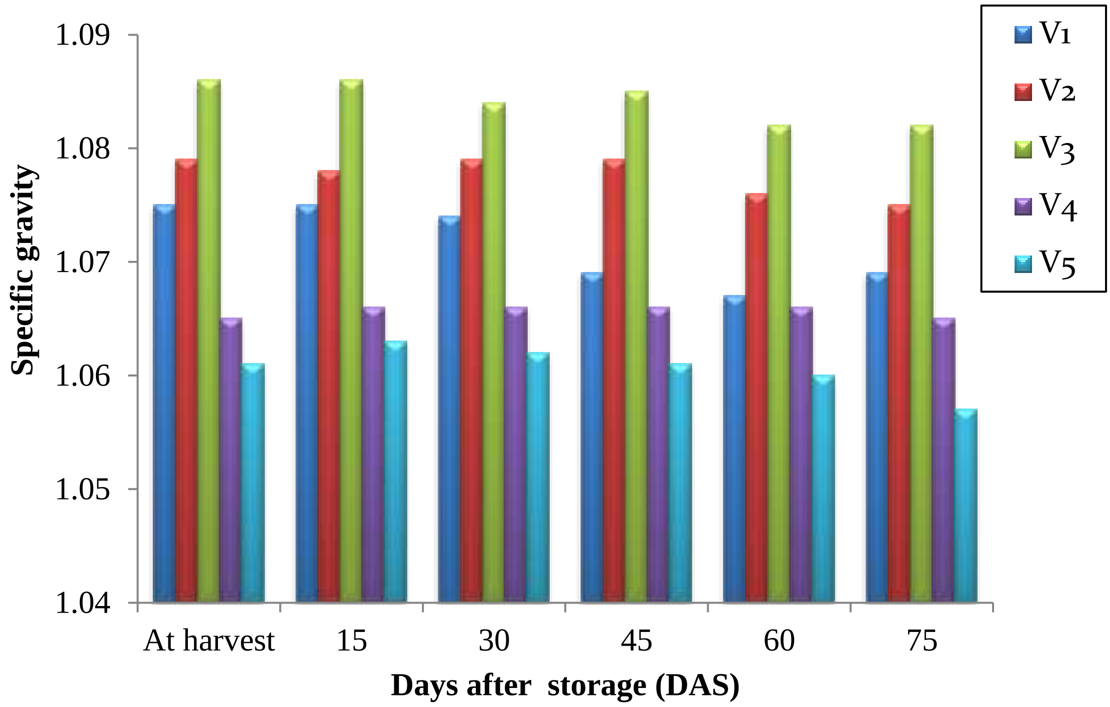


Figure 13. Effect of variety on the specific gravity of potato at different days after storage (LSD $_{0.05}$= 0.01, 0.01, 0.01, 0.01, 0.01 and 0.01 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.3.2.2 Effect of mulch material

Specific gravity of potato was significantly influenced by different mulch material (Figure 14). Result revealed that, M_2 mulching treatment showed its superiority by giving higher specific gravity over other mulching treatment for all sampling dates. On the other hand, control treatment showed the lowest values of specific gravity for all sampling dates. M_3 and M_1 mulching treatment showed the intermediate level of specific gravity.

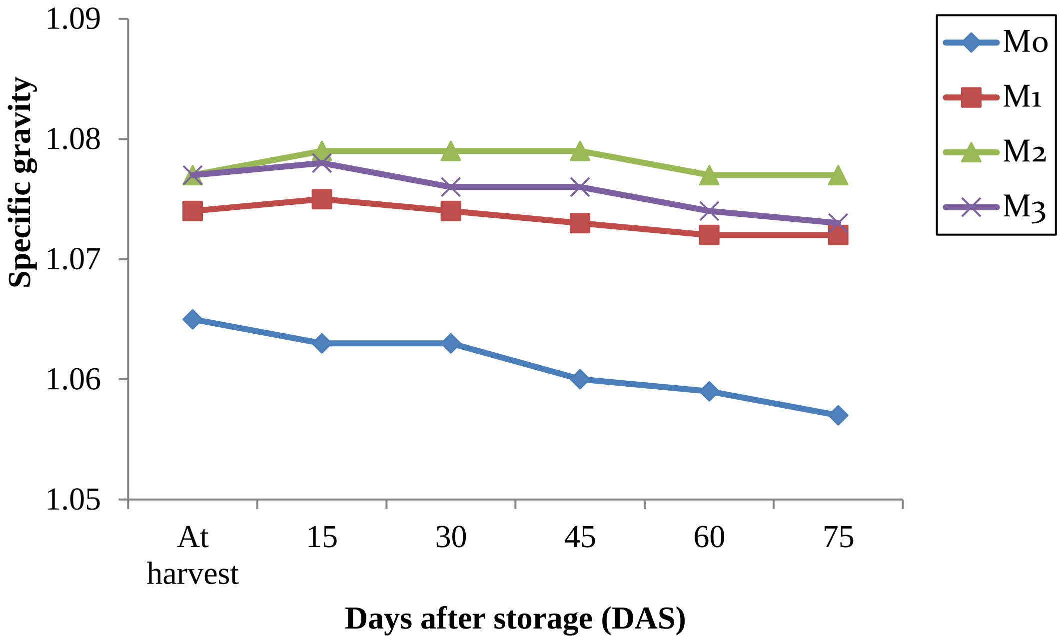


Figure 14. Effect of mulch material on the specific gravity of potato at different days after storage ($LSD_{0.05}$= 0.01, 0.01, 0.01, 0.01, 0.01 and 0.01 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, M_0 = Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk

4.3.2.3 Interaction effect of variety and mulch material

Specific gravity of potato was significantly influenced by interaction effect of variety and mulch material (Table 11). Result revealed that, the maximum specific gravity (1.093, 1.093, 1.093, 1.093, 1.093 and 1.093) were scored by V_3M_2 at harvest, 15, 30, 45, 60 and 75 DAS respectively, which was similar with V_1M_2, V_1M_3, V_2M_1, V_2M_2, V_2M_3, V_3M_1 and V_3M_3 at harvest, 15, 30 and 45 DAS; with V_1M_3, V_2M_1, V_2M_2, V_3M_1 and V_3M_3 at 60 DAS and with V_1M_3, V_2M_1, V_2M_2, V_3M_1, V_3M_3 and V_1M_2 at 75 DAS. At harvest the minimum specific gravity (1.057) was scored by V_5M_2 which showed similarity with V_1M_0, V_1M_1, V_2M_0, V_3M_0, V_4M_0, V_4M_1, V_4M_2, V_4M_3, V_5M_0, V_5M_1 and V_5M_3. At 15 DAS the minimum specific gravity (1.060) was scored by V_4M_0 and V_5M_0 which showed similarity with V_1M_0, V_1M_1, V_2M_0, V_3M_0, V_4M_1, V_4M_2, V_4M_3, V_5M_1, V_5M_2 and V_5M_3. At 30 DAS, the minimum specific gravity (1.060) was scored by V_4M_0, V_5M_0 and V_5M_2 which showed similarity with V_1M_0, V_1M_1, V_2M_0, V_3M_0, V_4M_1, V_4M_2, V_4M_3, V_5M_1 and V_5M_3. At 45, 60 and 75 DAS, the minimum specific gravity (1.050, 1.050 and 1.050, respectively) was scored by V_1M_0 which showed similarity with V_1M_1, V_2M_0, V_4M_0, V_5M_0, V_5M_1, V_5M_2 and V_5M_3 at 45 DAS; with V_1M_1, V_2M_0, V_4M_0, V_5M_0, V_5M_1, V_5M_2 and V_5M_3 at 60 DAS and V_2M_0, V_3M_0, V_4M_0, V_5M_0, V_5M_1, V_5M_2 and V_5M_3 at 75 DAS

Table 11. Interaction effect of variety and mulch material on the specific gravity of potato at different days after storage

Interaction (variety × mulch material)	Specific gravity of potato at different days after storage					
	At harvest	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
V_1M_0	1.063 d	1.063 d	1.063 d	1.050 e	1.050 f	1.050 h
V_1M_1	1.070 b-d	1.070 b-d	1.070 b-d	1.063 de	1.063 d-f	1.067 d-g
V_1M_2	1.083 ab	1.083 ab	1.083 ab	1.083 ab	1.077 b-d	1.080 a-d
V_1M_3	1.083 ab	1.083 ab	1.080 a-c	1.080 a-c	1.080 a-c	1.080 a-d
V_2M_0	1.067 cd	1.067 cd	1.063 d	1.063 de	1.060 ef	1.057 f-h
V_2M_1	1.083 ab	1.083 ab	1.083 ab	1.083 ab	1.080 a-c	1.080 a-d
V_2M_2	1.087 a	1.083 ab	1.090 a	1.090 a	1.087 ab	1.087 ab
V_2M_3	1.080 a-c	1.080 a-c	1.080 a	1.080 a-c	1.077 b-d	1.077 b-e
V_3M_0	1.070 b-d	1.067 cd	1.067 cd	1.067 cd	1.063 d-f	1.063 e-h
V_3M_1	1.090 a	1.090 a	1.087 a	1.090 a	1.087 ab	1.087 ab
V_3M_2	1.093 a	1.093 a	1.093 a	1.093 a	1.093 a	1.093 a
V_3M_3	1.090 a	1.093 a	1.090 a	1.090 a	1.087 ab	1.083 a-c
V_4M_0	1.063 d	1.060 d	1.060 d	1.060 de	1.060 ef	1.057 f-h
V_4M_1	1.063 d	1.067 cd	1.067 cd	1.067 cd	1.067 c-e	1.067 d-g
V_4M_2	1.067 cd	1.070 b-d	1.070 b-d	1.070 b-d	1.070 c-e	1.070 c-f
V_4M_3	1.067 cd	1.067 cd	1.067 cd	1.067 cd	1.067 c-e	1.067 d-g
V_5M_0	1.060 d	1.060 d	1.060 d	1.060 de	1.060 ef	1.057 f-h
V_5M_1	1.063 d	1.063 d	1.063 d	1.063 de	1.063 d-f	1.060 f-h
V_5M_2	1.057 d	1.063 d	1.060 d	1.057 de	1.057 ef	1.05 gh
V_5M_3	1.063 d	1.067 cd	1.063 d	1.063 de	1.060 ef	1.057 f-h
LSD $_{(0.05)}$	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
CV (%)	**0.44**	**0.62**	**0.61**	**0.92**	**0.84**	**0.92**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
M_0= Control (no mulch), M_1 = Water hyacinth, M_2 = Rice straw and M_3 = Rice husk
DAH = Days after harvesting

It is observered from the experiment no.1 that among the five tested varieties BARI Alu-25 (V_1), BARI Alu-28 (V_2) and BARI Alu-7 (V_4) showed the higher yield along with higher yield attributes like tuber weight and marketable yield. In case of quality parameter, BARI Alu-29 (V_3) , BARI Alu-28 (V_2) and BARI Alu-25 (V_1) showed higher tuber dry matter (%) and specific gravity in different days after storage. Among the four mulch materials, rice straw (M_2) and rice husk (M_3) produced higher tuber yield. Besides, rice straw (M_2), rice husk (M_3) and water hyacinth (M_1) gave the highest dry matter (%) and specific gravity in different days after storage.

Experiment No.2. Effect of organic manure on growth yield and quality of potato varieties

The experiment was conducted to study the effect of organic manure on growth, yield and quality of potato. Data on different growth, yield and quality of potato were recorded. The results have been presented and discussed and possible interpretations have been given under the following headings.

4.1 Potato growth parameter

4.1.1 Plant height

4.1.1.1 Effect of variety

Potato variety exerted significant influenced on plant height at different growth stages (Figure 15). The result revealed that V_1 (BARI Alu-25) showed the tallest plant for all sampling dates. On the other hand V_5 (BARI TPS-1) showed the shortest plant irrespective of sampling date. At 85 DAP except V_2 (BARI Alu-28), other four tested vaireties (V_1, V_3, V_4 and V_5) exhibited statistically similar plant height. However, V_2 (BARI Alu-28) showed the shortest plant.

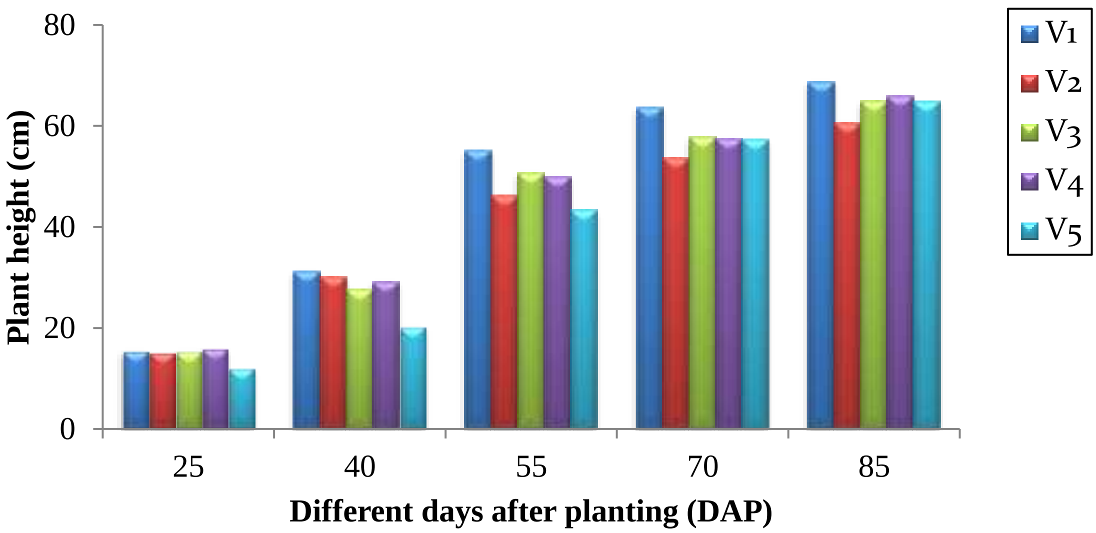


Figure 15. Effect of variety on the plant height of potato at different days after planting (LSD $_{0.05}$= 1.32, 2.27, 3.83, 4.40 and 5.14 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

The result indicated that varieties performed in respect of plant height according to their varietal characters which are governed by their genetic makeup. The obtained results concerning the vegetative growth characteristics seemed to cope with the findings of several investigators such as: Mirdad (2010), Swaminathan *et al.* (1999), Marwaha (1998) and El-Nashar *et al.* (1995). Since, they showed that potato cultivars differed significantly from each other in plant height of potato plants.

4.1.1.2 Effect of organic manure

Organic manure had significant influence on plant height for all growth stages of potato (Figure 16). The figure showed that ingeneral plant height increased steadily with the advances of growth stages and it continued up to last sampling date (85 DAP). However, the rate of increase was higher up to 55 DAP after that the increasing rate was slower. Ingeneral organic manure applied plants produced taller plants for all sampling dates than without organic manure application (control). However, all the organic manures showed statistically similar level of plant height to V_1, V_2 and V_3. Organic fertilizers were supplemented with adequate nitrogen in available form for plant (Sikder *et al.*, 2017, Bayite-Kasule, 2009 and Atiyeh *et al.*, 2000). Nitrogen is a vital nutrient for the activity of plant organs and a major for many components such as amino acids, nucleic acid and chlorophyll (Taiz and Zeiger, 2002). Nitrogen triggers the cell division and elongation and stimulates photosynthetic capacity (Mauromicale *et al.,* 2006). Wazir *et al.* (2018) and Bloom, (2015) reported that nitrogen encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant. Nitrogen content increases in soil by the application of organic fertilizers may stimulate the faster plant growth that lead to obtain longest plant height (Nogales *et al*., 2005) compare to control treatment. The obtained results were in agreement with those reported by Bilkis *et al.* (2018), Koireng *et al.* (2018), Zewide *et al.* (2018), Ram *et al.* (2017) and Shaheen *et al.,* (2014) who demonstrated that integrated use of manures and fertilizers significantly influenced the plant height of potato.

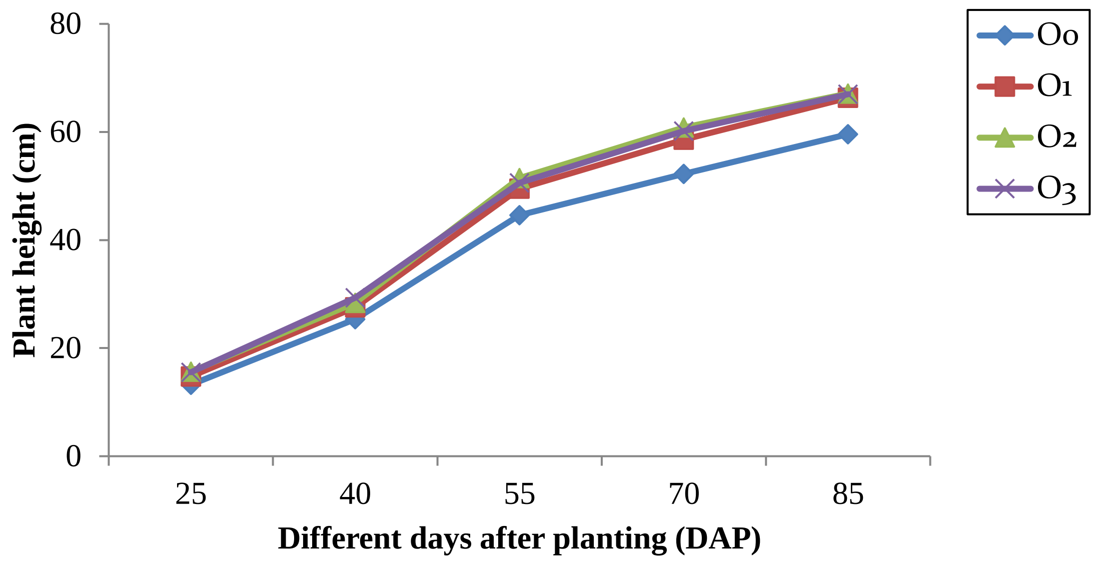


Figure 16. Effect of organic manure on the plant height of potato at different days after planting (LSD $_{0.05}$= 1.18, 2.03, 3.43, 3.93 and 4.60 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, O_0 = Control(no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1}and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.1.3 Interaction effect of variety and organic manure

Interaction of variety and organic manure had significant influence in respect of plant height of potato (Table 12). However, the tallest plant (17.13, 59.66, 68.97 and 74.33 cm at 25, 55, 70 and 85 DAP, respectively) were recorded from treatment combination V_1O_2 which was statistically similar with V_1O_1, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_0, V_3O_2, V_3O_3, V_4O_1, V_4O_2 and V_4O_3 at 25 DAP; with V_1O_1, V_1O_3, V_3O_2, V_3O_3 and V_4O_2 at 55 DAP; with V_1O_1, V_1O_3, V_3O_2, V_3O_3, V_4O_2 and V_5O_3 at 70 DAP and with V_1O_3, V_1O_1, V_2O_1, V_3O_1, V_3O_2, V_3O_3, V_4O_1, V_4O_2, V_4O_3, V_5O_1, V_5O_2 and V_5O_3 at 85 DAP. At 40 DAP the tallest plant (32.15 cm) was recorded from treatment combination V_1O_1 which was statistically similar with V_1O_0, V_1O_1, V_1O_2, V_1O_3, V_2O_0, V_2O_1, V_2O_2, V_2O_3, V_3O_2, V_3O_3, V_4O_1, V_4O_2 and V_4O_3. At 25, 40 and 55 DAP the shortest plant (11.18, 18.97 and 41.33 cm, respectively) were recorded from treatment combination V_5O_0 which was statistically similar with V_5O_3, V_5O_2, V_5O_1, V_2O_0 and V_1O_0 at 25 DAP; with V_5O_3, V_5O_2, V_5O_1 and V_3O_0 at 40 DAP and V_5O_3, V_5O_2, V_5O_1, V_3O_0, V_4O_0, V_3O_1, V_2O_3, V_2O_2, V_2O_0 and V_1O_0 at 55 DAP. Again at 70 DAP the shortest plant (49.06 cm) was recorded from treatment combination V_4O_0 which was statistically similar with V_5O_0, V_2O_2, V_2O_3, V_3O_0, V_3O_1, V_2O_0 and V_1O_0. The shortest plant (56.56 cm) was recorded from treatment combination V_2O_0 at 85 DAP which was statistically similar with V_5O_0, V_2O_2,V_2O_3, V_3O_0, V_3O_1, V_1O_0, V_1O_1, V_2O_1, V_4O_0, V_4O_3, V_5O_1 and V_5O_2. These results were in agreement with the findings of Mirdad (2010) who concluded that the combination between the cultivar Diamant and the application of organic manure at the rate of 15 ton ha^{-1} reflected the best interaction, which gave the significant highest plant height compare to that of control treatment.

Table 12. Interaction effect of variety and organic manure on the plant height of potato at different days after planting

Interaction (variety × organic manure)	Plant height (cm) of potato at different days after planting				
	25 DAP	40 DAP	55 DAP	70 DAP	85 DAP
V_1O_0	12.45 ef	29.79 ab	46.56 d-h	56.72 c-h	62.23 b-d
V_1O_1	15.49 a-c	32.15 a	56.56 a-c	61.57 a-d	65.56 a-d
V_1O_2	17.13 a	30.49 ab	59.66 a	68.97 a	74.33 a
V_1O_3	16.82 a-c	32.13 a	57.55 ab	67.27 ab	72.78 a
V_2O_0	12.79 d-f	29.10 ab	44.18 f-h	51.11 gh	56.56 d
V_2O_1	14.77 a-e	29.57 ab	49.66 c-g	58.30 c-g	65.55 a-d
V_2O_2	16.23 a-c	30.13 ab	45.00 f-h	52.13 e-h	60.45 b-d
V_2O_3	16.80 a-c	31.46 a	45.89 e-h	53.11 d-h	59.67 b-d
V_3O_0	15.60 ab-	22.49 cd	45.55 f-h	53.21 c-h	59.78 b-d
V_3O_1	14.49 b-e	26.49 bc	47.89 d-h	54.82 c-h	65.67 a-d
V_3O_2	15.16 a-d	30.26 ab	53.45 a-e	61.62 a-d	66.89 a-c
V_3O_3	16.28 a-c	31.27 a	55.78 a-c	61.80 a-d	67.44 a-c
V_4O_0	14.20 c-e	26.51 bc	45.22 f-h	49.06 h	60.44 b-d
V_4O_1	16.33 a-c	29.00 ab	49.55 c-g	59.98 b-f	68.78 a-c
V_4O_2	16.90 ab	30.56 ab	54.00 a-d	61.99 a-c	68.56 a-c
V_4O_3	16.51 a-c	30.43 ab	50.78 b-f	58.46 c-g	65.67 a-d
V_5O_0	11.18 f	18.97 d	41.33 h	51.22 f-h	58.89 cd
V_5O_1	12.70 d-f	20.37 d	44.00 f-h	58.15 c-g	66.00 a-d
V_5O_2	12.79 d-f	20.46 d	45.11 f-h	59.37 b-g	65.33 a-d
V_5O_3	11.30 f	21.18 d	42.89 gh	60.30 a-e	69.33 ab
LSD (0.05)	**2.64**	**4.55**	**7.66**	**8.80**	**10.27**
CV (%)	**10.77**	**9.95**	**9.46**	**9.18**	**9.56**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t $ha^{-1}$and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.2 Number of stems $hill^{-1}$

4.1.2.1 Effect of variety

Significant variation was observed on number of stem $hill^{-1}$ at different growth stages among potato varieties (Figure 17). It can be inferred from the figure that V_1 (BARI Alu-25) gave the highest stem $hill^{-1}$ than other tested varieties for all sampling dates. It can also observed that the stem $hill^{-1}$ increased gradually irrespective of advances of growth stages up to 70 DAP after that the rate of increase reduced slightly. Variety V_5 (BARI TPS-1 tuberlets) showed the lowest stem hill^{-1} for all sampling dates. It can also be observed that the evaluated cultivars varied in their general performances with respect to number of stem hill^{-1}. The obtained results concerning the stem hill^{-1} seemed to cope with the findings of several investigators such as Swaminathan *et al.* (1999), Marwaha (1998) and El-Nashar *et al.* (1995). Since, they showed that potato cultivars differed significantly from each other in number of stem hill^{-1}.

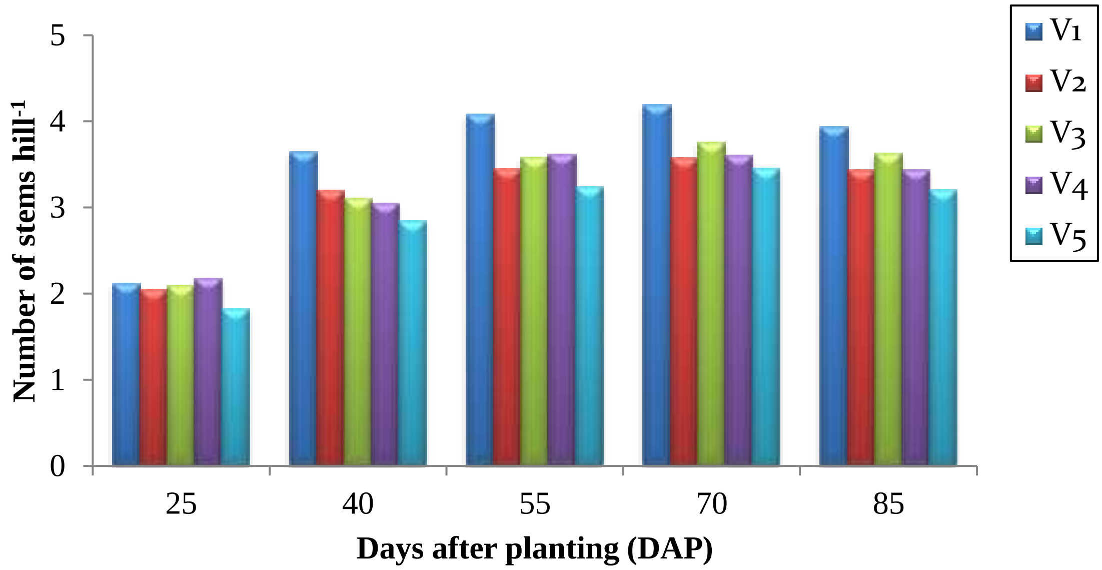


Figure 17. Effect of variety on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.18, 0.29, 0.30, 0.32 and 0.25 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.2.2 Effect of organic manure

Organic manure had a significant influenced on number of stem hill^{-1} for all growth stages of potato (Figure 18). The result revealed that ingeneral application of organic manure increased the stem hill^{-1} over O_0 (no manure). The figure showed an increasing trend of stem hill^{-1} from the early stage of growth and continued up to 70 DAP after that it reduced marginally. It also showed that O_1 and O_2 treatment produced higher level of stem hill^{-1} for all sampling dates and O_0 (no manure) treatment gave lowest stem hill^{-1}.

At 25 DAP the highest number of stem hill^{-1} (2.23) was obtained by O_2 which was statistically similar with O_1. Again at 40, 55, 70 and 85 DAP the highest number of of stem hill^{-1} (3.54, 3.90, 3.92 and 3.78, respectively) were obtained by O_1 which was statistically similar with O_2 at 40 DAP; with O_2 and O_3 at 55, 70 and 85 DAP. While at 25, 40, 55, 70 and 85 DAP the lowest number of stem hill^{-1} (1.70, 2.63, 3.04, 3.13 and 2.95, respectively) was obtained by O_0 treatment which was statistically differed from other organic manure treatments. Application of organic fertilizers add calcium, potassium, phosphorus and nitrogen to the soil (Ahmed *et al.*, 2015). The possible reason for increasing number of stem hill^{-1} due to the nitrogen helps in stem growth, phosphorus promotes rooting and K (potassium) is essential for stem and root growth and protein analysis. This might be attributed to increase the number of stem hill^{-1} of potato. Ahmed *et al.* (2015) reported that the highest number of stem hill^{-1} was obtained with the highest level of farmyard manure (20 m^3 fed^{-1}.). The results of the study were well corroborated with the findings of Bilkis *et al.* (2018), Ram *et al.* (2017) and Amara and Mourad (2013) who demonstrated that use of organic manures significantly influenced the number of stems hill^{-1} of potato.

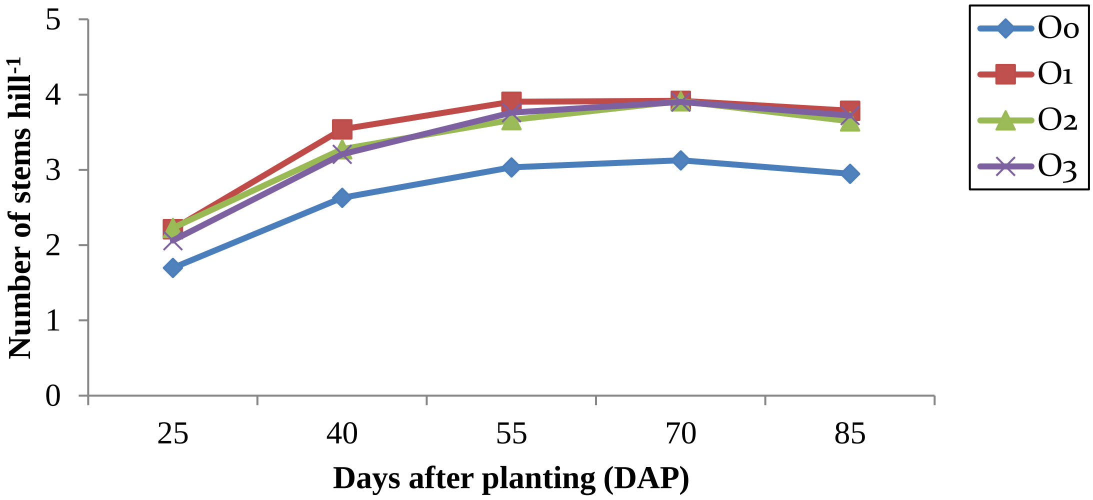


Figure 18. Effect of organic manure on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.16, 0.26, 0.27, 0.28 and 0.23 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, O_0 = Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1}and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.2.3 Interaction effect of variety and organic manure

Interaction of variety and organic manure significantly affected the number of stem hill^{-1} of potato at all growth stages (Table 13). At 25 DAP the highest number of stem hill^{-1} (2.48) was obtained by treatment combination V_2O_2 which was statistically similar with V_3O_1, V_4O_1, V_4O_2, V_3O_3, V_1O_3, V_1O_2 and V_1O_1 and that of lowest (1.49) was obtained by treatment combination V_5O_0 which was statistically similar with V_3O_0, V_2O_0 and V_1O_0. At 40, 55, and 85 DAP the highest number of stem hill^{-1} (4.04, 4.47 and 4.27, respectively) were obtained by treatment combination V_1O_1 which was statistically similar with V_1O_3,

V_1O_2, V_2O_1 and V_4O_1 at 40 DAP; with V_1O_3, V_1O_2, V_4O_1 and V_3O_1 at 55 DAP and with V_1O_3, V_1O_2, V_3O_1, V_3O_2 and V_3O_3 at 85 DAP. Again at 70 DAP the highest number of stem hill^{-1} (4.56) was obtained by treatment combination V_1O_2 which was statistically similar with V_1O_1, V_1O_3, V_3O_1, V_3O_2 and V_3O_3. At 40, 55, 70 and 85 DAP the lowest number of stem hill^{-1} (2.38, 2.72, 2.86 and 2.57, respectively) were obtained by treatment combination V_3O_0 which was statistically similar with V_5O_0, V_5O_2, V_5O_3, V_4O_3, V_4O_0, V_2O_0 and V_1O_0 at 40 DAP; with V_5O_0, V_5O_2, V_4O_3, V_4O_0 and V_2O_0 at 55 DAP; with V_5O_0, V_4O_0, V_2O_0 and V_5O_3 at 70 DAP and finally with V_5O_0 and V_2O_0 at 85 DAP. This finding was in accordance with observation of Mirdad (2010) who reported that the interaction effect of the cultivar Diamant and the application of organic manure at the rate of 15 Mt. ha^{-1} scored the highest number of stem hill^{-1} compare to that of control treatment.

Table 13. Interaction effect of variety and organic manure on the number of stems hill^{-1} of potato at different days after planting

Interaction (variety × organic manure)	Number of stems hill^{-1} of potato at different days after planting				
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**	**85 DAP**
V_1O_0	1.730 hj	2.790 e-i	3.390 e-h	3.520 c-e	3.220 d-g
V_1O_1	2.323 a-e	4.040 a	4.467 a	4.370 ab	4.270 a
V_1O_2	2.207 a-f	3.790 a-c	4.240 ab	4.557 a	4.263 a
V_1O_3	2.203 a-f	3.943 ab	4.220 a-c	4.310 ab	3.980 ab
V_2O_0	1.800 g-j	2.773 f-i	2.917 hi	3.007 ef	3.000 f-h
V_2O_1	2.037 c-h	3.517 a-d	3.743 b-e	3.627 c-e	3.687 b-d
V_2O_2	2.480 a	3.310 c-f	3.543 d-g	3.823 b-d	3.430 c-f
V_2O_3	1.857 f-i	3.167 d-g	3.580 d-g	3.840 b-d	3.613 b-e
V_3O_0	1.513 ij	2.377 i	2.717 i	2.860 f	2.567 h
V_3O_1	2.413 ab	3.373 b-e	4.013 a-d	4.100 a-c	3.963 ab
V_3O_2	2.103 b-g	3.327 c-f	3.757 b-e	3.953 a-c	3.893 a-c
V_3O_3	2.343 a-d	3.323 c-f	3.823 b-e	4.100 a-c	4.073 ab
V_4O_0	1.953 f-h	2.660 g-i	3.137 f-i	3.210 d-f	3.110 e-g
V_4O_1	2.363 a-c	3.630 a-d	3.940 a-e	3.740 b-d	3.630 b-d
V_4O_2	2.383 a-c	3.177 d-g	3.640 c-f	3.673 cd	3.410 c-f
V_4O_3	1.997 d-h	2.707 g-i	3.737 b-e	3.790 b-d	3.573 b-e
V_5O_0	1.487 j	2.557 hi	3.013 g-i	3.037 ef	2.840 gh
V_5O_1	1.920 f-h	3.133 d-h	3.357 e-h	3.747 b-d	3.370 d-f
V_5O_2	1.967 e-h	2.780 f-i	3.133 f-i	3.560 c-e	3.223 d-g
V_5O_3	1.903 f-h	2.900 e-i	3.433 d-h	3.470 c-f	3.370 d-f
LSD $_{(0.05)}$	**0.37**	**0.59**	**0.60**	**0.63**	**0.50**
CV (%)	**10.75**	**11.21**	**10.05**	**10.28**	**8.66**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
O_0= Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1} and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.3 SPAD value in leaf

4.1.3.1 Effect of variety

Significant variation was observed on SPAD value in leaf of potato due to varietal variation at all growth stages (Figure 19). The maximum SPAD value in leaf (40.83, 51.52 and 55.84 at 25, 55 and 70 DAP, respectively) was found in V_3 which was statistically at par with V_5 at 25 DAP; with V_1, V_2 and V_4 at 55 DAP; with V_1 V_2 and V_5 at 70 DAP. At 40 DAP the maximum SPAD value in leaf (49.82) was found in V_2 which was statistically at par with V_1 and V_3. At 85 DAP the maximum SPAD value in leaf (44.77) was found in V_5. The minimum SPAD value in leaf (35.83) was found in V_1 at 25 DAP which was statistically at par with V_2, V_4 and V_5. At 40 and 70 DAP the minimum SPAD value in leaf (43.67 and 52.15, respectively) were found in V_4 which was statistically at par with V_1 and V_5 at 40 DAP and with V_1, V_5 and V_2 at 70 DAP. At 55 DAP the minimum SPAD value in leaf (47.02) was found in V_5 which was statistically at par with V_4, V_2 and V_1. At 85 DAP the minimum SPAD value in leaf (37.51) was found in V_1 which was statistically at par with V_2 and V_4.

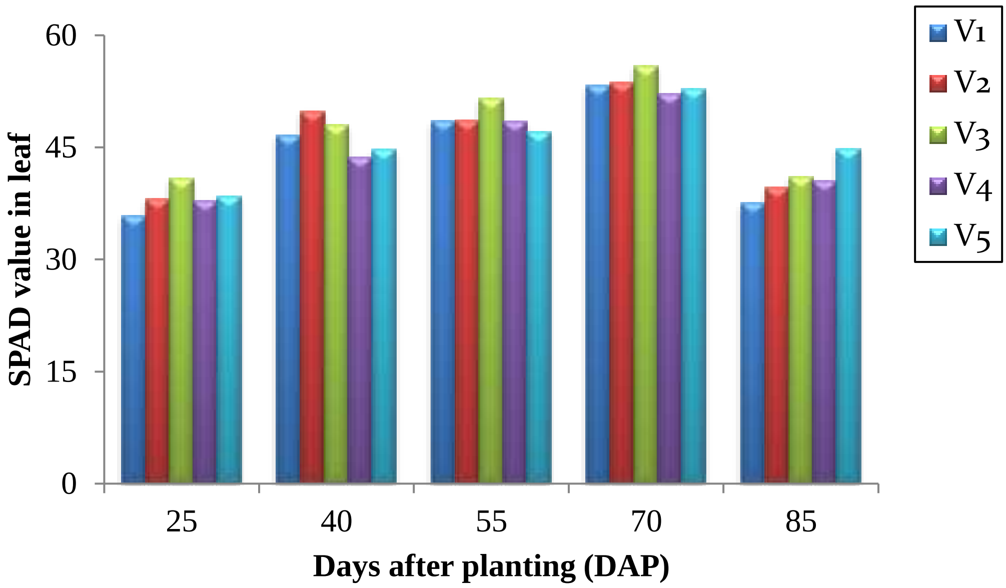


Figure 19. Effect of variety on the SPAD value in leaf of potato at different days after planting (LSD $_{0.05}$= 2.64, 3.38, 3.75, 3.59 and 3.08 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.3.2 Effect of organic manure

Significant variation was observed on SPAD value in leaf of potato due to different organic manures at all growth stages (Figure 20). The data presented in the figure exhibited that organic manure applied plot ingeneral, increased the SPAD value in potato leaf over control (without organic manure) plot. However, organic manure applied treatment showed similar level of SPAD value for all growth stages of potato. The present findings were in Ahmed *et al.* (2015) reported that leaf chlorophyll content was increased with increasing of farmyard manure levels up to 20 m^3 fed^{-1}. The highest chlorophyll content in leaf was obtained with 20 m^3 fed^{-1}. On the other hand, the lowest chlorophyll content in leaf was obtained with control treatment.

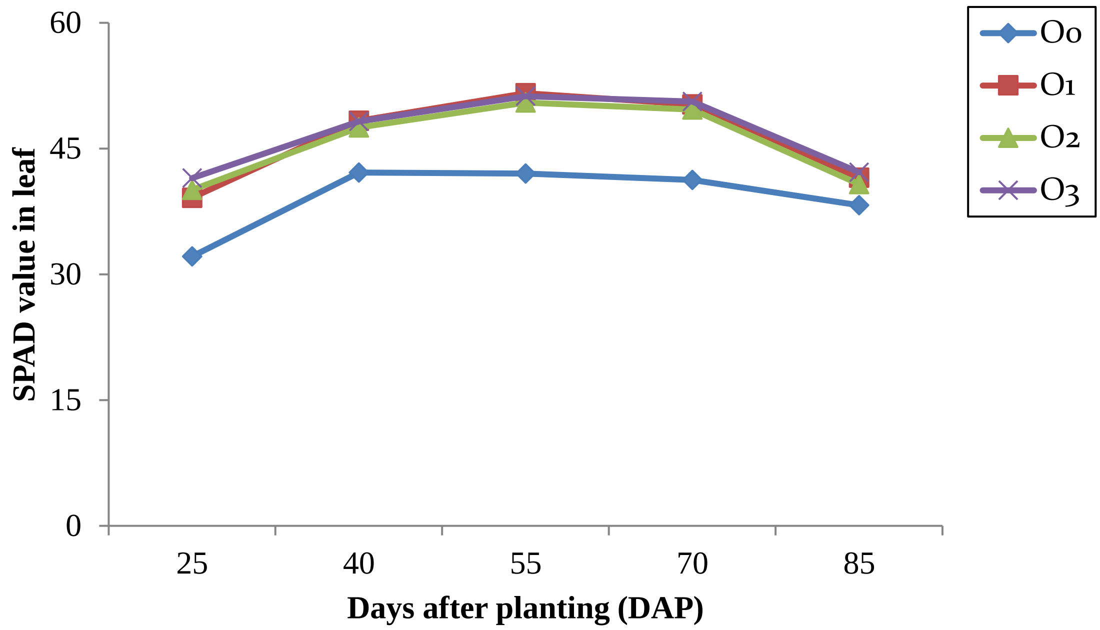


Figure 20. Effect of organic manure on the SPAD value in leaf of potato at different days after planting (LSD $_{0.05}$= 2.36, 3.02, 3.35, 3.21 and 2.76 at 25, 40, 55, 70 and 85 DAP, respectively)

Here, O_0 = Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t $ha^{-1}$and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.3.3 Interaction effect of variety and organic manure

Significant variation was observed on SPAD value in leaf of potato due to interaction different variety and organic manure at all growth stages (Table 14). At 25 DAP the maximum SPAD vaue in leaf (44.33) was found in V_3O_3 which was statistically at par with V_3O_1, V_3O_2, V_4O_2, V_4O_3, V_5O_1, V_5O_2, V_5O_3, V_2O_3, V_2O_2 and V_1O_3 and the minimum SPAD value in leaf (28.33) was found in V_1O_0 which was statistically at par with V_5O_0 and V_4O_0. At 40 DAP the maximum SPAD value in leaf (52.19) was found in V_3O_1 which was statistically at par with V_1O_3, V_1O_1, V_1O_2, V_2O_0, V_2O_1, V_2O_2, V_2O_3, V_3O_2, V_3O_3,

V_5O_2 and V_5O_3 and the minimum SPAD value in leaf (34.69) was found in V_1O_0 which was statistically at par with V_5O_0. At 55 DAP the maximum SPAD value in leaf (55.67) was found in V_3O_3 which was statistically at par with V_3O_1, V_3O_2, V_2O_3, V_2O_2, V_2O_1, V_1O_3, V_1O_2, V_1O_1, V_4O_1, V_4O_2, V_4O_3, V_5O_1 and V_5O_2 and the minimum SPAD value in leaf (39.62) was found in V_5O_0 which was statistically at par with V_4O_0, V_2O_0 and V_1O_0. At 70 DAP the maximum SPAD value in leaf (60.00) was found in V_3O_2 which was statistically at par with V_1O_1, V_1O_2, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_1, V_3O_3, V_4O_1, V_4O_3, V_5O_1 and V_5O_2 and the minimum SPAD value in leaf (45.36) was found in V_2O_0 which was statistically at par with V_1O_0, V_3O_0, V_4O_0, V_5O_0 and V_5O_3. At 85 DAP the maximum SPAD value in leaf (46.04) was found in V_5O_1 which was statistically at par with V_5O_3, V_5O_2, V_5O_0, V_4O_3, V_4O_2, V_4O_1, V_3O_3, V_3O_1, V_3O_0, V_2O_2, V_2O_1, V_1O_3 and V_1O_1 and the minimum SPAD value in leaf (30.93) was found in V_1O_0 which was statistically at par with V_4O_0.

Table 14. Interaction effect of variety and organic manures on the SPAD value in leaf of potato at different days after planting

Interaction (variety × organic manure)	SPAD value in leaf of potato at different days after planting				
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**	**85 DAP**
V_1O_0	28.33 g	34.69 f	43.51 d-f	47.64 c-e	30.93 e
V_1O_1	37.67 b-e	51.31 ab	51.86 a-c	55.33 ab	40.36 a-d
V_1O_2	36.00 c-f	48.24 a-d	49.72 a-d	55.67 ab	37.29 cd
V_1O_3	41.33 ab	52.18 a	49.11 a-d	54.54 a-c	41.48 a-d
V_2O_0	34.33 d-f	50.90 ab	40.50 f	45.36 e	38.60 b-d
V_2O_1	36.00 c-f	50.01 a-c	51.67 a-c	56.33 ab	40.14 a-d
V_2O_2	42.33 ab	48.38 a-d	50.89 a-d	57.67 ab	41.91 a-d
V_2O_3	39.67 a-c	50.00 a-c	51.39 a-c	55.33 ab	37.78 b-d
V_3O_0	33.67 d-f	42.67 de	45.31 c-f	47.84 c-e	41.54 a-d
V_3O_1	44.00 a	52.19 a	53.00 ab	56.17 ab	40.23 a-d
V_3O_2	41.33 ab	48.14 a-d	52.10 a-c	60.00 a	39.29 b-d
V_3O_3	44.33 a	48.95 a-d	55.67 a	59.33 ab	43.01 a-c
V_4O_0	32.67 e-g	42.47 de	41.04 ef	46.15 de	36.37 de
V_4O_1	38.00 b-d	43.00 de	51.48 a-c	53.94 a-c	40.91 a-d
V_4O_2	40.33 a-c	45.21 b-e	49.33 a-d	52.82 b-d	41.97 a-d
V_4O_3	40.33 a-c	44.01 c-e	51.88 a-c	55.67 ab	42.66 a-c
V_5O_0	31.67 fg	40.00 ef	39.62 f	47.84 c-e	43.77 ab
V_5O_1	40.00 a-c	45.09 b-e	50.00 a-d	55.79 ab	46.04 a
V_5O_2	40.33 a-c	47.62 a-d	50.33 a-d	55.33 ab	43.33 a-c
V_5O_3	41.67 ab	46.04 a-e	48.14 b-e	52.21 b-e	45.93 a
LSD $_{(0.05)}$	**5.27**	**6.76**	**7.49**	**7.17**	**6.16**
CV (%)	**8.35**	**8.78**	**9.28**	**8.10**	**9.16**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
O_0= Control (no manure) , O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t $ha^{-1}$and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.4 Leaf area

4.1.4.1 Effect of variety

Leaf area of potato significantly differed due to varietal difference at all growth stages except 25 DAP (Figure 21). Result of the investigation revealed that, the maximum leaf area (13.59, 14.77 and 15.80 cm^2) were recorded by V_3 at 40, 55 and 70 DAP, respectively which was statistically similar with V_2, V_4 and V_5 at 40 DAP; with V_2 and V_5 at 55 DAP and V_2 and V_4 at 70 DAP and the minimum leaf area (11.28, 12.62 and 13.09 cm^2) were received by V_1 at 40, 55 and 70 DAP, respectively which was statistically differed with other tested potato varieties.

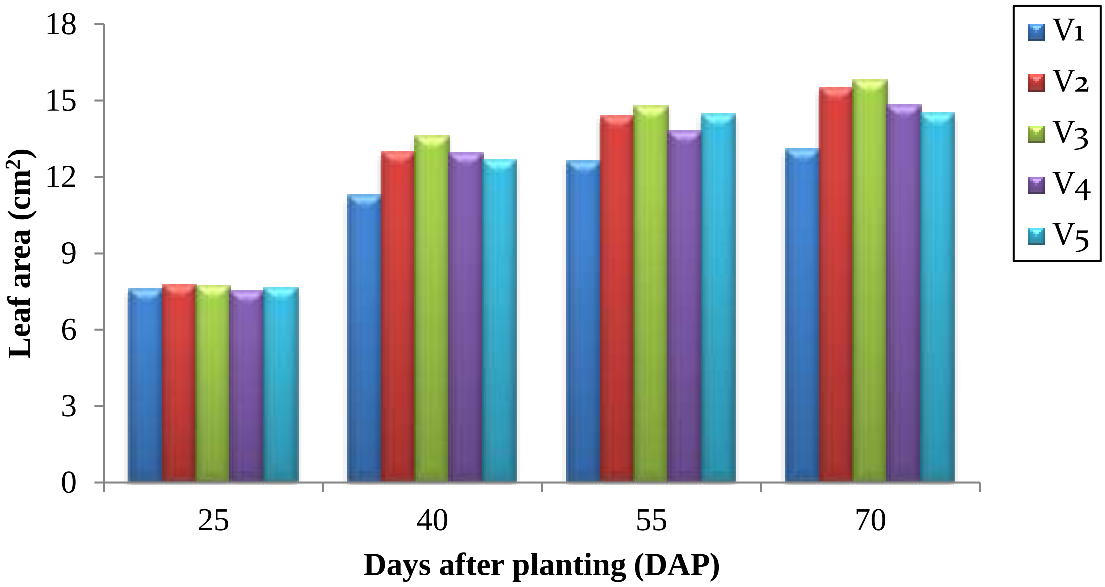


Figure 21. Effect of variety on the leaf area of potato at different days after planting (LSD $_{0.05}$= NS, 1.03, 0.93 and 1.20 at 25, 40, 55 and 70 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1} and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.4.2 Effect of organic manure

Leaf area of potato significantly differed due to different organic manure at all growth stages (Figure 22). The result revealed that in general application of organic manure increased the leaf area over control (without organic manure) treatments . Irrespective of organic manure applications, the value of leaf area increased gradually and it contuned up to last date of sampling (70 DAP). The rate of increase of leaf area was more rapid up to

40 DAP after that the increasing rate was much slower. O_3 (ACI organic fertilizer) treatment showed the highest leaf area than other treatments at 55 and 70 DAP. The possible reason for maximum leaf area with organic manure supply additional N which increased photosynthetic processes and leaf area production and the maximum leaf area that leaded attaining the maximum leaf area Rafiq *et al.* (2010). Similar findings were also reported by Amara and Mourad (2013), Ahmad *et al.* (2009), Al-Balikh (2008) and Hamedan (2006) who reported that application of organic manure substantially increased the leaf area of potato plant.

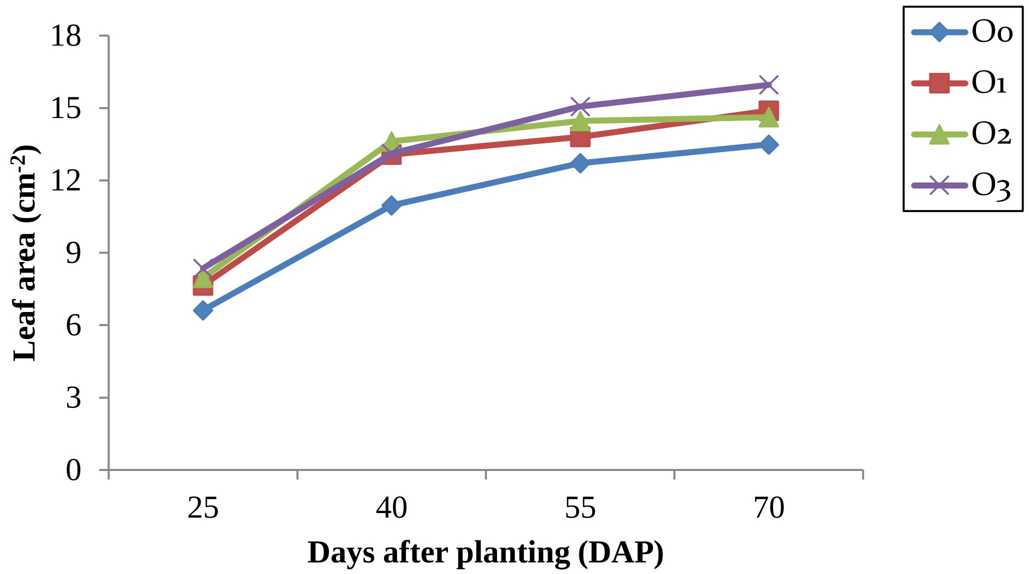


Figure 22. Effect of organic manure on the leaf area of potato at different days after planting (LSD $_{0.05}$= 0.50, 0.92, 0.83 and 1.07 at 25, 40, 55 and 70 DAP, respectively)

Here, O_0 = Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1} and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.4.3 Interaction effect of variety and organic manure

Leaf area of potato significantly differed due to interaction between different variety and organic manure at all growth stages (Table 15). Result revealed that, the maximum leaf area (8.65 and 14.62 cm^2) were received by treatment combination V_3O_3 at 25 and 40 DAP, respectively which was statistically similar with V_1O_3, V_1O_1, V_1O_2, V_2O_1, V_2O_2, V_2O_3, V_3O_1, V_3O_2, V_4O_2, V_4O_3, V_5O_2 and V_5O_3 at 25 DAP; with V_2O_1, V_2O_2, V_2O_3, V_3O_1, V_3O_2, V_4O_2, V_4O_3, V_5O_2 and V_5O_1 at 40 DAP. The maximum leaf area (15.71 cm^2) was received by treatment combination V_5O_3 at 55 DAP which was statistically similar with V_4O_3, V_4O_2, V_5O_1, V_5O_2, V_3O_3, V_3O_2, V_3O_1, V_2O_3, V_2O_2, V_2O_1 and V_1O_3. The maximum leaf area (16.70 cm^2) was received by treatment combination V_2O_3 at 70 DAP which was statistically similar with V_3O_3, V_3O_1, V_3O_2, V_2O_0, V_2O_1, V_2O_2, V_3O_0, V_4O, V_4O_3, V_5O_1, V_5O_2 and V_5O_3. The minimum leaf area (5.86 cm^2) was received by treatment combination V_3O_0 at 25 DAP which was statistically similar with V_4O_0 and V_1O_0. The minimum leaf area (10.21 and 11.43 cm^2) were received by treatment combination V_1O_0 at 40 and 55 DAP, respectively which was statistically similar with V_1O_1, V_1O_2, V_1O_3, V_2O_0, V_3O_0, V_4O_0, V_4O_1, V_5O_0 and V_5O_3 at 40 DAP and with V_1O_1, V_1O_2, V_2O_0, V_3O_0, V_4O_0 and V_4O_1 at 55 DAP. At 70 DAP the minimum leaf area (12.40 cm^2) was received by treatment combination V_5O_0 which was statistically similar with V_1O_1, V_1O_2, V_2O_0, V_3O_0, V_4O_0, V_4O_1, V_1O_0, V_1O_3, V_2O_2 and V_5O_2.

Table 15. Interaction effect of variety and organic manure on the leaf area of potato at different days after planting

Interaction (variety × organic manure)	Leaf area (cm^2) of potato at different days after planting			
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**
V_1O_0	6.607 e-g	10.21 f	11.43 h	12.41 f
V_1O_1	7.567 a-e	11.72 d-f	12.11 f-h	12.67 ef
V_1O_2	7.667 a-e	11.33 ef	13.04 e-h	13.50 d-f
V_1O_3	8.533 ab	11.87 c-f	13.90 a-g	13.76 c-f
V_2O_0	7.083 d-f	10.92 f	13.28 c-h	14.39 a-f
V_2O_1	7.937 a-d	13.67 a-d	14.34 a-e	16.13 a-c
V_2O_2	7.740 a-d	13.64 a-d	14.97 a-d	14.77 a-f
V_2O_3	8.310 a-c	13.68 a-d	15.05 a-d	16.70 a
V_3O_0	5.863 g	11.20 ef	13.20 d-h	14.67 a-f
V_3O_1	7.977 a-d	14.35 a	15.30 ab	16.46 ab
V_3O_2	8.430 ab	14.21 ab	15.13 a-c	15.44 a-d
V_3O_3	8.653 a	14.62 a	15.43 ab	16.62 a
V_4O_0	6.317 fg	11.48 ef	12.06 gh	13.57 d-f
V_4O_1	7.520 b-e	12.02 c-f	13.29 c-h	14.08 b-f
V_4O_2	8.107 a-d	15.07 a	14.66 a-e	15.04 a-e
V_4O_3	8.073 a-d	13.17 a-e	15.17 ab	16.54 a
V_5O_0	7.227 c-f	11.06 f	13.58 b-g	12.40 f
V_5O_1	7.250 c-f	13.61 a-d	13.97 a-f	15.12 a-d
V_5O_2	7.887 a-d	13.79 a-c	14.54 a-e	14.36 a-f
V_5O_3	8.210 a-c	12.22 b-f	15.71 a	16.18 ab
LSD $_{(0.05)}$	**1.12**	**2.05**	**1.86**	**2.40**
CV (%)	**8.84**	**9.78**	**8.02**	**9.85**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1} and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.1.5 Above ground dry matter content (%) of plant hill^{-1}

4.1.5.1 Effect of variety

Significant difference was observed on above ground dry matter content of plant hill^{-1} due to varietal difference shown in the figure 23. The figure revealed that, above ground dry matter content increased steadily with the advances of growth stages irrespective of varieties. The highest above ground dry matter content of plant hill^{-1} (9.30, 10.22, 11.45 and 18.61%) were produced by V_4 at 40, 55, 70 and 85 DAP, respectively which was statistically similar with V_3 at 40 and 85 DAP; with V_3 and V_5 at 55 DAP; with V_2 and V_5 at 70 DAP. At 40, 70 and 85 DAP the lowest above ground dry matter content hill^{-1} (8.22, 10.24 and 16.26 %) were produced by V_1 which was statistically similar with V_2 and V_5 at 40 and 85 DAP; with V_2, V_5 and V_3 at 70 DAP. Again the lowest above ground dry matter content of plant hill^{-1} (9.40 %) was produced by V_2 which was statistically similar with V_1, V_3 and V_5.

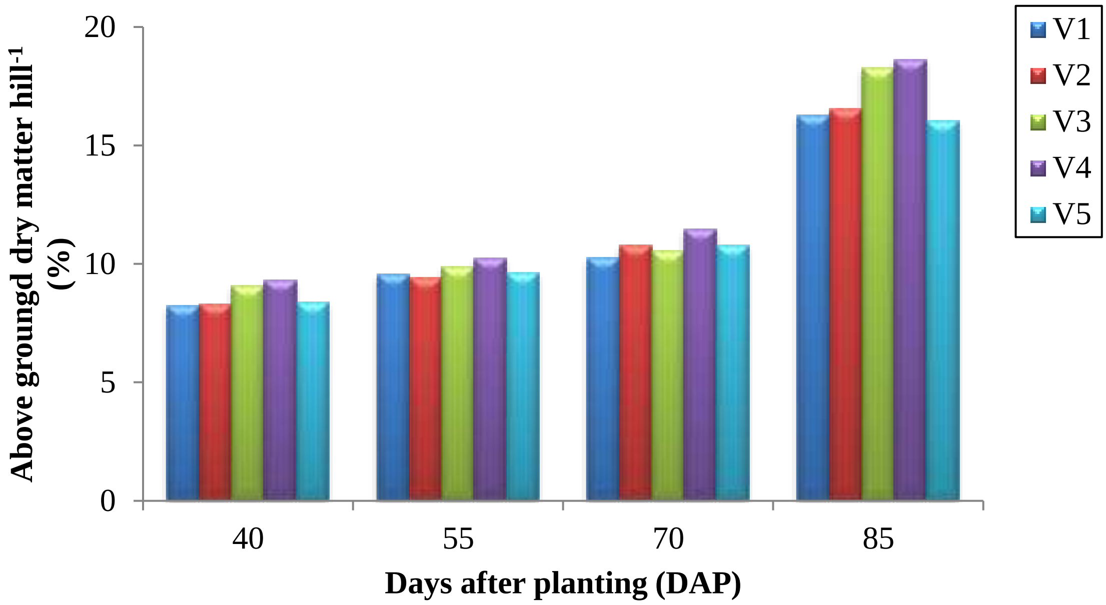


Figure 23. Effect of variety on the above ground dry matter (%) hill^{-1} of potato plant at different days after planting (LSD $_{0.05}$= 0.61, 0.65, 0.74 and 1.22 at 40, 55, 70 and 85 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.5.2 Effect of organic manure

Above ground dry matter (%) hill^{-1} of potato plant was significantly varied due to different organic manure shown in the figure 24. It can be inferred from the figure that above ground dry matter (%) increased slowly for the advancement of growth stages up to 70 DAP after that dry matter (%) production increased sharply up to 85 DAP, irrespective organic manure. From 40 to 70 DAP, all the organic manure exhibit similar level of dry matter (%) at different organic manure behaved differently in producing dry matter (%) from 70-80 DAP growth stage. In this stage O_1 showed the highest dry matter (%). However, without organic manure (control) treatment show statistically lower dry matter (%) that organic manure application for all sampling dates. Mirdad (2010) reported that increasing the above ground dry matter content plant^{-1} of potato after the application of organic manure may be due to increasing the soil organic matter content, cation exchange capacity and mineral nutrients, which in turn encouraged the plant growth to go forward. Kekong and Ojikpong (2009) reported that higher dry matter content plant^{-1} due to the application of cow dung and poultry manure especially at the higher rates is a manifestation of the role of animal manure on soil fertility status and consequently on its productivity. Similar results on increased dry matter production due to application of animal manure have also been reported by Lanre-lyanda *et al*. (2004) obtained similar increases in dry matter production in maize with the application of cow dung, while Ogboghodo *et al.* (2004) also obtained similar results on maize using poultry manure. Present results were illustrated by Zewide *et al.* (2018), Alam *et al*. (2007), El-Morsy *et al*. (2006), Singh and Kushwah (2006) and Danilchenko *et al*. (2005) who stated that application of organic manure fertilizer to potato plants increased the above ground dry matter content.

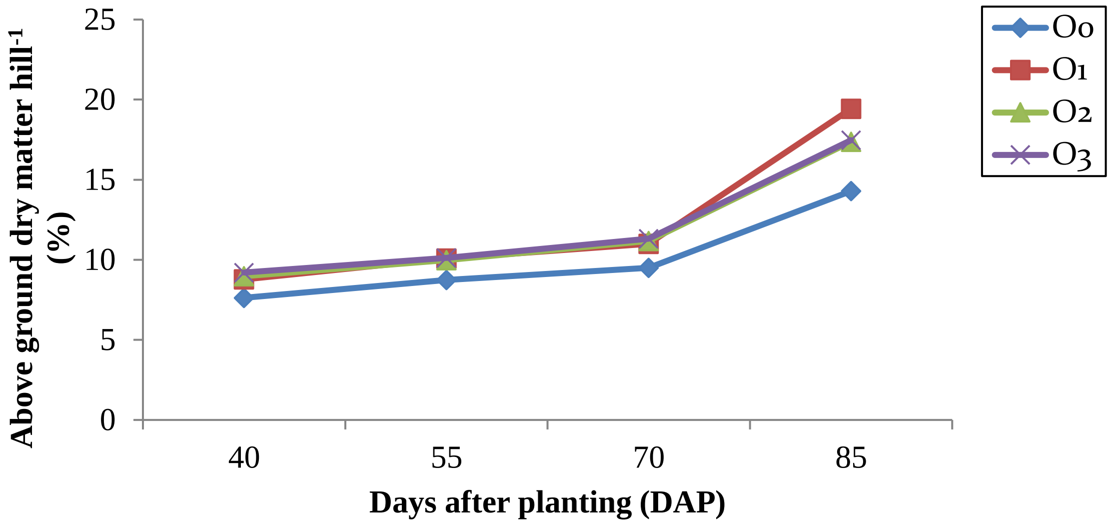


Figure 24. Effect of organic manure on the above ground dry matter (%) hill^{-1} of potato plant at different days after planting (LSD $_{0.05}$= 0.55, 0.58, 0.67 and 1.09 at 40, 55, 70 and 85 DAP, respectively)

Here, O_0 = Control(no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizr @ 10 t ha^{-1}

4.1.5.3 Interaction effect of variety and organic manure

Above ground dry matter content hill^{-1} of potato plant was significantly varied due to interaction between different variety and organic manure shown in the table 16. The result revealed that, the highest dry matter content above ground hill^{-1} (10.32, 10.94 and 12.59 %) were produced by V_4O_3 at 40, 55 and 70 DAP, respectively which was statistically similar with V_3O_2, V_3O_3 and V_4O_2 at 40 DAP; with V_3O_2, V_3O_3, V_4O_2, V_3O_1, V_4O_1, V_1O_1, V_1O_2, V_2O_1, V_5O_1, V_5O_2 and V_5O_3 at 55 DAP and with V_2O_2, V_3O_3, V_4O_1, V_4O_2 and V_5O_3 at 70 DAP. The highest above ground dry matter of plant hill^{-1} (20.85 %) was produced by V_2O_1 at 85 DAP which was statistically similar with V_3O_1, V_1O_1, V_3O_2, V_4O_1, V_4O_2 and V_4O_3. At 40 and 55 DAP the lowest above ground dry matter hill^{-1} (7.00 and 8.09 %) were produced by V_2O_0 which was statistically similar with V_1O_0, V_4O_0 and V_5O_0 at 40 DAP and with V_1O_0, V_4O, V_5O_0 and V_3O_0 at 55 DAP. At 70 and 85 DAP, the lowest above ground dry matter hill^{-1} (9.04 and 11.72 %) were produced by V_1O_0 which was statistically similar with V_2O_0, V_3O_0, V_4O_0 and V_5O_0 at 70 DAP, and with V_2O_0 at 40 DAP and at 85 DAP.

Table 16. Interaction effect of organic manure on the above ground dry matter (%) hill^{-1} of potato plant at different days after planting

Interaction (variety × organic manure)	Above ground dry matter (%) hill^{-1} of potato plant at different days after planting			
	40 DAP	**55 DAP**	**70 DAP**	**85 DAP**
V_1O_0	7.113 gh	8.537 fg	9.037 f	11.72 i
V_1O_1	8.683 c-f	9.857 a-e	10.84 b-e	18.53 a-e
V_1O_2	8.273 d-g	10.22 a-d	10.76 b-e	17.38 c-g
V_1O_3	8.790 b-f	9.580 b-f	10.32 c-f	17.42 c-g
V_2O_0	6.997 h	8.090 g	9.237 f	13.27 hi
V_2O_1	8.387 c-f	10.34 a-c	11.04 b-d	20.85 a
V_2O_2	8.770 b-f	9.560 b-f	12.05 ab	16.13 e-g
V_2O_3	8.983 b-e	9.603 b-f	10.76 b-e	15.86 fg
V_3O_0	8.547 c-f	9.027 d-g	9.477 ef	15.09 gh
V_3O_1	8.927 b-e	9.860 a-e	10.30 c-f	20.48 ab
V_3O_2	9.273 a-d	9.993 a-e	10.89 b-e	19.34 a-d
V_3O_3	9.527 a-c	10.54 ab	11.49 a-c	18.13 b-f
V_4O_0	7.850 e-h	9.137 c-fg	10.04 c-f	16.17 e-g
V_4O_1	9.093 b-d	10.57 ab	11.98 ab	20.04 ab
V_4O_2	9.940 ab	10.24 a-d	11.19 a-c	18.46 a-e
V_4O_3	10.32 a	10.94 a	12.59 a	19.79 a-c
V_5O_0	7.627 f-h	8.880 e-g	9.700 d-f	15.22 gh
V_5O_1	8.797 b-f	9.753 a-f	10.84 b-e	17.23 d-g
V_5O_2	8.623 c-f	9.857 a-e	11.03 b-d	15.52 gh
V_5O_3	8.410 c-f	9.913 a-e	11.46 a-c	16.13 e-g
LSD $_{(0.05)}$	**1.22**	**1.30**	**1.49**	**2.44**
CV (%)	**8.55**	**8.10**	**8.38**	**8.63**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}

4.2 Potato yield and yield parameters

4.2.1 Tuber number hill^{-1}

4.2.1.1 Effect of variety

Potato variety had a significant influence on the tuber number hill^{-1} (Table 17). Results showed that the maximum tuber number hill^{-1} (9.18 no.) was found in V_3 and the minimum tuber number hill^{-1} (7.22 no.) was found in V_4 which was statistically similar with V_1, V_2 and V_5. Similar findings was also reported by Mirdad (2010), Shafeek *et al.* (2001), Swaminathan *et al.* (1999) and Marwaha (1998) who found that the evaluated potato differed significantly from one another in the context of tuber number hill^{-1}.

4.2.1.2 Effect of organic manure

Organic manure had a non-significant difference on the tuber number hill^{-1} of potato (Table 17). Numerically the maximum tuber number hill^{-1} (7.94 no.) was found in O_3 and the minimum tuber number hill^{-1} (7.50 no.) was found in O_0.

4.2.1.3 Interaction effect of variety and organic manure

Interaction between variety and organic manure exerted a significant difference on the tuber number hill^{-1} (Table 18). Results showed that the maximum tuber number hill^{-1} (9.70 no.) was found in V_3O_3 which was statistically similar with V_3O_1 and V_3O_2 and the minimum tuber number hill^{-1} (6.71 no.) was found in V_4O_0 which was statistically similar with rest of the treatment combinations except V_3O_1, V_3O_2, V_3O_3 and V_3O_0. Similar findings were also reported by Mirdad (2010), Ashour and Sarhan (1998) and Karmanov and Gushchiva (1986) who reported that interaction of organic manure along with potato varieties significantly differed tuber number hill^{-1} of potato.

4.2.2 Tuber weight hill^{-1}

4.2.2.1 Effect of variety

Potato variety showed a significant difference on the tuber weight hill^{-1} (Table 17). Results showed that the maximum tuber weight hill^{-1} (0.32 kg) was found in V_3 which were statistically at par with rest of the tested potato varieties except V_5 and the minimum tuber weight hill^{-1} (0.26 kg) was found in V_5. This finding was in accordance with observation of Mirdad (2010) and Shafeek *et al.*, (2001) who found that the potato cultivars significantly differed from one another for tuber weight hill^{-1}.

4.2.2.2 Effect of organic manure

Organic manure had a significant difference on the tuber weight hill^{-1} (Table 17). Results showed that the maximum tuber weight hill^{-1} (0.31 kg) was found in O_2 and O_3 which was statistically similar with O_1 and the minimum tuber weight hill^{-1} (0.26 kg) was found in O_0. The organic manures are good sources of N and other nutrients, which can decease the demand of chemical fertilizer and it has been used for many centuries to increase soil fertility (Darzi, 2012, Mir and Quadri, 2009, Kolay, 2007 and White *et al.*, 2007), probably increases available P, mineralized N and improved cations exchange capacity of the soil (Tirol-Padre *et al.*, 2007), increases of hydraulic conductivity, raising the water holding capacity, changing the soil pH (decrease or increase in the pH, depending on soil type, elevating the soil aggregation and water infiltration, increase SOC (soil organic carbon), aggregate stability, microbial biomass, reducing the frequency of plant diseases (Conn and Lazarovits, 1999; Olson and Papworth, 2006; Tigoni, 2005) which facilitated more and comparatively larger tuber production hill^{-1} that attributed highest tuber weight hill^{-1}. This finding was in accordance with observation of Wazir *et al.* (2018), Amara and Mourad (2013), Avdinco *et al*., (2003) and Murashov (2003).

4.2.2.3 Interaction effect of variety and organic manure

Interaction between variety and organic manure exerted a significant difference on the tuber weight hill^{-1} (Table 18). Results showed that the maximum tuber weight hill^{-1} (0.34 kg.) was found in V_3O_2 which was statistically similar with V_3O_1, V_3O_3, V_4O_1, V_4O_2, V_4O_3, V_2O_3, V_2O_2, V_2O_1, V_1O_3, V_1O_2 and V_1O_1 and the minimum tuber weight hill^{-1} (0.23 kg) was found in V_5O_0 which was statistically similar with V_5O_1, V_5O_2, V_5O_3, V_4O_0, V_2O_0 and V_1O_0. This finding was in accordance with the findings of Mirdad (2010) and Shafeek *et al.*, (2001) who found that the interaction of potato cultivars and organic manures significantly influenced the potato tuber weight hill^{-1}.

Table 17. Effect of variety and organic manure on the yield and tuber characteristics of potato

Treatment	Tuber hill^{-1} (no.)	Tuber weight hill^{-1} (kg)	Yield of potato (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})
Effect of variety					
V_1	7.55 b	0.31 a	27.95 ab	24.67 a	3.28 b
V_2	7.45 b	0.30 a	26.89 b	23.73 a	3.16 b
V_3	9.18 a	0.32 a	27.08 b	24.73 a	2.36 c
V_4	7.22 b	0.30 a	29.40 a	25.02 a	4.31 a
V_5	7.48 b	0.26 b	23.00 c	19.84 b	3.16 b
LSD $_{(0.05)}$	**0.66**	**0.03**	**1.78**	**1.70**	**0.29**
CV (%)	**10.31**	**9.34**	**8.02**	**8.72**	**10.78**
Effect of organic manure					
O_0	7.50	0.26 b	23.39 c	19.71 b	3.68 a
O_1	7.92	0.30 a	28.89 a	25.33 a	3.56 a
O_2	7.75	0.31 a	27.24 b	24.50 a	2.74 c
O_3	7.94	0.31 a	27.94 ab	24.85 a	3.03 b
LSD $_{(0.05)}$	**NS**	**0.02**	**1.59**	**1.52**	**0.26**
CV (%)	**10.31**	**9.34**	**8.02**	**8.72**	**10.78**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets

O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer@ 10 t ha^{-1}

4.2.3 Yield of potato

4.2.3.1 Effect of variety

Yield of potato significantly influenced by potato variety (Table 17). Results of the experiment revealed that, the highest potato yield (29.40 t ha^{-1}) was recorded from V_4 which was statistically similar with V_1 and the lowest one (23.00 t ha^{-1}) was recorded from V_5. Field differences among the varieties may be attributed to the varietal characters, which is governed by the genetic make up of the varieties.

4.2.3.2 Effect of organic manure

Yield of potato was significantly influenced by different organic manure (Table 17). The result revealed that O_1 (cowdung) treatment out yielded by producing 3.40, 6.06 and 23.51% higher yield over O_3 (ACI organic fertilizer), O_2 (poultry litter) and O_0 (no manure). However, the highest potato yield (28.89 t ha^{-1}) was recorded from O_1 which was statistically similar with O_3 and the lowest one (23.39 t ha^{-1}) was recorded from O_0. The growth and yield of potato largely depends on the soil and soil conditions can be improved throughout the use of different organic fertilizer. Koireng *et al.* (2018) reported that organic manure has a direct influence on soil nutrient availability from soil native pool. Although there is a considerable variation in the percentage nutrient composition of animal manures depending mainly on the source, handling and management, the main nutrients supplied are; nitrogen, phosphorus, potassium, calcium and a host of micronutrients (Lombin *et al.*, 1991). Lunin (1977) reported that the composition of selected animal wastes including cattle and poultry to include; N, P, K, Ca, Mg, S, Mn, Fe, B, Cu, Zn and Mo. Esu (2005) stated that the nutrient composition of organic manures include: N, P, K, S as well as micronutrients such as B, Cu, Mo, Zn, Fe and Mn. Manures (cattle and poultry) have been used for centuries in agricultural production as a source of nutrients and to increase soil organic carbon (SOC) as a means to improve soil tilth (Brady 1974). Enhancement of tubers yield as a results of using of organic manure at different levels may be attributed to the positive effects of organic manure application on the vegetative growth characteristics of potato plants which consequently increased photosynthesis efficiency and synthesis of carbohydrates such as starch content which reflected on increasing of tubers yield of plants (Ahmed *et al.,* 2009 and Mauromicale *et al.,* 2006). Organic manure can improve chemical, physical and biological characteristics of the soil (Darzi and Haj Seyed Hadi, 2012, Najm *et al.,* 2012a and Benke *et al.,* 2008). The organic manures are good sources of N and other nutrients, which can decease the demand of chemical fertilizer and it has been used for many centuries to increase soil fertility (Darzi, 2012, Mir and Quadri, 2009, Kolay, 2007, White *et al.*, 2007) probably increases available P, mineralized N and improved cations exchange capacity of the soil (Tirol-Padre *et al.,* 2007), increases of hydraulic conductivity, raising the water holding capacity, changing the soil pH (decrease or increase in the pH, depending on soil type, elevating the soil aggregation and water infiltration, increase SOC (soil organic carbon), aggregate stability, microbial biomass, reducing the frequency of plant diseases (Conn and Lazarovits, 1999; Olson and Papworth, 2006 and Tigoni, 2005), in this experiment which favored healthy plant production along with obtaining the better yield of potato. Using of animal manure such as cattle manure has positively beneficial effects on vegetative growth, yield and tuber quality (Najm *et al.,* 2013, Balemi *et al.,* 2012, Najm *et al.,* 2010, Kolay, 2007 and White *et al.,* 2007). Nutrient contributions from manures can be substantial (Stark and Porter 2005). Rees *et al.* (2014) reported that manured treatments averaged 2649 mg L^{-1} soil CO_2 compared with 1716 mg L^{-1} soil CO_2 for controls, representing a 54% increase. Increased CO_2 emissions and thus increased microbial activity after manure applications are consistent with Carter (2002), who indicated that manure can increase microbial populations by up to 1000-fold. This higher CO_2 concentration may indicate that the manured soils supported more microbial activity or, since respiration is primarily an index of soil C availability that it was due to differences in how much available C was remaining at the time of sampling. Cleveland *et al*. (2007) suggested that the increase in soil respiration following available carbon additions might be linked to shifts in microbial community composition that might be a crucial sign of active and good soil health. Tuber yield of potato is much more after using organic manures than the recommended dose of inorganic fertilizers only (Boke, 2014). Balance fertilization is required for most of the crops also for potato (Alam *et al.,* 2007 and Sharma *et al.* 2003) but tuber yield increases with the application of high amount of organic manures (Roy *et al.* 2001, Fageria *et al.* 1997 and Johnston 1986). Zaman *et al.* (2011), Baishya (2009) and Kumar *et al.* (2008) reported that yield of tuber increases due to the availability of N, P and K contents in soil through the application of organic manures. Potato yielded more tubers from manure application along with inorganic fertilizers (Johnston 1986, Nyiraneza and Snapp 2007, Bereez *et al*. 2005, Alam *et al*. 2007, Gruhn *et al*. 2000, Daniel *et al*. 2008). Kimpinski *et al.* (2003) concluded that a 27% increase in potato production with beef manure applied at 12 Mt ha^{-1}. The impact of manure applications on yield has been reported for a number of crops including forages (Zheljazkov *et al*., 2006 and Lynch *et al*., 2005), grains (Khan *et al.* 2007 and Carter and

Campbell 2006), small fruits (Dean *et al*. 2000), and vegetable crops (Neilsen *et al*. 1998). Ojeniyi (2000) reported higher yield of okra due to the application of goat manure, significant increase in yield of corn using cow dung (Eghball *et al*., 2004), higher yield of oat using poultry manure (Zhang *et al*., 2006), increase in lint yield and quality of cotton using poultry manure (Tewolde *et al*., 2007) and increase in yield of ginger with the application of cow dung up to 30 t ha^{-1} and poultry droppings up to 20 t ha^{-1} (Ayuba *et al*., 2005). It was found that application with FYM and mineral fertilizers gave a tuber yield increase of 35-82 %, compared with the yield obtained using only mineral fertilizers (Baniuniene and Zekaite, 2008 and Repsiene and Mineikiene 2006). Other authors indicate that incorporation of 50 and 60 t ha^{-1} FYM can give a tuber yield increase of 20 and 23 %, respectively (Ciganov *et al.,* 2001, Simanaviciene *et al.,* 2001). On the other hand, Kumar *et al*. (2012) stated that integrated application of 50% of recommended NPK through chemical fertilizers and 50% recommended N dose through poultry manure produced significantly the highest tuber yield (22.73 t ha^{-1}). The present results were in harmony with those reported by Bilkis *et al.* (2018), Wazir *et al.* (2018), Boru *et al*. (2017), Sikder *et al.* (2017) and Ram *et al.* (2017) who reported that organic manure increase the yield of potato.

4.2.3.3 Interaction effect of variety and organic manure

Yield of potato was significantly influenced by interaction of different variety and organic manure (Table 18). Result revealed that, the highest potato yield (31.98 t ha^{-1}) was recorded from V_4O_1 which was statistically similar with V_1O_1, V_1O_2, V_1O_3, V_3O_1, V_4O_2 and V_4O_3 and the lowest one (20.31 t ha^{-1}) was recorded from V_5O_0 which was statistically similar with V_5O_2, V_3O_0, V_2O_0 and V_1O_0. These results were in agreement with those obtained by Sikder *et al.* (2017) who reported that interaction effect of variety and organic manure had significant variation on the yield of potato.

4.2.4 Marketable yield of potato

4.2.4.1 Effect of variety

Marketable yield of potato varied significantly due to different potato varieties (Table 17). Results of the experiment revealed that, the highest marketable potato yield (25.02 t ha^{-1}) was produced by V_4 which was statistically similar with rest of the potato varieties except V_5 and the lowest one (19.84 t ha^{-1}) was produced by V_5 which was statistically differed from other tested potato varieties. Significant difference for marketable tuber yield was also found by Bhardwaj *et al.* (2008) among different potato genotypes.

4.2.4.2 Effect of organic manure

Marketable yield of potato was significantly influenced by different organic manure (Table 17). Result revealed that, the highest marketable potato yield (25.33 t ha^{-1}) was produced by O_1 which was statistically similar with rest of the treatments except the control (O_0) and the lowest (19.71 t ha^{-1}) was produced by O_0 which was statistically differed from other treatments. The results were supported by Sikder *et al.* (2017) who observed that integrated nutrient management by the application of both inorganic fertilizers and organic manures increases the different grades tuber production (Kumar *et al.* 2008, 2011) and total tuber yield (Raghav and Kamal, 2008 and Kumar *et al*. 2001). Yield of tuber increases due to the availability of N, P and K contents in soil through the application of organic manures (Zaman *et al.* 2011, Baishya, 2009 and Kumar *et al.* 2008). Present results were in agreement with those obtained by Bilkis *et al.* (2018), Boru *et al*. (2017), Banjare *et al.* (2014), Chilephake and Trautz (2014) and Yeng *et al.* (2012) who reported that potato yield increased with organic manure application.

4.2.4.3 Interaction effect of variety and organic manure

Marketable yield of potato was significantly influenced by interaction of different variety and organic manure (Table 18). Result revealed that, the highest marketable potato yield (27.69 t ha^{-1}) was produced by treatment combination V_4O_1 which was statistically similar with V_4O_2, V_4O_3, V_3O_3, V_3O_1, V_3O_2, V_2O_2, V_2O_1, V_1O_1, V_1O_2, V_1O_3 and V_2O_3 and the lowest one (16.76 t ha^{-1}) was produced by V_5O_0 which was statistically similar with V_1O_0 and V_2O_0.

Table 18. Interaction effect of variety and organic manure on the yield and tuber characteristics of potato

Interaction (variety × organic manure)	Tuber hill^{-1} (No.)	Tuber weight hill^{-1} (kg)	Yield of potato (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})
V_1O_0	6.89 d	0.26 fg	23.65 e-g	19.62 de	4.03 bc
V_1O_1	7.91 b-d	0.32 a-d	29.95 ab	26.44 a	3.51 c-f
V_1O_2	7.69 cd	0.33 ab	28.84 a-c	26.00 a	2.84 g-i
V_1O_3	7.69 cd	0.32 a-c	29.36 ab	26.62 a	2.74 h-j
V_2O_0	7.70 cd	0.27 c-g	23.68 e-g	19.90 de	3.78 b-e
V_2O_1	7.45 cd	0.30 a-f	28.38 bc	25.12 a	3.26 e-h
V_2O_2	7.31 cd	0.31 a-e	27.46 b-d	24.96 ab	2.50 i-k
V_2O_3	7.34 cd	0.31 a-f	28.03 bc	24.92 ab	3.11 f-h
V_3O_0	8.60 a-c	0.28 b-f	23.83 e-g	21.64 b-d	2.19 j-l
V_3O_1	9.25 a	0.33 a	29.79 ab	27.09 a	2.69 h-j
V_3O_2	9.18 ab	0.34 a	26.75 b-e	24.31 a-c	2.44 i-k
V_3O_3	9.70 a	0.33 ab	27.96 bc	25.86 a	2.10 kl
V_4O_0	6.71 d	0.26 fg	25.47 c-f	20.62 d	4.85 a
V_4O_1	7.00 d	0.29 a-f	31.98 a	27.69 a	4.29 ab
V_4O_2	7.27 d	0.31 a-f	29.95 ab	25.72 a	4.23 b
V_4O_3	7.90 b-d	0.33 ab	30.17 ab	26.06 a	3.86 b-d
V_5O_0	7.59 cd	0.23 g	20.31 g	16.76 e	3.55 c-f
V_5O_1	7.56 cd	0.26 fg	24.35 d-f	20.31 d	4.04 bc
V_5O_2	7.29 cd	0.26 fg	23.18 fg	21.49 cd	1.69 l
V_5O_3	7.50 cd	0.27 d-g	24.17 d-f	20.81 d	3.36 d-g
LSD $_{(0.05)}$	**1.33**	**0.05**	**3.56**	**3.40**	**0.58**
CV (%)	**10.31**	**9.34**	**8.02**	**8.72**	**10.78**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}

4.2.5 Non-marketable yield of potato

4.2.5.1 Effect of variety

Non-marketable of potato was significantly varied by different potato varieties (Table 17). Results of the experiment revealed that, the highest non-marketable potato yield (4.31 t ha^{-1}) was produced by V_4 and the lowest one (2.36 t ha^{-1}) was produced by V_3.

4.2.5.2 Effect of organic manure

Non-marketable yield of potato was significantly influenced by different organic manure (Table 17). Result revealed that, the highest non-marketable potato yield (3.68 t ha^{-1}) was produced by O_0 treatment which was statistically similar with O_1 and the lowest one

(2.74 t ha^{-1}) was produced by O_2. The result is in accordance to those of Ahmed *et al.* (2015) who reported that non-marketable tubers yield was significantly affected by different farmyard manure levels. But the findings of Boru *et al*. (2017) was contradictory with the findings of Ahmed *et al.*(2015*)* who reported that the rate of FYM increased from 0 t ha^{-1} to 15 t ha^{-1}, the unmarketable tuberous root was increased from 0.58 t ha^{-1} to 1.3 t ha^{-1}. Their result indicated that as the yield of sweet potato increased due to increasing level of FYM, the amount of unmarketable yield also increased. This may be due to nutrient addition by applied FYM which enriched the soil for the uptake of macro and micro nutrients which are important for increasing tuber yield.

4.2.5.3 Interaction effect of variety and organic manure

Non-marketable yield of potato was significantly influenced by interaction of different variety organic manure (Table 18). Result revealed that, the highest non-marketable potato yield (4.85 t ha^{-1}) was produced by V_4O_0 which was statistically similar with V_4O_1 and the lowest one (1.69 t ha^{-1}) was recorded from V_5O_2 which was statistically similar with V_3O_3 and V_3O_0.

4.2.6 Marketable tuber number by percent

4.2.6.1 Effect of variety

There was observed a mark difference among marketable tuber number by percent due to different potato varieties (Table 19). Results showed that the maximum marketable tuber number (71.87%) was gained by V_3 followed by V_2 (68.19%) and the minimum marketable tuber number (56.36%) was gained by V_4.

4.2.6.2 Effect of organic manure

There was a mark difference among marketable tuber number by percent due to different organic manures (Table 19). Result showed that, the highest marketable tuber number (68.42%) was attained by O_1 treatment which was statistically similar with O_2 and O_3 , and the lowest marketable tuber number (61.16%) was attained by O_0 which was statistically similar to 0_2 and 0_3 treatments. The result was in accordance to those of Amara and Mourad (2013) and Zidan and Dauob (2005) who reported that the application of mixed manure has indicated maximum increase in percentage of standard tuber number at 80.84 % then it is followed by the chicken manure treatment at 76.65% then the common fertilization at 72.83%, the sheep manure at 69.8 %, and no manure at 61.45 %.

4.2.6.3 Interaction effect of variety and organic manure

A mark difference among marketable tuber number by percent was observed due to interaction of different varieties and organic manures (Table 20). Result showed that, the highest marketable tuber number (75.07 %) was attained by treatment combination V_2O_1 which was statistically similar with V_3O_2, V_3O_3, V_5O_2, V_5O_1, V_3O_0, V_2O_3, V_2O_2, V_2O_0, V_1O_3 and V_1O_1 and the lowest marketable tuber number (54.30 %) was attained by V_5O_0 which was statistically similar with V_4O_0, V_4O_2, V_4O_1, V_4O_3, V_5O_3, V_2O_0, V_1O_2 and V_1O_0.

4.2.7 Marketable tuber weight by percent

4.2.7.1 Effect of variety

Potato variety exerted a non-significant difference on the marketable tuber weight by percent of potato (Table 19). Results showed that numerically the maximum and minimum marketable tuber weight (91.29 and 84.89%, respectively) was recorded from V_3 and V_4, respectively.

Table 19. Effect of variety and organic manure on the tuber characteristics of potato

Treatments	Marketable tuber number (%)	Marketable tuber weight (%)	Non-marketable tuber number (%)	Non-marketable tuber weight (%)
Effect of variety				
V_1	66.06 b	88.35	33.94 bc	11.65 b
V_2	68.19 ab	88.61	31.98 c	11.39 b
V_3	71.87 a	91.29	28.13 d	8.710 c
V_4	56.36 c	84.89	43.64 a	15.11 a
V_5	63.09 b	86.04	36.91 b	13.96 a
LSD $_{(0.05)}$	**5.67**	**NS**	**3.42**	**1.31**
CV (%)	**10.53**	**10.93**	**11.86**	**13.04**
Effect of organic matter				
O_0	61.16 b	84.94	38.91 a	15.06 a
O_1	68.42 a	88.92	31.58 c	11.08 b
O_2	65.52 ab	88.88	34.48 bc	11.12 b
O_3	65.36 ab	88.61	34.71 b	11.39 b
LSD $_{(0.05)}$	**5.07**	**NS**	**3.06**	**1.17**
CV (%)	**10.53**	**10.93**	**11.86**	**13.04**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}

4.2.7.2 Effect of organic manure

Organic manure exerted a non-significant difference on the marketable tuber weight by percent of potato (Table 19). Results showed that numerically the maximum and minimum marketable tuber weight (88.92 and 84.94 %, respectively) was recorded from O_1 and O_0, respectively. The result was in accordance to those of Yeng *et al.* (2012) and Hahn and Hozyo (1984) who concluded that higher initial soil nutrients and better climatic conditions might have contributed to this outcome

4.2.7.3 Interaction effect of variety and organic manure

Interaction between variety and organic manure exerted a non-significant difference on the marketable tuber weight of potato (Table 20). Result showed that, numerically the highest and lowest marketable tuber weight (92.51 and 81.00 %, respectively) was attained by treatment combination V_3O_2 and V_4O_0 respectively.

4.2.8 Non-marketable tuber number by percent

4.2.8.1 Effect of variety

Mark difference among non-marketable tuber number was observed due to different potato varieties (Table 19). Results showed that the maximum non-marketable tuber number (43.64 %) was gained by V_4 followed by V_5 (36.91%) and the minimum non-marketable tuber number (31.98 %) was gained by V_2 followed by V_1 (33.94 %).

4.2.8.2 Effect of organic manure

There was observed a mark difference among non-marketable tuber number due to different organic manures (Table 19). Result showed that, the highest non-marketable tuber number (38.91 %) was attained by O_0 treatment which was statistically differed from other treatments and the lowest non-marketable tuber number (31.58 %) was attained by O_1 which was statistically similar with O_2.

4.2.8.3 Interaction effect of variety and organic manure

Non-marketable tuber number differed significantly interaction of different varieties and organic manures (Table 20). Result showed that, the highest non-marketable tuber number (45.70 %) was attained by treatment combination V_5O_0 which was statistically similar with V_4O_0, V_4O_2, V_4O_1, V_4O_3 and V_1O_0 and the lowest non-marketable tuber number (24.93 %) was attained by V_2O_1 which was statistically similar with V_3O_0, V_3O_2, V_3O_3, V_3O_1, V_1O_3 and V_5O_2.

4.2.9 Non-marketable tuber weight by percent

4.2.9.1 Effect of variety

Potato variety exerted a significant difference on the non-marketable tuber weight of potato (Table 19). Results showed that the maximum non-marketable tuber weight (15.11%) was found in V_4 which was statistically similar with V_5 and the minimum non-marketable tuber weight (8.71%) was found in V_3.

4.2.9.2 Effect of organic manure

Organic manure exerted a significant difference on the non-marketable tuber weight of potato (Table 19). Results showed that the maximum non-marketable tuber weight (15.06 %) was found in O_0 which was statistically differed with other treatments and the minimum non-marketable tuber weight (11.08 %) was found in O_1 which was statistically similar with O_2 and O_3.

4.2.9.3 Interaction effect of variety and organic manure

Interaction between variety and organic manure exerted a significant difference on the non-marketable tuber weight of potato (Table 20). Results showed that the maximum non-marketable tuber weight (19.00 %) was found in V_4O_0 which was statistically similar with V_5O_0 and the minimum non-marketable tuber weight (7.49 %) was found in V_3O_2 which was statistically similar with V_3O_3, V_3O_1, V_1O_1, V_1O_3, V_2O_1 and V_3O_0.

Table 20. Interaction effect of variety and organic manure on the tuber characteristics of potato

Interaction (variety × organic manure)	Tuber characteristics of potato			
	Marketable tuber number (%)	Marketable tuber weight (%)	Non-marketable tuber number (%)	Non-marketable tuber weight (%)
V_1O_0	60.96 b-f	84.17	39.04 a-d	15.83 bc
V_1O_1	71.22 ab	90.26	28.78 gh	9.74 h-j
V_1O_2	62.81 b-f	88.88	37.19 b-e	11.12 f-i
V_1O_3	69.26 a-c	90.09	30.74 e-h	9.91 h-j
V_2O_0	64.44 a-f	86.29	35.89 c-f	13.71 c-f
V_2O_1	75.07 a	90.77	24.93 h	9.23 h-j
V_2O_2	65.74 a-e	88.42	34.26 d-g	11.58 e-i
V_2O_3	67.51 a-d	88.95	32.83 d-g	11.05 g-i
V_3O_0	71.61 ab	90.77	28.39 gh	9.23 h-j
V_3O_1	69.94 a-c	90.87	30.06 f-h	9.13 ij
V_3O_2	75.04 a	92.51	24.96 h	7.49 j
V_3O_3	70.88 ab	91.01	29.12 f-h	8.99 ij
V_4O_0	54.49 ef	81.00	45.51 a	19.00 a
V_4O_1	58.75 c-f	85.28	41.25 a-c	14.72 cd
V_4O_2	55.59 ef	86.34	44.41 a	13.66 c-g
V_4O_3	56.62 d-f	86.95	43.38 ab	13.05 d-g
V_5O_0	54.30 f	82.47	45.70 a	17.53 ab
V_5O_1	67.11 a-d	87.41	32.89 d-g	12.59 d-g
V_5O_2	68.44 a-c	88.23	31.56 e-h	11.77 e-h
V_5O_3	62.52 b-f	86.05	37.48 b-e	13.95 c-e
LSD $_{(0.05)}$	**11.33**	**NS**	**6.84**	**2.62**
CV (%)	**10.53**	**10.93**	**11.86**	**13.04**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}

4.3 Post-harvest quality of potato

4.3.1 Dry matter content (%) of potato after storage

4.3.1.1 Effect of variety

Dry matter (%) of potato after storage was significantly influenced by potato varieties (Figure 25). The result revealed that, the highest dry matter of potato after storage (21.53, 21.59, 21.66, 21.19, 20.85 and 20.40 %) were observed in V_3 at harvest, 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_1 and V_2 at all the growth stages and the lowest dry matter of potato after harvest (18.29, 18.13, 18.09, 17.81, 17.42 and 16.84 %) were produced by V_5 at harvest, 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_4 at all the growth stages. Similar findings were also reported by Mirdad (2010), Shafeek *et al.*, (2001) and Swaminathan *et al*., (1999) who found that the evaluated potato cultivars in their studied, significantly, differed from one another in the context of dry matter content of potato.

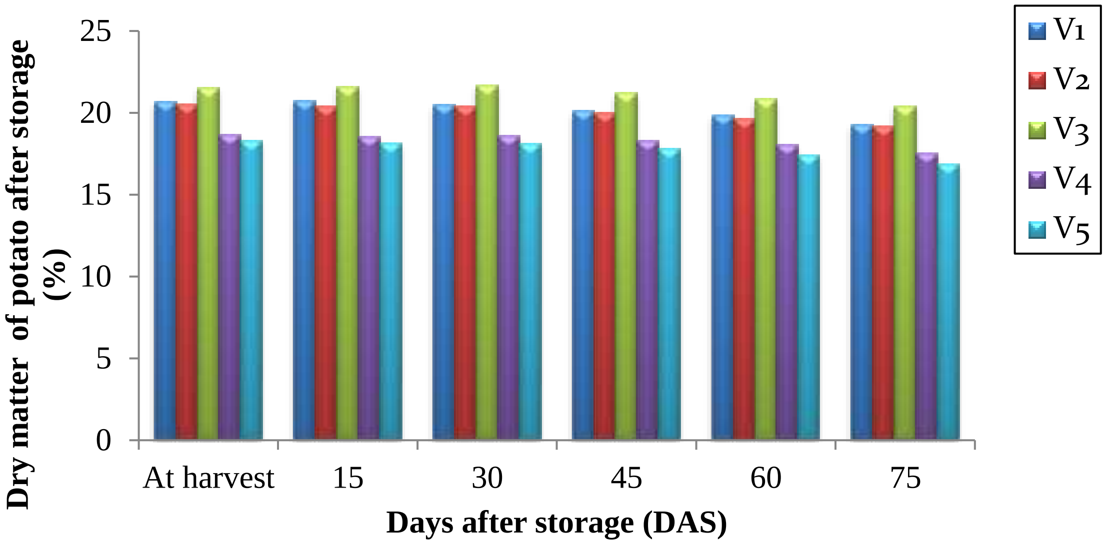


Figure 25. Effect of variety on the dry matter (%) of potato at different days after storage ($LSD_{0.05}$= 1.67, 1.45, 1.59, 1.43, 1.56 and 1.41 at harvest, 15, 10, 45, 60 and 75 DAS, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.3.1.2 Effect of organic manure

Dry matter (%) of potato after storage was significantly varied due to different organic manure (Figure 26). The figure showed that ingeneral application of organic manure gave highest and statistically similar dry matter (%) after storage and that of lowest was observed in without organic mnanure (control) applied treatment for all sampling dates. Rembialkowska (1999) indicated that the application of phosphorus combined with organic manure lead to trapping enough solar energy for higher food production which will finally be translocated to the roots for appreciable tuber development, better root dry matter and bulking which is the ultimate target of crop production. Zewide *et al.* (2018) revealed that the nutrients applied from mineral sources coupled with organic sources might have attributed to more availability of N that played a vital role in cell division, increased photosynthesis and translocated more photosynthates from source to sink. For consequence potato dry matter content was increased. Similar findings were also reported by Zewide *et al.* (2018), Boru *et al.* (2017) and Ram *et al.* (2017 who reported that dry matter content of potato increased with the application of organic manure compare to that of control treatment.

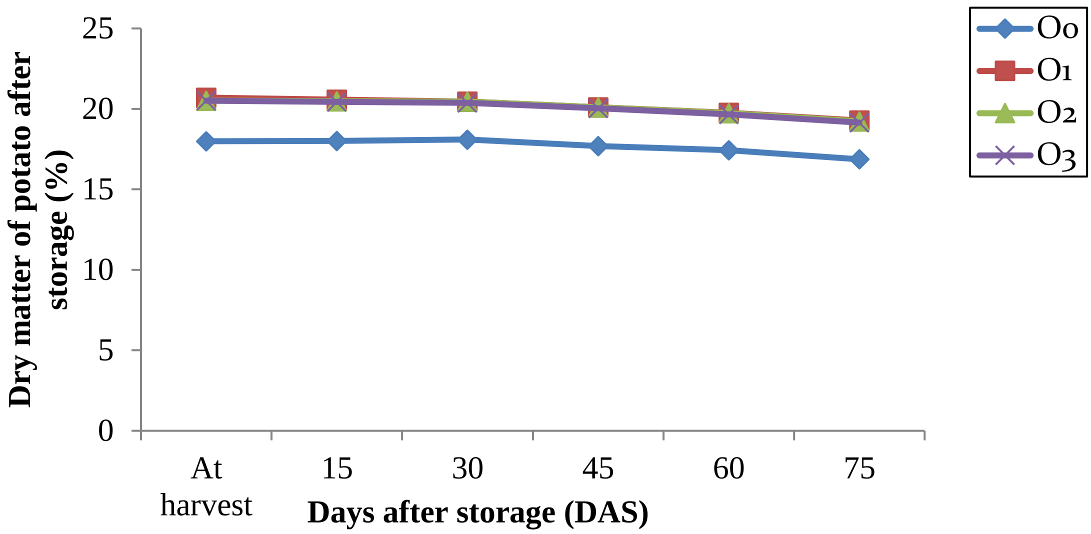


Figure 26. Effect of organic manure on the dry matter (%) of potato at different days after storage (LSD $_{0.05}$= 1.49, 1.30, 1.42, 1.28, 1.40 and 1.26 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, O_0 = Control(no manure), O_1 = Cowdung @10 t ha^{-1} , O_2 = Poultry litter @10 t ha^{-1}and O_3 = ACI organic fertilizer Cowdung @10t ha^{-1}

4.3.1.3 Interaction effect of variety and organic manure

Dry matter (%) of potato after storage was significantly varied due to interaction between variety and organic manure (Table 21). The result expressed that, the maximum dry matter of potato (22.72%) was observed in treatment combination V_3O_1 at harvest (100 days) which was statistically similar with V_1O_1, V_1O_2, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_2, V_3O_3 and V_4O_2. Again the maximum dry matter of potato after storage (23.11, 22.91, 22.46, 22.15 and 21.92 %) were observed in treatment combination V_3O_2 at 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_1O_1, V_1O_2, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_1 and V_3O_3 at 15, 30, 45, 60 and 75 DAS and the lowest dry matter of potato after storage (17.61, 17.43, 17.49, 17.07, 16.80 and 16.26 %) were observed in treatment combination V_5O_0 at harvest, 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_1O_0, V_2O_0, V_3O_0, V_4O_0, V_4O_1, V_4O_2, V_4O_3, V_5O_1, V_5O_2 and V_5O_3 at harvest , 15, 30, 45, 60 and 75 DAS. Similar findings was also reported by Mirdad (2010) who reported that the effects of the interaction between cultivars and organic manure rates tuber dry matter content was found to be significant and cultivar Diamant combined with the application of organic manure at the rate of 15m^3 ha^{-1} gave the highest dry matter content of potato compare to that of no organic manure treatment.

Table 21. Interaction effect of variety and organic manure on the dry matter (%) of potato at different days after storage

Interaction (variety × organic manure)	Dry matter (%) of potato					
	At harvest	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
V_1O_0	18.14 fg	18.81 b-e	18.57 c-h	18.23 c-e	17.93 c-f	17.34 c-h
V_1O_1	21.78 a-c	21.71 ab	21.21 a-e	20.86 a-c	20.56 a-d	20.14 a-c
V_1O_2	21.15 a-f	20.92 a-d	20.82 a-g	20.45 a-d	20.19 a-e	19.44 a-g
V_1O_3	21.56 a-e	21.46 a-c	21.39 a-d	20.90 a-c	20.63 a-d	20.13 a-d
V_2O_0	18.06 fg	17.83 e	17.96 f-h	17.57 e	17.31 ef	16.84 gh
V_2O_1	21.16 a-f	21.12 a-d	20.96 a-f	20.61 a-d	20.26 a-e	19.85 a-e
V_2O_2	21.14 a-f	20.94 a-d	20.94 a-f	20.56 a-d	20.15 a-e	19.67 a-f
V_2O_3	21.74 a-d	21.71 ab	21.74 a-c	21.21 ab	20.77 a-c	20.31 ab
V_3O_0	18.45 c-g	18.42 de	18.79 c-h	18.20 c-e	17.95 c-f	17.35 c-h
V_3O_1	22.72 a	22.56 a	22.62 a	22.19 a	21.80 a	21.32 a
V_3O_2	22.61 a	23.11 a	22.91 a	22.46 a	22.15 a	21.92 a
V_3O_3	22.32 ab	22.29 a	22.32 ab	21.90 a	21.49 ab	20.99 a
V_4O_0	17.75 g	17.55 e	17.68 gh	17.39 e	17.16 ef	16.57 h
V_4O_1	19.04 b-g	18.90 b-e	19.11 c-h	18.80 b-e	18.56 b-f	18.01 b-h
V_4O_2	19.40 a-g	19.20 b-e	19.35 b-h	18.88 b-e	18.59 b-f	18.11 b-h
V_4O_3	18.49 c-g	18.42 de	18.24 d-h	18.09 c-e	17.85 c-f	17.31 d-h
V_5O_0	17.61 g	17.43 e	17.49 h	17.07 e	16.80 f	16.26 h
V_5O_1	18.80 c-g	18.56 c-e	18.35 d-h	18.01 de	17.65 c-f	17.08 e-h
V_5O_2	18.33 e-g	18.23 de	18.29 d-h	18.09 c-e	17.69 c-f	17.01 f-h
V_5O_3	18.44 d-g	18.30 de	18.21 e-h	18.05 c-e	17.53 d-f	16.99 f-h
LSD $_{(0.05)}$	**3.34**	**2.91**	**3.18**	**2.85**	**3.12**	**2.82**
CV (%)	**10.13**	**8.85**	**9.70**	**8.86**	**9.82**	**9.16**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}

4.3.2 Specific gravity

4.3.2.1 Effect of variety

Specific gravity of potato was significantly influenced by potato varieties (Figure 27). The result revealed that V_3 (BARI Alu-29) showed its superiority by producing maximum specific gravity (1.083, 1.081, 1.083, 1.082, 1.077 and 1.075 at harvest, 15, 30, 45, 60 and 75 DAS , respectively). V_1 (BARI Alu-25) and V_2 (BARI Alu-28) also showed statistically similar specific gravity with V_3 (BARI Alu-29) . The minimum specific gravity (1.065, 1.065, 1.064, 1.063, 1.061 and 1.059) were scored by V_5 (BARI TPS-1 tuberlets) at harvest, 15, 30, 45, 60 and 75 DAS, respectively which showed similarity with V_4 (BARI Alu-7) at harvest, 15, 30, 45, 60 and 75 DAS.

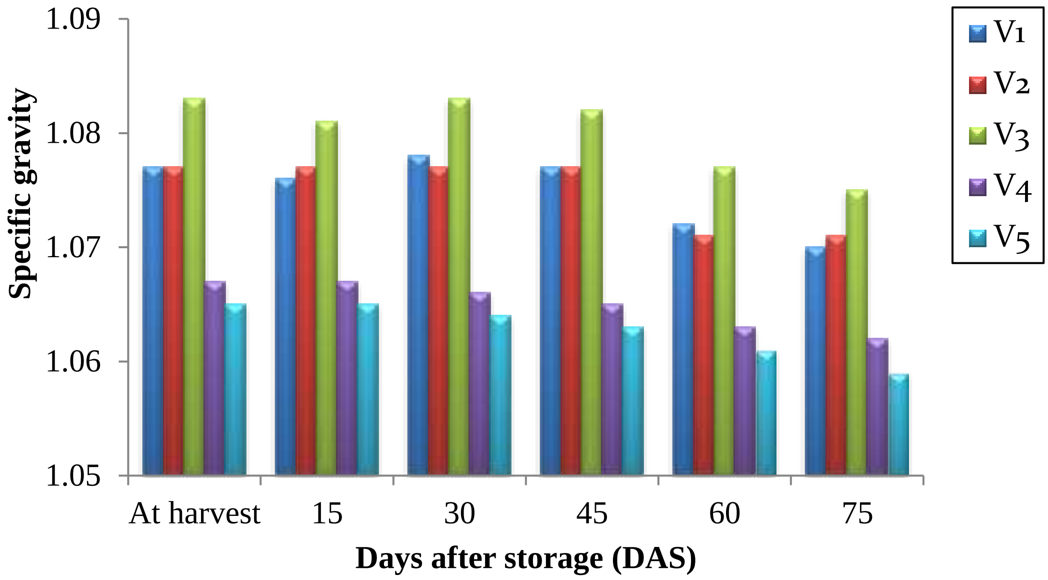


Figure 27. Effect of variety on the specific gravity of potato at different days after storage (LSD $_{0.05}$= 0.01, 0.01, 0.01, 0.01, 0.01 and 0.01 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.3.2.2 Effect of organic manure

Specific gravity of potato was significantly influenced by different organic manure (Figure 28). Result revealed that irrespective organic manure increased the specific gravity over O_0 control (no manure) for all sampling dates. The result also revealed that all the tested organic manure showed statistically similar level of specific gravity for all the sampling dates. Dry matter is directly related to specific gravity and higher the dry matter higher the specific gravity. Boru *et al*. (2017) reported that the highest specific gravity (1.12) was recorded at 15 t ha^{-1} of FYM and the lowest (0.65) recorded at control. The result indicated that, the specific gravity of potato was increased with increased rate of FYM (Isiaka, 2013). This result is in line with the findings of Ram *et al.* (2017), Ahmed *et al.* (2015) and Abou Hussein *et al.* (2003) who found that application of cattle with chicken manures increased specific gravity of potato.

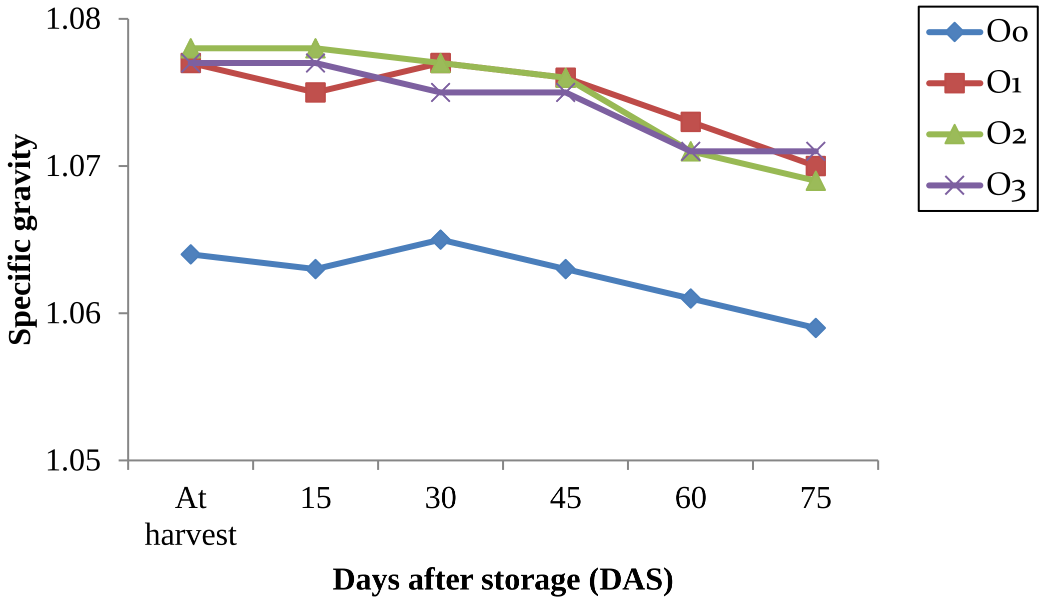


Figure 28. Effect of organic manure on the specific gravity of potato at different days after storage ($LSD_{0.05}$= 0.01, 0.01, 0.01, 0.01, 0.01 and 0.01 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}

4.3.2.3 Interaction effect of variety and organic manure

Specific gravity of potato was significantly influenced by interaction effect of variety and organic manure (Table 22). Result revealed that, the maximum specific gravity (1.090, 1.093, 1.090 and 1.090) were scored by V_3O_2 at harvest (100 days), 15, 30 and 45 DAS, respectively which showed similarity with V_1O_1, V_1O_2, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_1 and V_3O_3 at harvest, 30 and 45 DAS; with V_1O_2, V_1O_3, V_2O_1, V_2O_2, V_2O_3, V_3O_1 and V_3O_3 at 15 DAS. The maximum specific gravity (1.083 and 1.080) were scored by V_3O_1, V_3O_2 and V_3O_3 at 160 and 75 DAS, respectively which showed similarity with V_1O_1, V_1O_2, V_1O_3, V_2O_1, V_2O_2 and V_2O_3 at 60 and 75 DAS. At harvest and 15 DAS the minimum specific gravity (1.060 and 1.060, respectively) was scored by V_5O_0 which showed similarity with V_1O_0, V_2O_0, V_3O_0, V_4O_0, V_4O_1, V_4O_2, V_4O_3, V_5O_1, V_5O_2 and V_5O_3 at harvest and 15 DAS. At 30 and 45 DAS the minimum specific gravity (1.060 and 1.060, respectively) was scored by V_4O_0 and V_5O_0 which showed similarity with V_1O_0, V_2O_0, V_3O_0, V_4O_1, V_4O_2, V_4O_3, V_5O_1, V_5O_2 and V_5O_3. At 60 DAS , the minimum specific gravity (1.060) was scored by V_2O_0, V_3O_0, V_4O_3, V_5O_2, V_5O_3, V_4O_0 and V_5O_0 which showed similarity with V_1O_0, V_1O_2, V_2O_1, V_2O_2, V_4O_1, V_4O_2 and V_5O_1. At 75 DAS the minimum specific gravity (1.057) was scored by V_4O_0 and V_5O_0 which showed similarity with V_1O_0, V_1O_2, V_2O_0, V_2O_2, V_3O_0, V_4O_1, V_4O_2, V_4O_3, V_5O_1, V_5O_2 and V_5O_3.

Table 22. Interaction effect of variety and organic manure on the specific gravity of potato at different days after storage

Interaction (variety × organic manure)	Specific gravity of potato					
	At harvest	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
V_1O_0	1.063 d	1.067 d-f	1.070 b-d	1.070 b-e	1.063 bc	1.060 cd
V_1O_1	1.083 ab	1.077 b-e	1.080 a-c	1.080 a-c	1.077 ab	1.073 a-c
V_1O_2	1.080 a-c	1.080 a-d	1.080 a-c	1.077 a-d	1.073 a-c	1.070 a-d
V_1O_3	1.083 ab	1.080 a-d	1.080 a-c	1.080 a-c	1.077 ab	1.077 ab
V_2O_0	1.063 d	1.063 ef	1.063 d	1.063 de	1.060 c	1.063 b-d
V_2O_1	1.080 a-c	1.080 a-d	1.080 a-c	1.080 a-c	1.073 a-c	1.073 a-c
V_2O_2	1.083 ab	1.080 a-d	1.080 a-c	1.080 a-c	1.073 a-c	1.070 a-d
V_2O_3	1.083 ab	1.083 a-c	1.083 ab	1.083 ab	1.077 ab	1.077 ab
V_3O_0	1.070 b-d	1.063 ef	1.070 b-d	1.063 de	1.060 c	1.060 cd
V_3O_1	1.087 a	1.080 a-d	1.087 a	1.087 a	1.083 a	1.080 a
V_3O_2	1.090 a	1.093 a	1.090 a	1.090 a	1.083 a	1.080 a
V_3O_3	1.087 a	1.087 ab	1.087 a	1.087 a	1.083 a	1.080 a
V_4O_0	1.063 d	1.063 ef	1.060 d	1.060 e	1.060 c	1.057 d
V_4O_1	1.070 b-d	1.070 c-f	1.070 b-d	1.067 c-e	1.067 bc	1.063 b-d
V_4O_2	1.070 b-d	1.070 c-f	1.070 b-d	1.070 b-e	1.067 bc	1.067 a-d
V_4O_3	1.067 cd	1.067 d-f	1.063 d	1.063 de	1.060 c	1.060 cd
V_5O_0	1.060 d	1.060 f	1.060 d	1.060 e	1.060 c	1.057 d
V_5O_1	1.067 cd	1.067 d-f	1.067 cd	1.067 c-e	1.063 bc	1.060 cd
V_5O_2	1.067 cd	1.067 d-f	1.067 cd	1.063 de	1.060 c	1.060 cd
V_5O_3	1.067 cd	1.067 d-f	1.063 d	1.060 e	1.060 c	1.060 cd
LSD $_{(0.05)}$	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**
CV (%)	**0.44**	**0.64**	**0.34**	**0.37**	**0.46**	**0.43**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
O_0 = Control (no manure), O_1 = Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and O_3 = ACI organic fertilizer @ 10 t ha^{-1}
DAS = Days after storage

It is observered from the experiment no.2 that considering the five tested varieties BARI Alu-7 (V_4), BARI Alu-25 (V_1) showed the higher yield along with higher yield attributes like tuber weight, marketable yield. For quality parameter, BARI Alu-29 (V_3), BARI Alu-25 (V_1) and BARI Alu-28 (V_2) performed best which gave higher tuber dry matter (%) and specific gravity after storage in different days. Among the four organic manure treatments, cowdung (O_1) and ACI organic fertilizer (O_3) produced maximum tuber weight, tuber yield and marketable yield. Considering tuber quality, cowdung (O_1), poultry litter (O_2) and ACI organic fertilizer (O_3) gave similar performance in respect to dry matter (%) and specific gravity irrespective of storage period.

Experiment No. 3 : Effect of harvesting time on growth yield and quality of potato varieties

This experiment was conducted to study the effect of harvesting time on growth, yield and quality of potato. Data on different growth, yield and quality of potato were recorded. The results have been presented and discussed and possible interpretations have been given under the following headings.

4.1 Potato growth parameters

4.1.1 Plant height

4.1.1.1 Effect of variety

Plant height of potato varied significantly at different growth stages due to different varieties (Figure 29). The results of the study expressed irrespective of varieties plant height increased gradually with the advantages of growth stages and the highest increase was found at 70 DAP. At 25 DAP the tallest plant (17.85 cm) was recorded from V_3 (BARI Alu-29) which was statistically similar with V_1 (BARI Alu-25) and V_4 (BARI Alu-7) and the shortest plant (14.75 cm) was recorded from V_5 (BARI TPS-1tuberlets) which was statistically differed from other tested potato varieties. Again the tallest plant (30.81, 55.83 and 66.09 cm at 40, 55 and 70 DAP, respectively) were recorded from V_1 (BARI Alu-25) which was statistically similar with V_2, V_3 and V_4 at 40 DAP and with V_3 at 55 DAP. At 25, 40 and 55 DAP the shortest plant (14.75, 22.01 and 44.00 cm, respectively) were recorded from V_5 (BARI TPS-1 tuberlets). At 70 the shortest plant (59.33 cm) was recorded from V_2 (BARI Alu-28) which was statistically similar with V_3, V_4 and V_5 at 70 DAP. Plant height varied among the varieties was also observed by Mirdad (2010), Swaminathan *et al.* (1999), Marwaha (1998) and El-Nashar *et al.* (1995). Since, they showed that potato cultivars differed significantly from each other in plant height of potato plants.

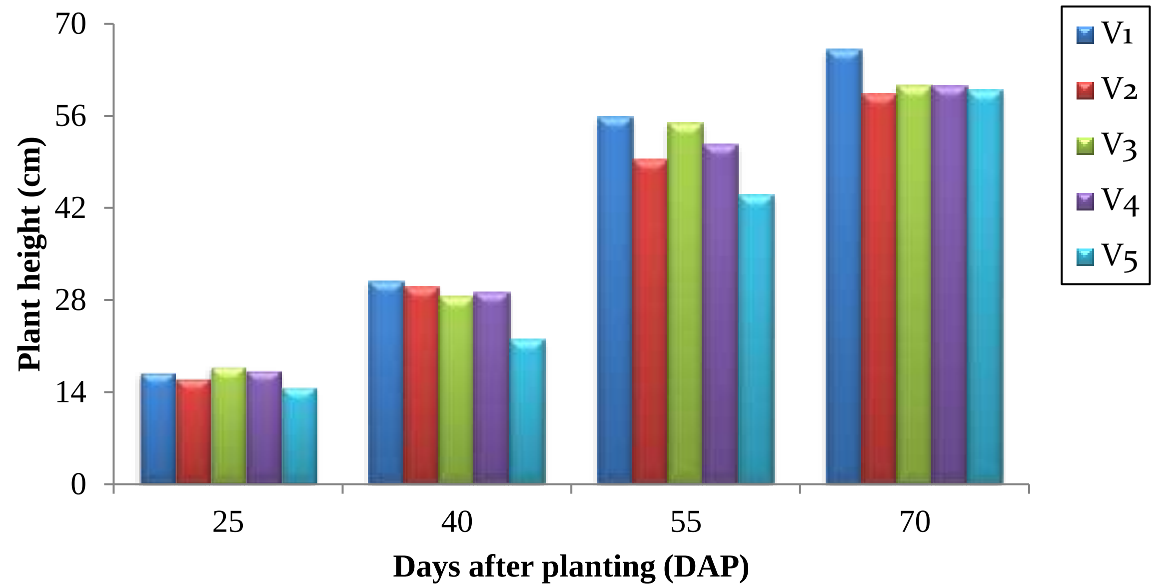


Figure 29. Effect of variety on the plant height of potato at different days after planting (LSD $_{0.05}$= 1.27, 2.60, 3.32 and 4.88 at 25, 40, 55 and 70 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.1.2 Effect of harvesting time

Harvesting time had significant influence on plant height for all growth stages of potato except 40 DAP (Figure 30). The figure indicated that plant height showed an gradual increasing trend with the advances of growth stages irrespective of harvesting times. It is also observed that rate of increase was much sharp from 40 to 55 DAP than other stages. However at 25, 55 and 70 DAP the tallest plant (17.80, 53.62 and 63.75 cm, respectively) was found from harvesting time H_4 (110 DAP) which was statistically similar with H_3 (100 DAP) at 25 DAP and with H_2 (90 DAP) and H_3 (100 DAP) at 55 and 70 DAP. On the other hand, at 25, 55 and 70 DAP the shortest plant (15.19, 46.64 and 56.48 cm, respectively) was found from H_1 (80 DAP) which was statistically differed from other treatments.

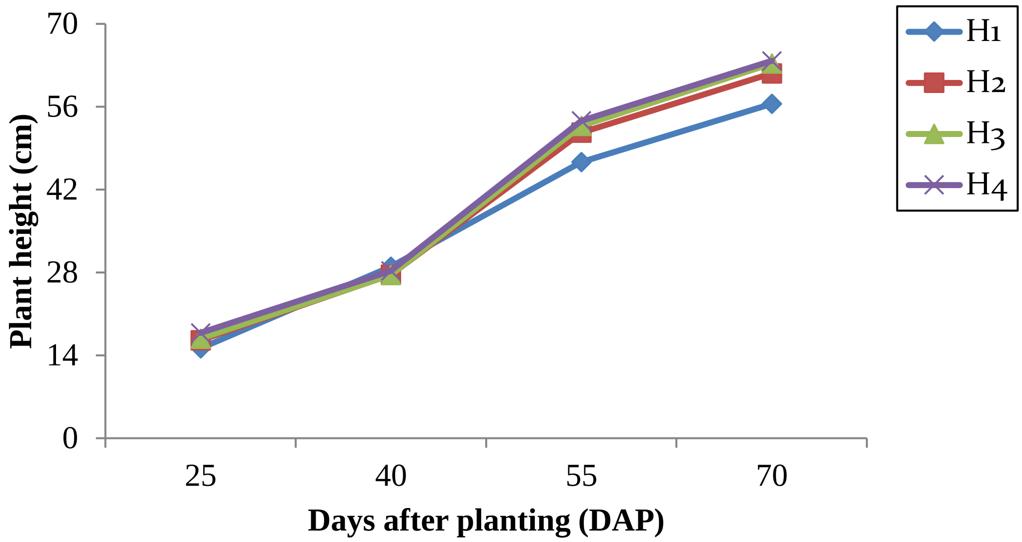


Figure 30. Effect of harvesting time on the plant height of potato at different days after planting (LSD $_{0.05}$= 1.14, NS, 2.97 and 4.36 at 25, 40, 55 and 70 DAP, respectively)

Here, H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.1.1.3 Interaction effect of variety and harvesting time

Interaction of variety and harvesting time had significant influence in respect of plant height of potato (Table 23). However, the tallest plant (18.92 cm) was recorded from the treatment combination V_3H_4 at 25 DAP which was statistically similar with rest of the treatment combinations except V_2H_1, V_2H_2, V_1H_1, V_5H_1, V_5H_2, V_5H_3 and V_5H_4 and the shortest plant (13.53 cm) was recorded from treatment combination V_2H_1 which was statistically similar with V_1H_1, V_2H_2, V_5H_1, V_5H_2, V_5H_3 and V_5H_4. At 40 DAP the tallest plant (32.58 cm) was recorded from treatment combination V_1H_3 which was statistically similar with rest of the treatment combinations except V_5H_4, V_5H_3, V_5H_2, V_5H_1, V_3H_3 and V_3H_2 and the shortest plant (20.46 cm) was recorded from treatment combination V_5H_4 which was statistically similar withV_5H_3, V_5H_2, V_5H_1 and V_3H_2. At 55 DAP the tallest plant (59.66 cm) was recorded from treatment combination V_1H_3 which was statistically similar with V_1H_4, V_1H_2, V_3H_4, V_3H_3, V_3H_2, V_4H_3 and V_4H_4 and the shortest plant (41.89 cm) was recorded from treatment combination V_5H_1 which was statistically similar with V_5H_2, V_5H_3, V_5H_4, V_4H_1 and V_1H_1. Finally at 70 DAP the tallest plant (71.07 cm) was recorded from treatment combination V_1H_4 which was statistically similar with V_1H_3, V_1H_2, V_2H_2, V_3H_3, V_3H_4, V_4H_2, V_4H_3, V_4H_4, V_5H_3 and V_5H_4 and the shortest one

(53.67 cm) was recorded from treatment combination V_4H_1 which was statistically similar with rest of the treatment combinations except V_1H_2, V_1H_3, V_1H_4 and V_4H_3.

Table 23. Interaction effect of variety and harvesting time on the plant height of potato at different days after planting

Interaction (variety × harvesting time)	Plant height of potato (cm)			
	25 DAP	**40 DAP**	**55 DAP**	**70 DAP**
V_1H_1	14.45 fg	28.12 a-d	45.78 e-h	58.73 b-e
V_1H_2	17.34 a-d	31.15 ab	58.78 a	66.33 a-c
V_1H_3	17.47 a-d	32.58 a	59.66 a	68.22 ab
V_1H_4	18.76 a	31.40 ab	59.11 a	71.07 a
V_2H_1	13.53 g	30.46 ab	48.78 d-g	56.00 de
V_2H_2	15.77 b-g	30.80 ab	49.66 c-g	61.33 a-e
V_2H_3	16.64 a-f	28.57 a-d	48.67 d-g	59.33 b-e
V_2H_4	18.38 a	30.04 ab	50.44 c-f	60.67 b-e
V_3H_1	17.26 a-d	32.27 a	50.78 c-f	58.36 c-e
V_3H_2	17.70 a-c	24.59 c-f	54.33 a-d	58.89 b-e
V_3H_3	17.53 a-c	26.49 b-e	55.89 a-c	61.80 a-e
V_3H_4	18.92 a	30.92 ab	58.56 ab	63.33 a-e
V_4H_1	16.60 a-f	30.10 ab	46.00 e-h	53.67 e
V_4H_2	17.00 a-e	29.42 a-c	52.11 b-e	61.74 a-e
V_4H_3	17.23 a-e	28.59 a-d	54.34 a-d	65.00 a-d
V_4H_4	18.23 ab	28.58 a-d	54.33 a-d	61.67 a-e
V_5H_1	14.12 fg	23.93 d-f	41.89 h	55.67 de
V_5H_2	14.92 d-g	22.11 ef	43.22 gh	59.84 b-e
V_5H_3	15.26 c-g	21.53 ef	45.22 f-h	62.11 a-e
V_5H_4	14.70 e-g	20.46 f	45.67 e-h	62.00 a-e
$LSD_{(0.05)}$	**2.55**	**5.19**	**6.65**	**9.75**
CV (%)	**9.28**	**11.18**	**7.86**	**9.62**

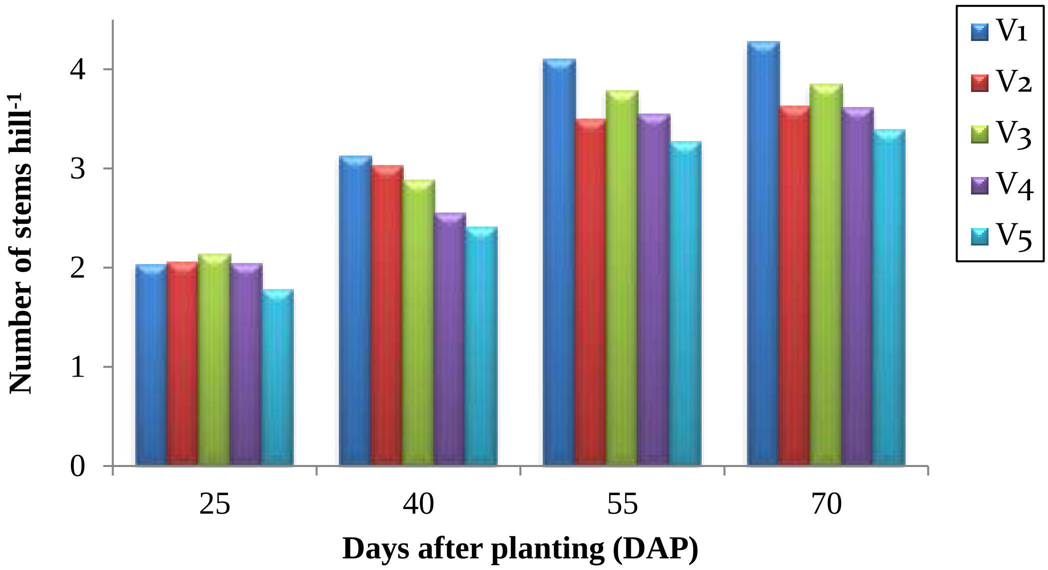
Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP) and H_4 = harvesting at (110 DAP)

4.1.2 Number of stems hill^{-1}

4.1.2.1 Effect of variety

Statistically significant variation was found on number of stem hill^{-1} at different growth stages among potato varieties (Figure 31). Stems hill^{-1} increased steadily with the increment of growth stages irrespective of varieties and the highest stems hill^{-1} was found with 70 DAP. At 25 DAP the maximum number of stems hill^{-1} (2.13) was obtained by V_3 which was statistically similar with all the tested potato varieties except V_5. Again the maximum number of stems hill^{-1} (3.12, 4.10 and 4.27) were obtained by V_1 at 40, 55 and

70 DAP, respectively which was statistically similar with V_2 only at 40 DAP. Whereas the minimum number of stem hill^{-1} (1.77, 2.40, 3.27 and 3.39) were obtained by V_5 at 25, 40, 55, 70 and 85 DAP, respectively which was statistically similar with V_4 at 40 DAP; with V_2 and V_4 at 55 and 70 DAP.



Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

Figure 31. Effect of variety on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.15, 0.24, 0.29 and 0.28 at 25, 40, 55 and 70 DAP, respectively)

4.1.2.2 Effect of harvesting time

Statistically significant variation was found on number of stems hill^{-1} at different growth stages due to different harvesting times (Figure 32). The figure shows that number of stems hill^{-1} increased steadily from 25 DAP to 70 DAP and the rate of increase was higher up to 55 DAP, then after the rate of increase reduced slightly. At 25 and 70 DAP the highest number of stems hill^{-1} (2.21 and 3.90, respectively) were obtained by H_3 which was statistically similar with H_2 and H_4 at 70 DAP. Again at 40 and 55 DAP the highest number of stems hill^{-1} (2.92 and 3.78, respectively) were obtained by H_4 which was statistically similar with H_2 and H_3 at 40 and 55 DAP. While at 25, 40, 55 and 70 DAP the lowest number of stems hill^{-1} (1.88, 2.62, 3.26 and 3.34, respectively) were obtained by H_1 treatment which was statistically similar with H_2 at 25 and 40 DAP.

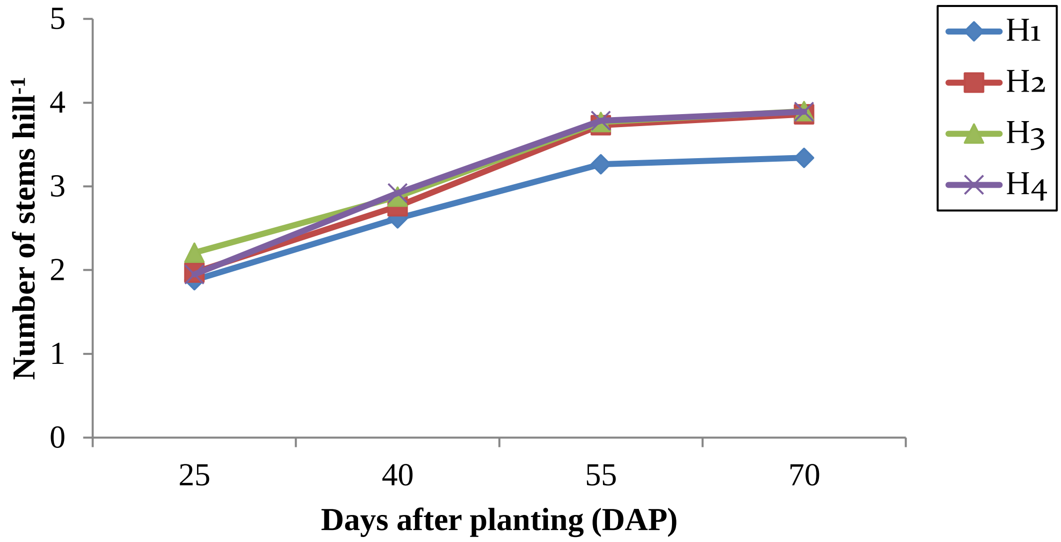


Figure 32. Effect of harvesting time on the number of stems hill^{-1} of potato at different days after planting (LSD $_{0.05}$= 0.13, 0.22, 0.26 and 0.25 at 25, 40, 55 and 70 DAP, respectively)

Here, H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP) and H_4 = harvesting at (110 DAP)

4.1.2.3 Interaction effect of variety and harvesting time

Statistically significant variation was found on number of stem hill^{-1} at different growth stages due to interaction of different varieties and harvesting times (Table 24). At 25 DAP the highest number of stems hill^{-1} (2.38) was obtained by treatment combination V_4H_3 which was statistically similar with V_1H_3, V_1H_2, V_2H_2, V_2H_3, V_3H_2, V_3H_4 and V_3H_3. At 40 DAP the highest number of stems hill^{-1} (3.39) was obtained by treatment combination V_1H_4 which was statistically similar with V_1H_3, V_1H_2, V_2H_3, V_2H_2, V_2H_1, V_3H_4 and V_3H_3. At 55 and 70 DAP, the highest number of stems hill^{-1} (4.36 and 4.56, respectively) was obtained by treatment combination V_1H_3 which was statistically similar with V_1H_4, V_1H_2, V_3H_2, V_3H_4 and V_4H_3 at 55 DAP; with V_1H_2, V_1H_3, V_3H_2 and V_3H_4 at 70 DAP. At 25, 40, 55 and 70 DAP the lowest number of stems hill^{-1} (1.62, 2.16, 3.11, 3.17, respectively) was obtained by treatment combination V_5H_1 which was statistically similar with V_5H_3, V_5H_4, V_4H_2, V_2H_4, V_3H_1, V_1H_4 and V_1H_1 at 25 DAP; with V_5H_2, V_5H_4, V_5H_3, V_4H_4, V_4H_2, V_4H_1 and V_3H_1 at 40 DAP; with V_5H_2, V_5H_4, V_5H_3, V_4H_4, V_4H_2, V_4H_1, V_3H_1, V_2H_4, V_2H_2 and V_2H_1 at 55 DAP and with V_5H_2, V_5H_4, V_5H_3, V_4H_4, V_4H_1, V_3H_1, V_2H_2 and V_2H_1 at 70 DAP.

Table 24. Interaction effect of variety and harvesting time on the number of stems hill^{-1} of potato at different days after planting

Interaction (variety × harvesting time)	Number of stems hill^{-1} of potato at different days after planting			
	25 DAP	40 DAP	55 DAP	70 DAP
V_1H_1	1.897 c-g	2.657 c-e	3.723 b-f	3.853 b-d
V_1H_2	2.097 a-d	3.057 a-c	4.093 a-d	4.370 ab
V_1H_3	2.207 ab	3.373 a	4.357 a	4.557 a
V_1H_4	1.893 c-g	3.393 a	4.213 ab	4.310 ab
V_2H_1	1.943 b-f	2.940 a-d	3.117 g	3.20 fg
V_2H_2	2.203 ab	3.177 ab	3.543 d-g	3.627 c-g
V_2H_3	2.180 a-c	3.183 ab	3.743 b-f	3.823 b-e
V_2H_4	1.890 c-g	2.800 b-e	3.580 d-g	3.840 b-e
V_3H_1	1.900 c-g	2.377 ef	3.187 fg	3.270 fg
V_3H_2	2.180 a-c	2.757 b-e	4.013 a-d	4.100 a-c
V_3H_3	2.303 a	2.993 a-c	3.757 b-f	3.917 b-d
V_3H_4	2.143 a-c	3.373 a	4.157 a-c	4.100 a-c
V_4H_1	1.987 b-e	2.493 d-f	3.137 g	3.210 fg
V_4H_2	1.763 e-g	2.387 ef	3.640 c-g	3.740 c-f
V_4H_3	2.383 a	2.673 c-e	3.857 a-e	3.897 b-d
V_4H_4	1.997 b-e	2.620 c-f	3.537 d-g	3.590 c-g
V_5H_1	1.677 fg	2.627 c-f	3.147 g	3.170 g
V_5H_2	1.620 g	2.427 ef	3.357 e-g	3.470 d-g
V_5H_3	1.967 b-f	2.157 f	3.133 g	3.293 e-g
V_5H_4	1.820 d-g	2.407 ef	3.433 e-g	3.613 c-g
LSD $_{(0.05)}$	**0.29**	**0.49**	**0.57**	**0.55**
CV (%)	**8.80**	**10.59**	**9.48**	**8.87**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP),
H_3 = harvesting at (100 DAP) and H_4 = harvesting at (110 DAP)

4.1.3 SPAD value in leaf

4.1.3.1 Effect of variety

Potato variety showed significant variation on SPAD value in leaf at all growth stages (Figure 33). The figure shows that SPAD value of leaf increase gradually with the advancement of growth stages irrespective of varieties, but the rate of increase was marginal. However, the maximum SPAD value in leaf (43.08) was obtained from V_3 at 25 DAP and minimum one (37.50) was obtained from V_1 which was statistically at par with all the tested variety except V_3. The maximum SPAD value in leaf (47.01) was obtained from V_1 at 40 DAP which was statistically at par with V_2 and V_3. Again the maximum

SPAD value in leaf (49.68 and 54.75) was obtained from V_3 at 55 and 70 DAP which was statistically at par with V_1, V_2, and V_4 at both 55 and 70 DAP. The minimum SPAD value in leaf (42.16, 46.00 and 51.00) were found in V_5 at 40, 55 and 70 DAP, respectively which was statistically at par with V_4 at 40, 55 and 70 DAP.

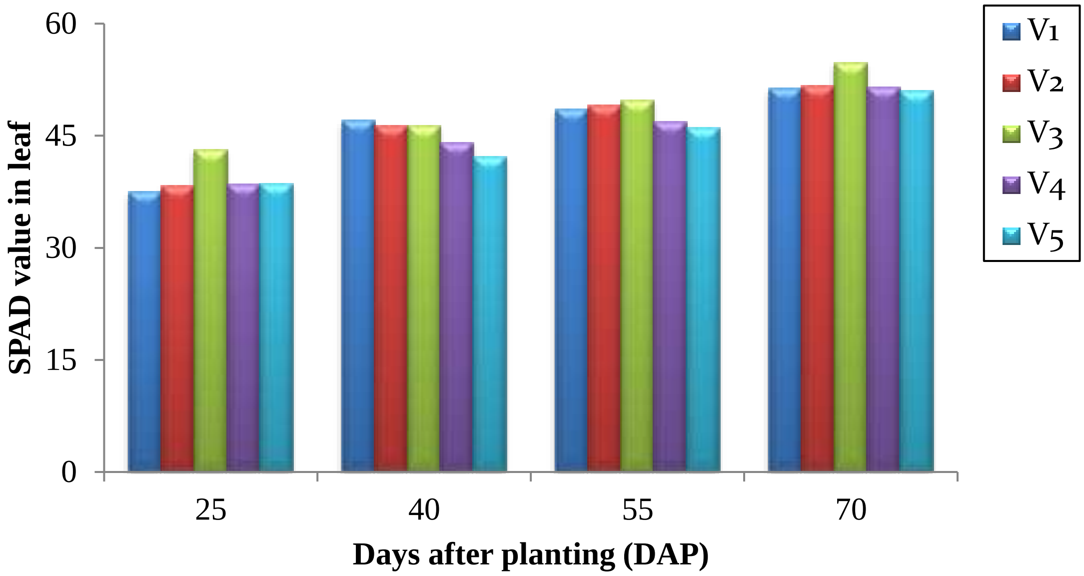


Figure 33. Effect of variety on the SPAD value in leaf of potato at different days after planting (LSD $_{0.05}$= 2.26, 2.73, 3.37 and 3.69 at 25, 40, 55 and 70 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.3.2 Effect of harvesting time

Harvesting time showed significant variation on SPAD value in leaf of potato at all growth stages (Figure 34). The figure indicated that the SPAD value leaf showed a steady increase in trend with the advancement of growth stages irrespective of harvesting time. H_1 harvesting time showed the lowest values of SPAD value than other times for all sampling dates. Harvesting time of H_2, H_3 and H_4 showed the higher level of SPAD than H_1 for all sampling dates.

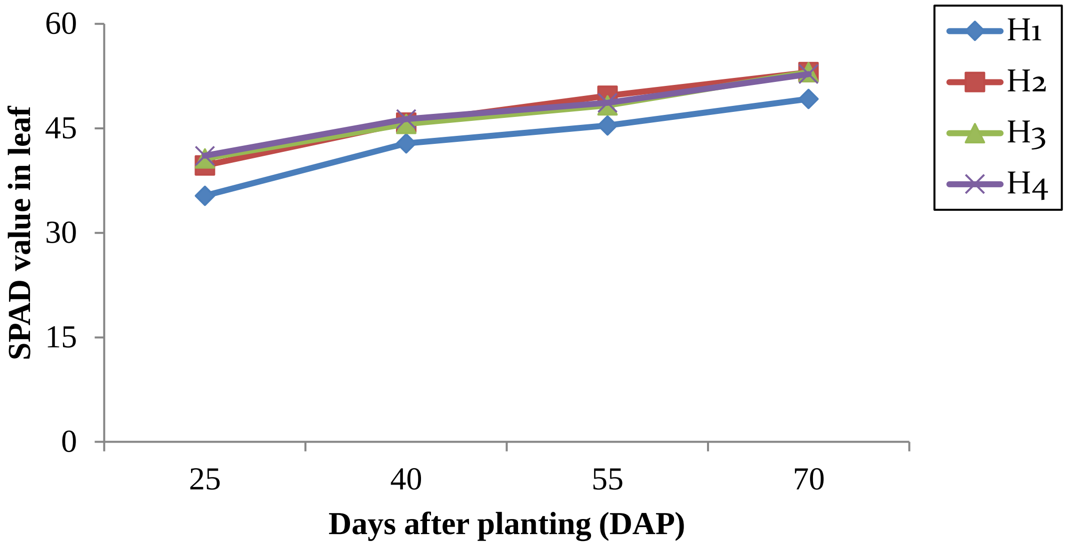


Figure 34. Effect of harvesting time on the SPAD value in leaf of potato at different days after planting (LSD $_{0.05}$= 2.02, 2.44, 3.01 and 3.30 at 25, 40, 55 and 70 DAP, respectively)

Here, H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP) and H_4 = harvesting at (110 DAP)

4.1.3.3 Interaction effect of variety and harvesting time

Interaction of variety and harvesting time showed significant variation on SPAD value in leaf of potato at all growth stages (Table 25). At 25 DAP the maximum SPAD value in leaf (45.33) was found in V_3H_4 which was statistically at par with V_3H_3, V_3H_2 and V_2H_3 and the minimum SPAD value in leaf (33.67) was found in V_2H_1 which was statistically at par with V_4H_1, V_5H_1, V_5H_2, V_1H_1 and V_1H_3. At 40 DAP the maximum SPAD value in leaf (50.00) was found in V_1H_4 which was statistically at par with V_1H_2, V_1H_3, V_2H_1, V_2H_2, V_2H_3, V_2H_4, V_3H_2, V_3H_3, V_3H_4 and V_4H_3 and the minimum SPAD value in leaf (40.00) was found in V_5H_1 which was statistically at par with V_1H_1, V_3H_1, V_2H_4, V_4H_1, V_4H_2, V_4H_3, V_4H_4, V_5H_2, V_5H_3 and V_5H_4. At 55 DAP, the maximum SPAD value in leaf (51.33) was found in V_3H_2 and V_3H_4 which were statistically at par with rest of the treatment combinations except V_5H_1 and the minimum SPAD value in leaf (43.00) was found in V_5H_1 which was statistically at par with rest of the treatment combinations except V_3H_4, V_3H_3, V_3H_2, V_2H_3 and V_1H_2. At 70 DAP, the maximum SPAD value in leaf (57.00) was found in V_3H_4 which was statistically at par with rest of the treatment combinations except V_1H_1, V_2H_1, V_4H_1 and V_5H_1 and the minimum SPAD value in leaf (48.13) was found in V_1H_1 which was statistically at par with rest of the treatment combinations except V_3H_4 and V_3H_3.

Table 25. Interaction effect of variety and harvesting time on SPAD value in leaf of potato at different days after planting

Interaction (variety × harvesting time)	SPAD value of potato at different days after planting			
	25 DAP	40 DAP	55 DAP	70 DAP
V_1H_1	35.00 f-h	41.64 ef	45.34 ab	48.13 c
V_1H_2	38.33 d-g	48.67 ab	50.67 a	53.33 a-c
V_1H_3	37.00 d-h	47.71 a-c	48.67 ab	52.67 a-c
V_1H_4	39.67 c-e	50.00 a	49.33 ab	51.00 a-c
V_2H_1	33.67 h	47.67 a-c	47.67 ab	49.00 c
V_2H_2	39.33 d-f	46.33 a-e	49.67 ab	52.33 a-c
V_2H_3	41.00 a-d	46.13 a-e	50.22 a	54.00 a-c
V_2H_4	39.00 d-f	45.00 a-f	48.67 ab	51.33 a-c
V_3H_1	38.33 d-g	41.82 d-f	46.06 ab	50.67 a-c
V_3H_2	44.00 a-c	47.67 a-c	51.33 a	54.67 a-c
V_3H_3	44.67 ab	47.21 a-d	50.00 a	56.67 ab
V_3H_4	45.33 a	48.50 ab	51.33 a	57.00 a
V_4H_1	34.33 gh	43.00 c-f	45.00 ab	49.33 bc
V_4H_2	38.67 d-g	43.67 b-f	49.00 ab	52.11 a-c
V_4H_3	40.33 b-d	45.02 a-f	46.00 ab	51.00 a-c
V_4H_4	40.67 b-d	44.37 b-f	47.33 ab	53.33 a-c
V_5H_1	35.33 e-h	40.00 f	43.00 b	49.00 c
V_5H_2	38.00 d-h	42.84 c-f	47.67 ab	52.79 a-c
V_5H_3	40.33 b-d	42.13 d-f	46.67 ab	51.00 a-c
V_5H_4	40.67 b-d	43.67 b-f	46.67 ab	51.21 a-c
LSD (0.05)	**4.51**	**5.46**	**6.74**	**7.37**
CV (%)	**6.96**	**7.32**	**8.49**	**8.57**

Here, V_1 = Asterix (BARI Alu-25), V_2 = Lady rosetta (BARI Alu-28), V_3 = Courage (BARI Alu-29), V_4 = Diamant (BARI Alu-7) and V_5 = BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP)
H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.1.4 Leaf area (cm^2)

4.1.4.1 Effect of variety

Leaf area of potato was increased gradually with increasing of growth stages and the highest increase was found at 70 DAP irrespective of varieties (Figure 35). Result of the investigation revealed that, the maximum leaf area (7.65, 14.53 and 16.13 cm^2) was attained by V_3 at 25, 55 and 70 DAP, respectively which was statistically similar with V_1 and V_2 at 25 and 55 DAP; with V_1 at 70 DAP. At 40 DAP the maximum leaf area (12.86 cm^2) was attained by V_1 which was statistically similar with V_2, V_3 and V_4. The minimum leaf area (6.77, 11.67 and 13.96 cm^2) was attained by V_5 at 25, 40 and 70 DAP, respectively which was statistically similar with V_4 at 25, 40 DAP and with V_4 and V_2 at

70 DAP. The minimum leaf area (13.33 cm^2) was attained by V_4 at 55 DAP which was statistically similar with V_1, V_2 and V_5.

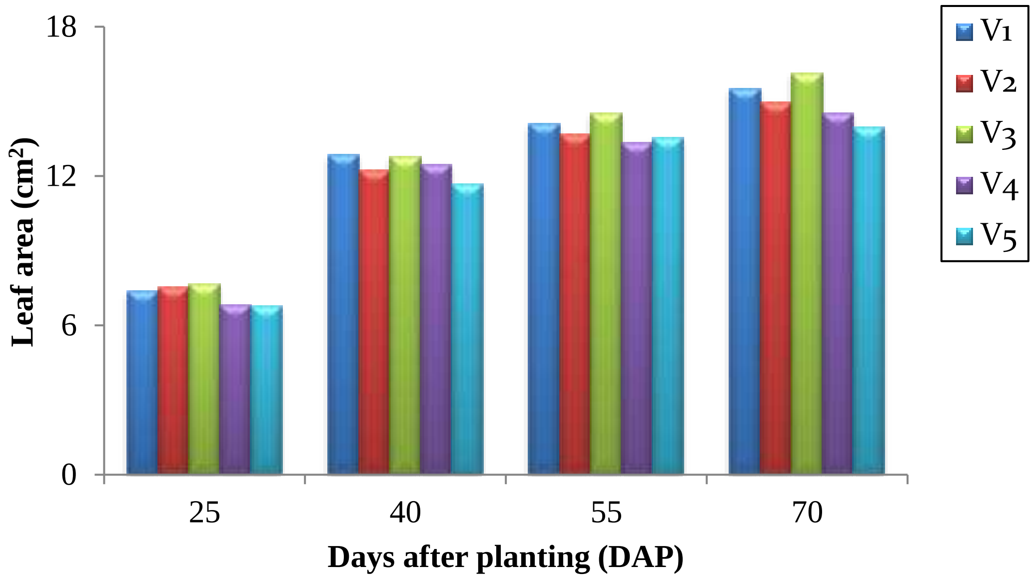


Figure 35. Effect of variety on the leaf area (cm^2) of potato at different days after planting (LSD $_{0.05}$= 0.50, 1.03, 1.03 and 1.16 at 25, 40, 55 and 70 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.4.2 Effect of harvesting time

Leaf area of potato did not significantly differ due to varietal difference at all growth stages except 25 DAP (Figure 36). Result revealed that, the maximum leaf area (7.72 cm^2) was attained by H_4 at 25 DAP which was statistically similar with H_3 and the minimum leaf area (6.66 cm^2) was attained by H_1 treatment which was distinctly statistically differed from other treatments.

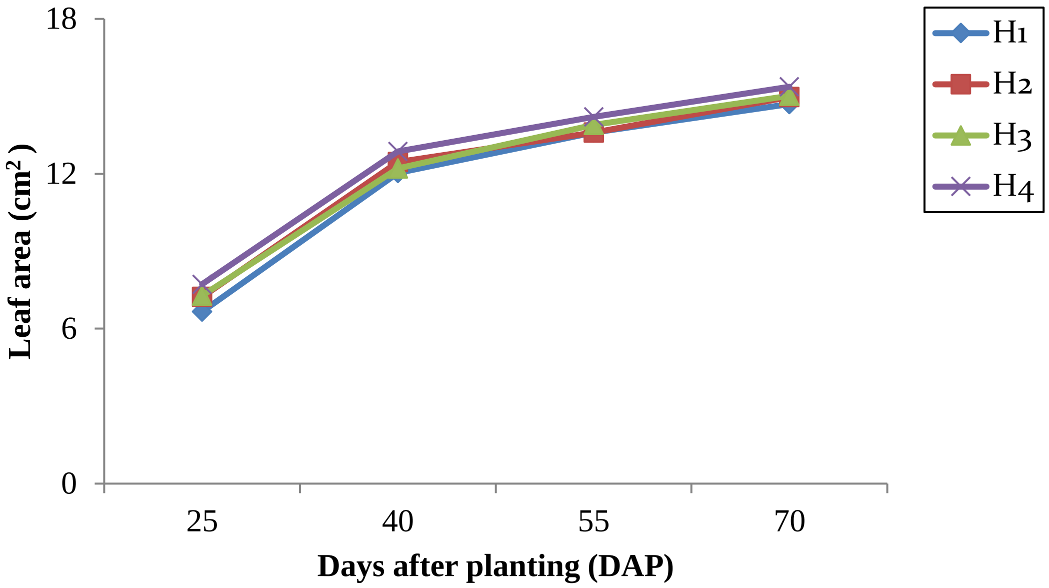


Figure 36. Effect of harvesting time on the leaf area (cm^2) of potato at different days after planting (LSD $_{0.05}$= 0.45, NS, NS and NS at 25, 40, 55 and 70 DAP, respectively)

Here, H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP) and H_4 = harvesting at (110 DAP)

4.1.4.3 Interaction effect of variety and harvesting time

Leaf area of potato significantly differed due to interaction between different varieties and harvesting time at all growth stages (Table 26). Result revealed that, the maximum leaf area (8.31 cm^2) was attained by treatment combination V_3H_4 at 25 DAP which was statistically similar with V_1H_4, V_2H_4, V_2H_3, V_2H_2, V_1H_3, V_3H_3 and V_3H_2 and the minimum one (6.10 cm^2) was from V_4H_1 which was statistically similar with rest of the treatment combinations except V_1H_3, V_1H_4, V_2H_2, V_2H_3, V_2H_4, V_3H_2, V_3H_3, V_3H_4 and V_4H_2. The maximum leaf area (14.53, 15.77 and 16.76) were attained by treatment combination V_1H_4 at 40, 55 and 70 DAP which was statistically similar withV_1H_2, V_2H_4, V_3H_2, V_3H_3, V_3H_4, V_4H_1, V_4H_3, V_4H_4 and V_5H_2 at 40 DAP; with V_1H_1, V_2H_3, V_2H_4, V_3H_1, V_3H_2, V_3H_3, V_3H_4, V_4H_3, V_4H_4 and V_5H_3 at 55 DAP and finally with V_1H_1, V_2H_3, V_2H_4, V_3H_1, V_3H_2, V_3H_3, V_3H_4, V_4H_3, V_4H_4, V_1H_2, V_1H_3 and V_2H_2 at 70 DAP. At 40 DAP the minimum leaf area (11.12 cm^2) was attained by treatment combination V_5H_3 which was statistically similar with rest of the treatment combinations except V_1H_4. At 55 DAP the minimum leaf area (12.62 cm^2) was attained by treatment combination V_4H_2 which was statistically similar with rest of the treatment combinations except V_1H_4 and V_3H_2. Finally at 70 DAP the minimum leaf area (13.49 cm^2) was attained by treatment combination V_5H_4 which was statistically similar with rest of the treatment combinations except V_1H_4, V_3H_2, V_3H_3 and V_3H_4.

Table 26. Interaction effect of variety and harvesting time on the leaf area of potato at different days after planting

Interaction (variety × harvesting time)	Leaf area (cm^2) of potato at different days after planting			
	25 DAP	40 DAP	55 DAP	70 DAP
V_1H_1	6.707 c-f	12.21 b	13.77 a-c	15.34 a-e
V_1H_2	7.017 c-f	12.72 ab	13.45 bc	14.75 a-e
V_1H_3	7.450 a-d	12.00 b	13.37 bc	15.17 a-e
V_1H_4	8.283 a	14.53 a	15.77 a	16.76 a
V_2H_1	6.867 c-f	11.58 b	13.28 bc	14.39 b-e
V_2H_2	7.470 a-d	12.34 b	13.34 bc	15.13 a-e
V_2H_3	7.657 a-c	12.31 b	13.97 a-c	15.10 a-e
V_2H_4	8.127 ab	12.68 ab	14.05 a-c	15.23 a-e
V_3H_1	6.530 d-f	12.20 b	14.53 a-c	15.78 a-e
V_3H_2	7.643 a-c	12.95 ab	15.30 ab	16.46 ab
V_3H_3	8.130 ab	12.88 ab	14.13 a-c	15.96 a-d
V_3H_4	8.307 a	13.01 ab	14.17 a-c	16.33 a-c
V_4H_1	6.100 f	12.48 ab	12.86 c	13.91 de
V_4H_2	7.200 b-e	11.69 b	12.62 c	14.41 b-e
V_4H_3	6.790 c-f	12.74 ab	13.99 a-c	14.71 a-e
V_4H_4	7.100 c-f	12.84 ab	13.84 a-c	15.04 a-e
V_5H_1	7.093 c-f	11.73 b	13.58 bc	14.07 c-e
V_5H_2	6.810 c-f	12.61 ab	13.30 bc	14.12 c-e
V_5H_3	6.370 ef	11.12 b	14.05 a-c	14.18 b-e
V_5H_4	6.797 c-f	11.22 b	13.21 c	13.49 e
$LSD_{(0.05)}$	**1.00**	**2.07**	**2.06**	**2.32**
CV (%)	**8.38**	**10.09**	**9.00**	**9.33**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.1.5 Above ground dry matter content (%) of plant hill^{-1}

4.1.5.1 Effect of variety

Potato varieties exerted significant variation on above ground dry matter content hill^{-1} of plant at different growth stages of potato shown in the figure 37. The result revealed that, the highest above ground dry matter content hill^{-1} (8.61, 10.10 and 12.12 %) were produced by V_3 at 40, 55 and 70 DAP, respectively which was statistically similar with V_2 at 40 DAP; with V_1 at 55 DAP and the lowest above ground dry matter content hill^{-1} (7.09, 8.58 and 10.09 %) were produced by V_5 which was statistically similar with V_4 at 40 DAP; with V_2 at 55 and 70 DAP.

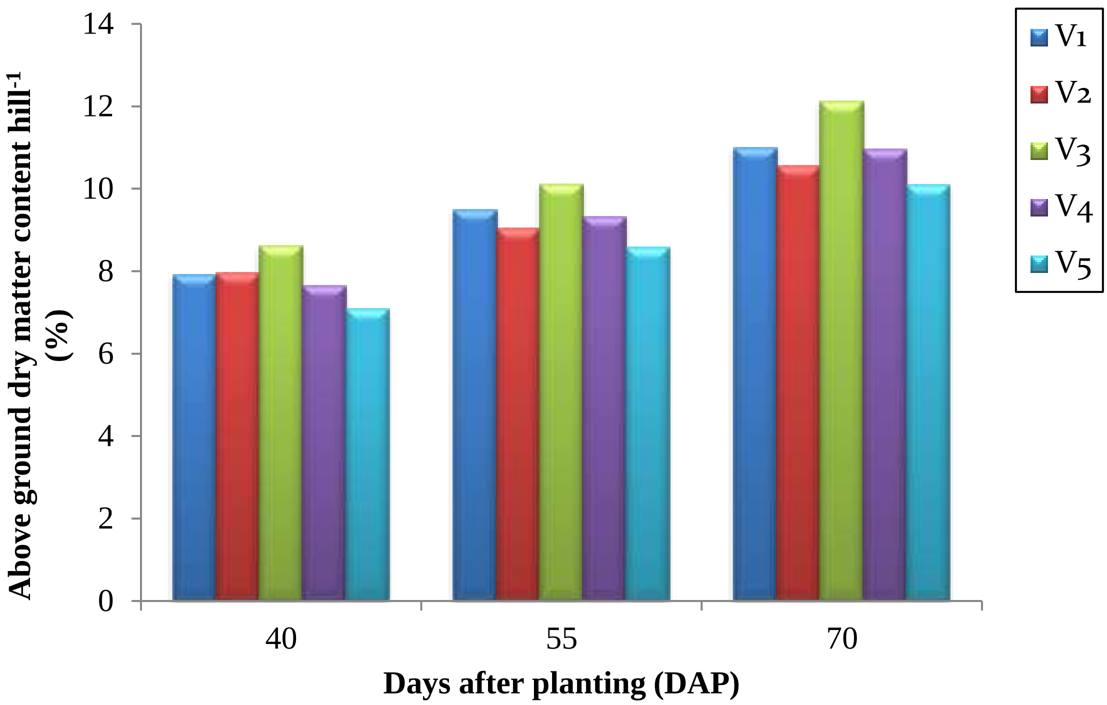


Figure 37. Effect of variety on the above ground dry matter content (%) hill^{-1} of potato plant at different days after planting (LSD $_{0.05}$= 0.66, 0.67 and 0.67 at 40, 55 and 70 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.5.2 Effect of harvesting time

Harvesting time exerted significant variation on above ground dry matter content hill^{-1} at different growth stages of potato except 25 DAP shown in the figure 38. The result exposed that, the highest above ground dry matter content hill^{-1} (9.54 and 11.26 %) were produced by H_4 at 55 and 70 DAP, respectively which was statistically similar with rest of the treatments except H_1 and the lowest above ground dry matter content hill^{-1} (8.92 and 10.32 %) were produced by H_1 at 55 and 70 DAP, respectively which was similar with H_2 and H_3 at 55 DAP and with H_2 at 70 DAP.

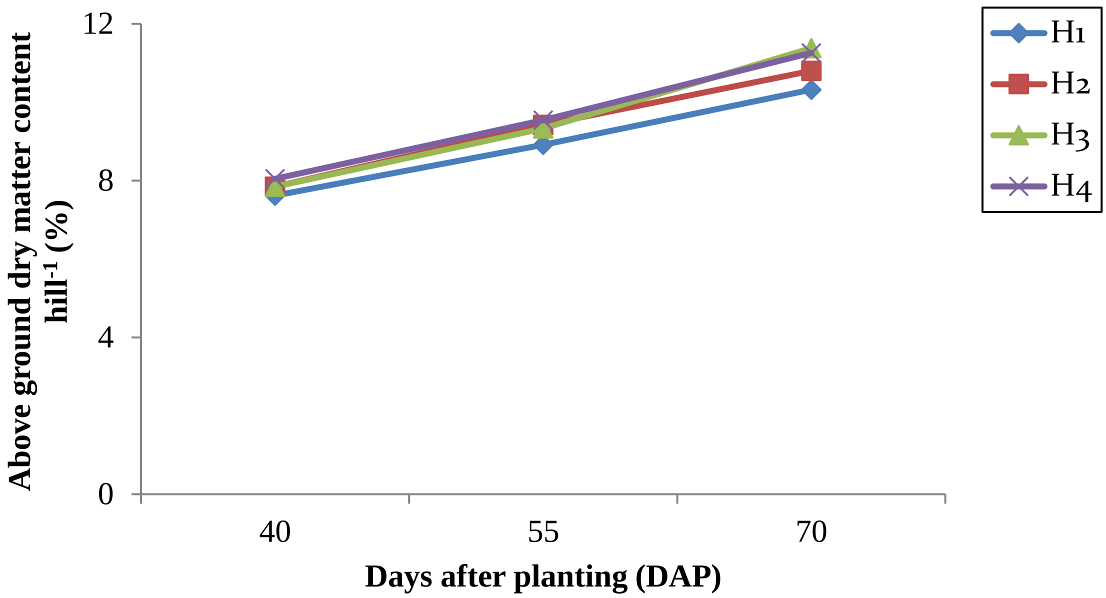


Figure 38. Effect of harvesting time on the above ground dry matter content (%) hill^{-1} of potato plant at different days after planting (LSD $_{0.05}$= NS, 0.60 and 0.60 at 40, 55 and 70 DAP, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.1.5.3 Interaction effect of variety and harvesting time

Interaction between variety and harvesting time exerted significant variation on above ground dry matter content (%) hill^{-1} at different growth stages of potato shown in the table 27. The result revealed that, the highest above ground dry matter content hill^{-1} (9.43 and 10.87 %) were produced by V_3H_4 at 40 and 55 DAP, respectively which was statistically similar with V_3H_3, V_3H_2, V_2H_3, V_1H_4, V_1H_2 and V_4H_4 at 40 DAP; with V_3H_3, V_3H_2, V_1H_4, V_1H_2, V_4H_4 and V_1H_3 at 55 DAP. At 70 DAP the highest above ground dry matter content hill^{-1} (12.89 %) were produced by V_3H_3 which was statistically similar with V_3H_4, V_3H_2 and V_1H_4. The lowest above ground dry matter content hill^{-1} (6.44 %) was produced by V_5H_4 at 40 DAP which was statistically similar with rest of the treatment combinations except V_1H_2, V_1H_3, V_1H_4, V_2H_2, V_2H_3, V_2H_4, V_3H_1, V_3H_2, V_3H_3 and V_4H_4. At 55 and 70 DAP the lowest above ground dry matter content hill^{-1} (8.30 and 9.70 %, respectively) were produced by V_5H_1 which was statistically similar with rest of the treatment combinations except V_1H_2, V_1H_3, V_3H_2, V_3H_3 and V_3H_4 at 55 DAP and with V_1H_3, V_3H_2, V_3H_3, V_3H_4, V_1H_4, V_2H_3, V_3H_1, V_4H_3 and V_4H_4 at 70 DAP.

Table 27. Interaction effect of variety and harvesting time on the above ground dry matter content hill^{-1} of potato plant at different days after planting

Interaction (variety × harvesting time)	Above ground dry matter content hill^{-1} of potato plant (%)		
	40 DAP	**55 DAP**	**70 DAP**
V_1H_1	7.467 b-d	8.567 de	10.04 de
V_1H_2	8.190 a-c	9.890 a-d	10.84 b-e
V_1H_3	7.800 bc	9.890 a-d	11.43 bc
V_1H_4	8.173 a-c	9.580 a-e	11.66 ab
V_2H_1	7.547 b-d	8.647 de	10.04 de
V_2H_2	8.013 bc	9.340 b-e	10.70 b-e
V_2H_3	8.187 a-c	8.893 c-e	11.05 b-d
V_2H_4	8.083 bc	9.270 b-e	10.42 b-e
V_3H_1	8.043 bc	9.027 b-e	11.14 b-d
V_3H_2	8.413 a-c	10.19 a-c	11.63 ab
V_3H_3	8.550 ab	10.33 ab	12.89 a
V_3H_4	9.427 a	10.87 a	12.83 a
V_4H_1	7.467 b-d	9.470 b-e	10.71 b-e
V_4H_2	7.467 b-d	8.907 c-e	10.65 b-e
V_4H_3	7.507 b-d	9.237 b-e	11.19 b-d
V_4H_4	8.110 a-c	9.607 a-e	11.26 b-d
V_5H_1	7.577 b-d	8.880 c-e	9.700 e
V_5H_2	7.150 cd	8.753 de	10.17 c-e
V_5H_3	7.183 cd	8.300 e	10.36 b-e
V_5H_4	6.443 d	8.370 e	10.12 c-e
LSD (0.05)	**1.32**	**1.35**	**1.34**
CV (%)	**10.17**	**8.77**	**7.40**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.2. Potato yield and yield parameters

4.2.1 Tuber number hill^{-1}

4.2.1.1 Effect of variety

Potato variety had a significant difference on the tuber number hill^{-1} (Table 28). Results showed that the maximum tuber number hill^{-1} (9.17) was found in V_1 and the minimum tuber number hill^{-1} (6.36) was found in V_4 which was statistically similar with V_2 and V_5. The results were corroborated with the findings of Sogut and Ozturk (2011) who found that potato cultivars differed significantly in tuber number per plant due to varietal difference.

4.2.1.2 Effect of harvesting time

Harvesting time influenced significantly on the tuber number hill^{-1} of potato (Table 28). Results showed that the maximum tuber number hill^{-1} (7.55) was found in H_4 (110 DAP) which was statistically similar with H_2 (90 DAP) and H_3 (100 DAP) and the minimum tuber number hill^{-1} (6.58) was found in H_1 (80 DAP). There was an incremental increase in tuber number hill^{-1} when crop was allowed in the field for longer growth period. Sogut and Ozturk (2011) reported that the lowest tuber number hill^{-1} (3.8) was recorded at 75 DAP and the highest one (5.67) was counted from 120 DAP. The results were well corroborated with the findings of El-Zohiri and Samy (2013) who reported that time of harvesting had significant effects on tuber numbers hill^{-1}.

4.2.1.3 Interaction effect of variety and harvesting time

Interaction between variety and harvesting time exerted a significant difference on the tuber number hill^{-1} (Table 29). Results showed that the maximum tuber number hill^{-1} (10.16) was found in V_1H_4 which was statistically similar with V_1H_2 and V_1H_3 and the minimum tuber number hill^{-1} (5.59) was found in V_4H_4 which was statistically similar with V_4H_3, V_4H_2, V_3H_3, V_3H_2, V_3H_1, V_2H_4, V_2H_3 and V_2H_1. The results were well corroborated with the findings of Sogut and Ozturk (2011) who reported that statistically significant interaction occurred between the effects of harvesting time and cultivars on tuber number per plant. Similar results were also reported by Ozkaynak *et al.* (2005) and Caliskan *et al.* (1999).

4.2.2 Tuber weight hill^{-1}

4.2.2.1 Effect of variety

Potato variety had a significant difference on the tuber weight hill^{-1} (Table 28). Results showed that the maximum tuber weight hill^{-1} (0.26 kg) was found in V_1 and V_2 which were statistically at par with V_3 and V_4 and the minimum tuber weight hill^{-1} (0.18 kg) was found in V_5 .

4.2.2.2 Effect of harvesting time

Harvesting time had a significant difference on the tuber weight hill^{-1} (Table 28). Results showed that the maximum tuber weight hill^{-1} (0.28 kg) was found in H_4 which was statistically similar with H_3 and the minimum tuber weight hill^{-1} (0.18 kg) was found in

H_1. The higher tuber weight might be attributed to higher tuber number hill^{-1}. Beside this the late harvesting potato had the long growth period and had chance to partion more dry matter to the sink (tuber) consequently scored higher tuber weight hill^{-1} compare to that of early harvesting time. El-Zohiri and Samy (2013) found that the early harvested date at 100 DAP produced the lowest tuber weight (97.16 and 88.81g) during 2011/2012 and 2012/2013 seasons, respectively. Whereas, the maximum tuber weight (102.98 and 109.92g) was obtained from the harvested potato crop at 110 days after planting during the first season and at 120 DAP in the second season.

4.2.2.3 Interaction effect of variety and harvesting time

Interaction between variety and harvesting time exerted a significant difference on the tuber weight hill^{-1} (Table 29). Results showed that the maximum tuber weight hill^{-1} (0.31) was found in V_1H_3, V_1H_4 and V_2H_4 which were statistically similar with V_2H_3, V_3H_3, V_3H_4, V_4H_3 and V_4H_4 and the minimum tuber weight hill^{-1} (0.16 kg) was found in V_5H_1 which was statistically similar with V_5H_2, V_5H_3, V_5H_4, V_4H_1, V_3H_1, V_2H_1 and V_1H_1. The present findings were in accordance with Bombik *et al.* (2013) who reported that significantly higher weight of tubers plant^{-1} for cultivars 'Sante' and 'Żagiel' at delayed harvesting time than the earlier one.

Table 28. Effect of variety and harvesting time on the yield and tuber characteristics of potato

Treatment	Tuber hill^{-1} (no.)	Tuber weight hill^{-1} (kg)	Yield of potato (t ha^{-1})	Marketable yield of potato (t ha^{-1})	Non-marketable yield of potato (t ha^{-1})
Effect of variety					
V_1	9.17 a	0.26 a	23.16 a	20.16 a	3.00 bc
V_2	6.51 c	0.26 a	23.08 a	20.00 a	3.08 bc
V_3	7.31 b	0.24 a	22.00 a	19.08 a	2.83 c
V_4	6.36 c	0.24 a	21.39 a	17.22 b	4.17 a
V_5	6.63 c	0.18 b	16.68 b	13.43 c	3.25 b
LSD $_{(0.05)}$	**0.65**	**0.03**	**1.90**	**1.58**	**0.32**
CV (%)	**10.97**	**11.54**	**10.82**	**10.60**	**11.69**
Effect of harvesting time					
H_1	6.583 b	0.18 c	16.36 c	13.03 c	3.33
H_2	7.411 a	0.21 b	18.75 b	15.42 b	3.27
H_3	7.237 a	0.27 a	24.56 a	21.30 a	3.26
H_4	7.547 a	0.28 a	25.38 a	22.18 a	3.21
LSD $_{(0.05)}$	**0.58**	**0.02**	**1.70**	**1.41**	**NS**
CV (%)	**10.97**	**11.54**	**10.82**	**10.60**	**11.69**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.2.3 Yield of potato t ha^{-1}

4.2.3.1 Effect of variety

Yield of potato significantly influenced by potato variety (Table 28). Results of the experiment revealed that, the highest potato yield (23.16 t ha^{-1}) was recorded from V_1 (BARI Alu-25) which was statistically similar with V_2 (BARI Alu-28), V_3 (BARI Alu-29) and V_4 (BARI Alu-7) and the lowest potato yield (16.68 t ha^{-1}) was recorded from V_5 (BARI TPS-1). Yield diffeences among the varieties may be attributed by the varietal characters of the cultivars, which is governed by the genetic make up of the varieties.

4.2.3.2 Effect of harvesting time

Yield of potato was significantly influenced by different harvesting time (Table 28). Result revealed that, the highest potato yield (25.38 t ha^{-1}) was recorded when the potato harvested at H_4 (110 DAP) followed by H_3 (100 DAP) with (24.56 t ha^{-1}) and the lowest potato yield (16.36 t ha^{-1}) was recorded at H_1 (80 DAP). Sogut and Ozturk (2011) reported that the growing period of early potato is extremely short; only 50 to 80 days from planting to harvest. As tuber yield and quality during a short growing season are affected mainly by intercepted radiation, methods to increase tuber yield should focus on reducing the time to emergence, improving haulm growth after emergence and increasing the harvest index (Mustonen, 2004). Sogut and Ozturk (2011) reported that time of harvesting had significant effects on tuber yield. Tuber yield increased from 8.9 to 17.2 t ha^{-1} when harvesting was delayed from 75 to 120 days from planting. Tuber yield increased with the progress of growth and maturing of the tuber. This may be explained with a progressive increase of day- length and sunlight intensity during the crop cycle (Ierna, 2009). The obtained results were in agreement with those reported by Rębarz *et al.* (2015), Rymuza *et al*. (2015), Bombik *et al.* (2013) and Lombardo *et al*. (2013) who reported that delayed harvest gave higher yield of potato.

4.2.3.3 Interaction effect of variety and harvesting time

Yield of potato was significantly influenced by interaction of different variety and harvesting time (Table 29). Result revealed that, the highest potato yield (28.44 t ha^{-1}) was recorded from V_1H_4 which was statistically similar with V_1H_3, V_2H_3, V_2H_4, V_3H_3,V_3H_4, V_4H_3 and V_4H_4 and the lowest potato yield (14.13 t ha^{-1}) was recorded from V_5H_1 which was statistically similar with V_5H_2, V_5H_3, V_4H_1, V_2H_1 and V_1H_1. The obtained results were in agreement with those reported by Sogut and Ozturk (2011) who reported that the interaction effects of harvesting time and cultivar in respect of tuber yield ranged from 6.7 to 7.1 t ha^{-1} (in 2006 and 2007, respectively) and 24.6 to 27.8 t ha^{-1} (in 2006 and 2007, respectively). Thus, maximum tuber yield was recorded at late harvesting time (120 DAP) in association with 'Carrera', while the minimum tuber yield was found in 'Adora' when harvested early (75 DAP) in each years.

4.2.4 Marketable yield of potato t ha^{-1}

4.2.4.1 Effect of variety

Marketable yield of potato was significantly varied by potato variety (Table 28). Results revealed that, the highest marketable potato yield (20.16 t ha^{-1}) was produced by V_1 which was statistically similar with rest of the potato varieties except V_4 and V_5 and the lowest marketable potato yield (13.43 t ha^{-1}) was produced by V_5 which was statistically different from other tested potato varieties. Similar findings were also reported by Sogut and Ozturk (2011) who reported that significant differences were observed among cultivars for marketable tuber yield.

4.2.4.2 Effect of harvesting time

Marketable yield of potato was significantly influenced by different harvesting time (Table 28). Result revealed that, late harvest H_4 (110 DAP) produced the highest marketable potato yield (22.18 t ha^{-1}) which was statistically similar with H_3 (100 DAP) and that of lowest (13.03 t ha^{-1}) was produced by H_1 (80 DAP) which was statistically different from other treatments. Similar findings were also reported by Alvaro *et al.* (2017) who reported that harvesting period had a highly significant effect on marketable root yield of sweet potato.

4.2.4.3 Interaction effect of variety and harvesting time

Marketable yield of potato was significantly influenced by interaction of different variety and harvesting time (Table 29). Result revealed that, the highest marketable potato yield (25.44 t ha^{-1}) was produced by treatment combination V_1H_3 which was statistically similar with V_1H_4, V_2H_3, V_2H_4 and V_3H_4 and the lowest marketable potato yield (10.79 t ha^{-1}) was produced by V_5H_1 which was statistically similar with V_5H_2, V_4H_1, V_2H_1 and V_1H_1.

4.2.5 Non-marketable potato yield t ha^{-1}

4.2.5.1 Effect of variety

Non-marketable potato yield was significantly varied by different potato varieties (Table 28). Results revealed that, the highest non-marketable potato yield (4.17 t ha^{-1}) was produced by V_4 (BARI Alu-7) and the lowest one (2.83 t ha^{-1}) was produced by V_3 (BARI Alu-29) which showed similarity with V_1 (BARI Alu-25) and V_2 (BARI Alu-28).

4.2.5.2 Effect of harvesting time

Non-marketable potato yield was not significantly influenced by different harvesting time (Table 28). However, numerically the highest and lowest non-marketable potato yield (3.33 and 3.21 t ha^{-1}, respectively) was produced by H_1 (80 DAP) and H_4 (110 DAP) treatment respectively. Contradictory results were also reported by Alvaro *et al.* (2017) who concluded that harvesting period significantly affected non-marketable root yield of sweet potato.

4.2.5.3 Interaction effect of variety and harvesting time

Non-marketable potato yield was significantly influenced by interaction of different variety and harvesting time (Table 29). Result revealed that, the highest non-marketable potato yield (4.33 t ha^{-1}) was produced by V_4H_2 and V_4H_3 which were statistically similar with V_4H_4 and the lowest non-marketable potato yield (2.33 t ha^{-1}) was recorded from V_3H_2 which was statistically similar with V_1H_3.

Table 29. Interaction effect of variety and harvesting time on the yield and tuber characteristics of potato

Interaction (variety × harvesting time)	Tuber $hill^{-1}$ (no.)	Tuber weight $hill^{-1}$ (kg)	Yield of potato (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})
V_1H_1	6.99 b-d	0.17 e-g	15.62 ef	12.62 h-j	3.00 d
V_1H_2	9.79 a	0.22 c-e	20.17 cd	17.17 ef	3.00 d
V_1H_3	9.73 a	0.31 a	28.40 a	25.44 a	2.96 de
V_1H_4	10.16 a	0.31 a	28.44 a	25.40 a	3.04 cd
V_2H_1	6.33 c-e	0.18 e-g	16.05 ef	13.05 g-j	3.00 d
V_2H_2	7.02 b-d	0.24 b-d	21.57 bc	18.24 de	3.33 cd
V_2H_3	6.44 c-e	0.30 a	26.84 a	23.84 ab	3.00 d
V_2H_4	6.23 c-e	0.31 a	27.88 a	24.88 ab	3.00 d
V_3H_1	6.13 de	0.20 d-g	18.46 c-e	15.46 e-h	3.00 d
V_3H_2	6.20 c-e	0.21 d-f	18.80 c-e	16.13 e-g	2.33 e
V_3H_3	6.68 b-e	0.28 ab	25.15 ab	22.15 bc	3.00 d
V_3H_4	7.50 bc	0.28 ab	25.59 a	22.59 a-c	3.00 d
V_4H_1	5.59 e	0.17 fg	15.41 ef	11.41 ij	4.00 ab
V_4H_2	6.66 b-e	0.21 d-f	19.09 c-e	14.75 f-h	4.33 a
V_4H_3	6.37 c-e	0.29 ab	24.89 ab	20.56 cd	4.33 a
V_4H_4	5.59 e	0.27 a-c	26.16 a	22.16 bc	4.00 ab
V_5H_1	7.88 b	0.16 g	14.13 f	10.79 j	3.67 bc
V_5H_2	7.39 b-d	0.18 e-g	16.26 ef	12.59 h-j	3.33 cd
V_5H_3	6.97 b-d	0.19 d-g	17.50 d-f	14.50 f-i	3.00 d
V_5H_4	7.00 b-d	0.21 d-g	18.85 c-e	15.85 e-g	3.00 d
LSD $_{(0.05)}$	**1.31**	**0.05**	**3.80**	**3.15**	**0.63**
CV (%)	**10.97**	**11.54**	**10.82**	**10.60**	**11.69**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.2.6 Marketable tuber number (%)

4.2.6.1 Effect of variety

A significant difference was observed on marketable tuber number due to different potato varieties (Table 30). Results showed that the maximum marketable tuber number (78.04 %) was gained by V_1 followed by V_3 (77.20 %) and V_2 (76.87%) and the minimum marketable tuber number (51.02 %) was gained by V_4.

4.2.6.2 Effect of harvesting time

Significant difference was observed on marketable tuber number due to different harvesting times (Table 30). Result showed that, the highest marketable tuber number (72.90 %) was attained by H_3 (100 DAP) treatment which was statistically similar with H_2 (90 DAP) and H_4 (110 DAP) and the lowest marketable tuber number (65.24 %) was attained by H_1 (80 DAP) which was statistically similar with H_2.

4.2.6.3 Interaction effect of variety and harvesting time

There observed a mark difference on marketable tuber number due to interaction of different varieties and harvesting times (Table 31). Result showed that, the highest marketable tuber number (80.66 %) was attained by treatment combination V_1H_4 which was statistically similar with rest of the treatment combinations except V_4H_1, V_4H_2, V_4H_3, V_4H_4, V_5H_1 and V_5H_2 and the lowest Marketable tuber number (46.48 %) was attained by V_4H_1 which was statistically similar with V_4H_2, V_4H_3, V_4H_4 and V_5H_1.

4.2.7 Marketable tuber weight (%)

4.2.7.1 Effect of variety

Potato variety exerted a non-significant difference on the marketable tuber weight of potato (Table 30). Results showed that numerically the maximum and minimum marketable tuber weight (86.15 and 79.57 %, respectively) was recorded from V_1 (BARI Alu-25) and V_4 (BARI Alu-7), respectively.

4.2.7.2 Effect of harvesting time

Harvesting time had non-significant difference on the marketable tuber weight of potato (Table 30). Numerically the maximum and minimum marketable tuber weight (86.70 and 79.42 %, respectively) was recorded from H_3 (100 DAP) and H_1 (80 DAP), respectively.

4.2.7.3 Interaction effect of variety and harvesting time

Interaction between variety and harvesting time exerted a non-significant difference on the marketable tuber weight of potato (Table 31). Result showed that, numerically the highest and lowest marketable tuber weight (89.42 and 73.95 %, respectively) was attained by treatment combination V_1H_4 and V_4H_1, respectively.

Table 30. Effect of variety and harvesting time on the tuber characteristics of potato

Treatments	Marketable tuber number (%)	Marketable tuber weight (%)	Non-marketable tuber number (%)	Non-marketable tuber weight (%)
Effect of variety				
V_1	78.04 a	86.15	21.96 c	13.85 b
V_2	76.87 a	85.94	23.13 c	14.06 b
V_3	77.20 a	86.13	22.80 c	13.96 b
V_4	51.02 c	79.57	48.98 a	20.43 a
V_5	66.90 b	80.14	33.10 b	19.86 a
LSD $_{(0.05)}$	**6.82**	**NS**	**2.98**	**1.63**
CV (%)	**11.79**	**12.41**	**12.01**	**11.97**
Effect of harvesting time				
H_1	65.24 b	79.42	34.76 a	20.58 a
H_2	69.94 ab	82.17	30.06 b	18.50 b
H_3	72.90 a	86.70	27.10 c	13.30 c
H_4	71.95 a	86.06	28.05 bc	13.34 c
LSD $_{(0.05)}$	**6.10**	**NS**	**2.66**	**1.45**
CV (%)	**11.79**	**12.41**	**12.01**	**11.97**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.2.8 Non-marketable tuber number (%)

4.2.8.1 Effect of variety

There was a mark difference was observed among non-marketable tuber number due to different potato varieties (Table 30). Results showed that the maximum non-marketable tuber number (48.98 %) was gained by V_4 and the minimum non-marketable tuber number (21.96 %) was gained by V_1 followed by V_2 (23.13 %) and V_3 (22.80 %).

4.2.8.2 Effect of harvesting time

Non-marketable tuber number showed significant difference due to different harvesting times on potato (Table 30). Result showed that, the highest non-marketable tuber number (34.76 %) was attained by H_1 treatment and the lowest non-marketable tuber number (27.10 %) was attained by H_3 which was statistically similar with H_4. The results were well corroborated with the findings of El-Zohiri and Samy (2013) who reported that the early harvest time (100 DAP) produced the highest percentage of small size tubers yield while, the lowest percentage was recorded in case of harvesting at 120 DAP.

4.2.8.3 Interaction effect of variety and harvesting time

Non-marketable tuber number exerted significant difference due to interaction of different varieties and harvesting times (Table 31). Result showed that, the highest non-marketable tuber number (53.52%) was attained by treatment combination V_4H_1 which was statistically similar with V_4H_2, V_4H_4 and V_5H_1 and that of lowest (20.91 %) was attained by V_1H_2 which was statistically similar with rest of the treatment combinations except V_4H_1, V_4H_2, V_4H_3, V_4H_4, V_5H_1 and V_5H_2.

4.2.9 Non-marketable tuber weight (%)

4.2.9.1 Effect of variety

Potato variety exerted a significant difference on the non-marketable tuber weight of potato (Table 30). Results showed that the maximum non-marketable tuber weight (20.43 %) was found in V_4 which was statistically similar with V_5 and the minimum non-marketable tuber weight (13.85 %) was found in V_1 which was statistically similar with V_2 and V_3.

4.2.9.2 Effect of harvesting time

Harvesting time exerted a significant difference on the non-marketable tuber weight of potato (Table 30). Results showed that the maximum non-marketable tuber weight (20.58 %) was found in H_1 and the minimum non-marketable tuber weight (13.30 %) was found in H_3 which was statistically similar with H_4.

4.2.9.3 Interaction effect of variety and harvesting time

Interaction between variety and harvesting time exerted a significant difference on the non-marketable tuber weight of potato (Table 31). Results showed that the maximum non-marketable tuber weight (26.05 %) was found in V_4H_1 which was statistically similar with V_5H_2 and the minimum non-marketable tuber weight (10.58 %) was found in V_1H_3 which was statistically similar with V_1H_4, V_2H_3, V_2H_4, V_3H_3 and V_3H_4.

Table 31. Interaction effect of variety and harvesting time on the tuber characteristics of potato

Interaction (variety × harvesting time)	Marketable tuber number (%)	Marketable tuber weight (%)	Non-marketable tuber number (%)	Non-marketable tuber weight (%)
V_1H_1	75.09 ab	80.70	24.91 d	19.30 cd
V_1H_2	79.09 a	85.12	20.91 d	14.88 fg
V_1H_3	77.32 ab	89.34	22.68 d	10.58 h
V_1H_4	80.66 a	89.42	19.34 d	10.66 h
V_2H_1	77.35 ab	81.28	22.65 d	18.72 de
V_2H_2	77.96 a	84.56	22.04 d	15.44 f
V_2H_3	76.37 ab	88.73	23.63 d	11.27 h
V_2H_4	75.81 ab	89.21	24.19 d	10.79 h
V_3H_1	76.47 ab	83.69	23.53 d	16.31 d-f
V_3H_2	77.06 ab	87.50	22.94 d	15.83 ef
V_3H_3	78.33 a	88.05	21.67 d	11.95 gh
V_3H_4	76.94 ab	85.26	23.06 d	11.74 gh
V_4H_1	46.48 d	73.95	53.52 a	26.05 a
V_4H_2	51.41 cd	77.34	48.59 ab	22.66 b
V_4H_3	54.68 cd	84.63	45.32 b	15.37 f
V_4H_4	51.52 cd	82.36	48.48 ab	17.64 d-f
V_5H_1	50.78 cd	77.48	49.22 ab	22.52 bc
V_5H_2	64.21 bc	76.32	35.79 c	23.68 ab
V_5H_3	77.78 ab	82.73	22.22 d	17.27 d-f
V_5H_4	74.83 ab	84.03	25.17 d	15.97 ef
LSD $_{(0.05)}$	**13.64**	**NS**	**5.95**	**3.25**
CV (%)	**11.79**	**12.41**	**12.01**	**11.97**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.3 Post-harvest quality of potato

4.3.1 Dry matter of potato after storage (%)

4.3.1.1 Effect of variety

Dry matter content (%) of potato after storage was significantly influenced by potato varieties (Figure 39). The result revealed that, the highest dry matter content of potato after storage (18.92, 19.45, 19.73, 19.40, 19.06, 18.91 %) were observed in V_3 at harvest, 15, 30, 45, 60 and 75 DAP, respectively which was statistically similar with V_1 and V_2 at all the growth stages and the lowest dry matter content of potato after storage (16.90, 17.07, 17.26, 17.00, 16.79 and 16.60%) were observed in V_5 at harvest, 15, 30, 45, 60 and 75 DAS, respectively which was statistically similar with V_4 at all the growth stages. Similar findings was also reported by Sogut and Ozturk (2011) who reported that the maximum dry matter content of tubers (26.7 %) was recorded in 'Vangogh' and the lowest dry matter content (19.7 %) was recorded in 'Carrera'.

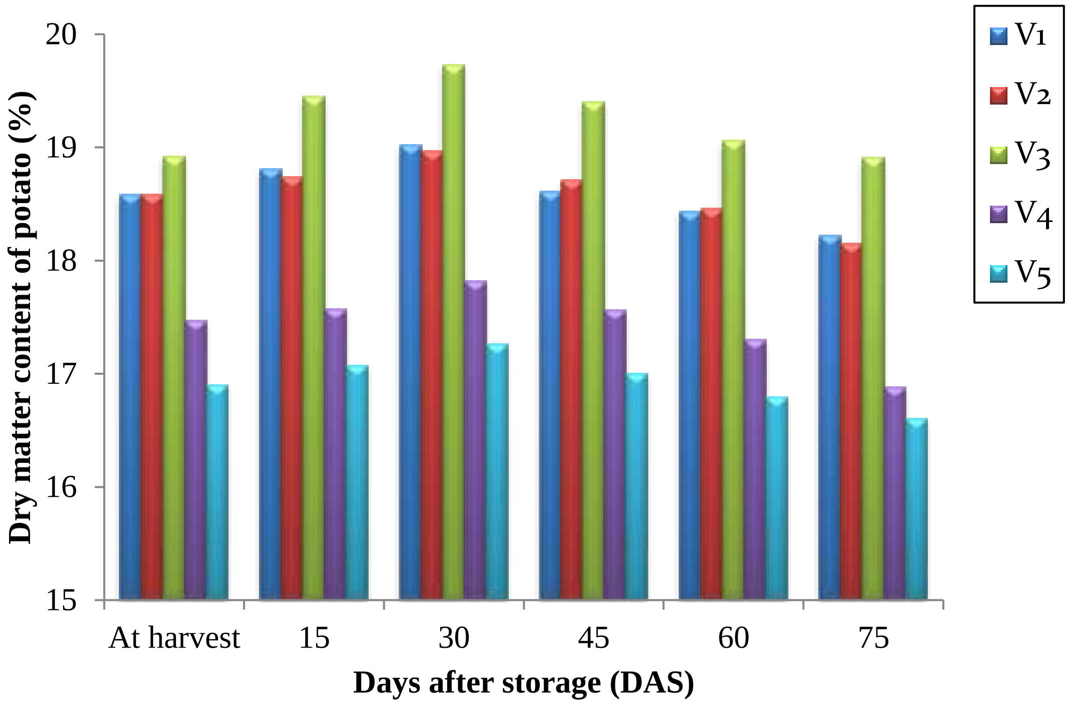


Figure 39. Effect of variety on the dry matter content (%) of potato at different days after storage ($LSD_{0.05}$= 1.31, 1.42, 1.46, 1.56, 1.40 and 1.35 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.3.1.2 Effect of harvesting time

Dry matter content (%) of potato after storage was significantly varied due to different harvesting time (Figure 40). The result exposed that, the highest dry matter content of potato after storage (18.59 and 18.88%) were observed in H_4 at harvest and 15 DAS, respectively, which was statistically similar with rest of the treatments except H_1. At 30, 45, 60 and 75 DAS the highest dry matter content of potato after storage (19.43, 19.07, 18.80 and 18.61%) was observed in H_3 which was statistically similar with rest of the treatments except H_1. On the other hand, the lowest dry matter content of potato after storage (17.15, 17.36, 17.27, 17.08, 16.88 and 16.57 %) were observed in H_1 which was statistically similar with H_2 at all the growth stages. Sogut and Ozturk (2011) found that the dry matter content of potato increased as the growing period was extended. In the present study the dry matter content in potato tubers was the highest at the last harvest date which might be due to longer growth period might facilitate more dry matter accumulation. Similar findings were also reported by Rymuza *et al*. (2015) and Rębarz *et al.* (2015).

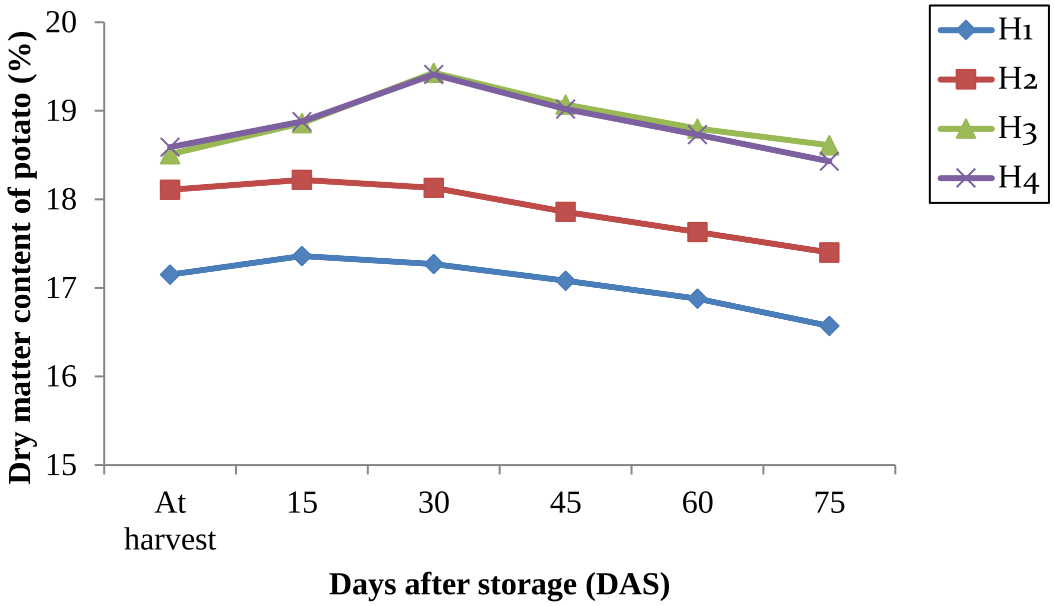


Figure 40. Effect of harvesting time on the dry matter content of potato at different days after storage (LSD $_{0.05}$= 1.17, 1.27, 1.31, 1.39, 1.25 and 1.21 at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

,
Here, H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), and H_4 = harvesting at (110 DAP)

4.3.1.3 Interaction effect of variety and harvesting time

Dry matter content of potato after storage was significantly varied due to interaction between variety and harvesting time (Table 32). The result expressed that, the maximum dry matter content of potato after storage (19.62 %) was observed in treatment combination V_1H_3 at 100 DAP (H_3) which was statistically similar with rest of the treatment combinations except V_5H_1 and V_5H_2. Again the maximum dry matter content of potato after storage (20.07, 20.80, 20.44, 20.12 and 19.99%) were observed in treatment combination V_3H_3 at 15, 30, 45, 60 and 75 DAS, respectively. On the other hand, the lowest dry matter content of potato after storage (16.15, 16.36, 16.30, 16.13, 15.95 and 15.82 %) were observed in treatment combination V_5H_1 at harvest, 15, 30, 45, 60 and 75 DAS, respectively. The results of the study was also supported by Sogut and Ozturk (2011) who stated that tuber dry matter was the highest at 105 DAP for vangogh variety (27.4%). The lowest dry matter of tubers was recorded for carrera (19.62 %) when harvested at 75 DAP.

Table 32. Interaction effect of variety and harvesting time on the dry matter content of potato at different days after storage

Interaction (variety × harvesting time)	Dry matter content (%) of potato at different days after storage					
	At harvest	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
V_1H_1	17.17 a-c	17.35 a-d	17.29 e-g	16.99 b-d	16.75 c-f	16.53 d-f
V_1H_2	18.09 a-c	18.24 a-d	17.81 b-g	17.51 a-d	17.41 a-f	17.18 b-f
V_1H_3	19.62 a	19.77 ab	20.40 a-c	19.93 ab	19.79 ab	19.58 ab
V_1H_4	19.42 a	19.87 ab	20.60 ab	19.99 ab	19.77 ab	19.59 ab
V_2H_1	17.35 a-c	17.55 a-d	17.44 d-g	17.36 a-d	17.18 b-f	16.68 c-f
V_2H_2	18.89 ab	19.02 a-d	19.03 a-g	18.76 a-d	18.60 a-f	18.31 a-f
V_2H_3	19.06 ab	19.26 a-c	19.82 a-e	19.52 a-c	19.16 a-d	18.97 a-d
V_2H_4	19.04 ab	19.14 a-d	19.58 a-f	19.21 a-d	18.91 a-e	18.64 a-e
V_3H_1	17.88 a-c	18.48 a-d	18.35 a-g	18.11 a-d	17.97 a-f	17.63 a-f
V_3H_2	19.40 a	19.52 a-c	19.49 a-f	19.12 a-d	18.64 a-f	18.71 a-e
V_3H_3	19.05 ab	20.07 a	20.80 a	20.44 a	20.12 a	19.99 a
V_3H_4	19.35 a	19.72 ab	20.26 a-d	19.92 ab	19.52 a-c	19.31 a-c
V_4H_1	17.22 a-c	17.04 b-d	17.00 e-g	16.80 cd	16.55 d-f	16.16 ef
V_4H_2	17.45 a-c	17.50 a-d	17.57 c-g	17.43 a-d	17.19 b-f	16.71 c-f
V_4H_3	17.17 a-c	17.39 a-d	17.86 b-g	17.46 a-d	17.16 b-f	16.96 b-f
V_4H_4	18.05 a-c	18.36 a-d	18.86 a-g	18.57 a-d	18.29 a-f	17.70 a-f
V_5H_1	16.15 c	16.36 d	16.30 g	16.13 d	15.95 f	15.82 f
V_5H_2	16.71 bc	16.80 cd	16.73 fg	16.45 cd	16.31 ef	16.12 ef
V_5H_3	17.65 a-c	17.83 a-d	18.27 a-g	18.02 a-d	17.78 a-f	17.55 a-f
V_5H_4	17.07 a-c	17.30 a-d	17.73 b-g	17.40 a-d	17.14 b-f	16.92 b-f
LSD (0.05)	**2.62**	**2.83**	**2.92**	**3.11**	**2.79**	**2.71**
CV (%)	**8.76**	**9.35**	**9.52**	**10.31**	**9.38**	**9.22**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1= harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP) and H_4 = harvesting at (110 DAP)

4.3.2 Specific gravity

4.3.2.1 Effect of variety

Specific gravity of potato was significantly influenced by potato varieties except 75 DAS (Figure 41). The figure showed that V_3 (1.068) variety was superior among the tested varieties by producing highest specific gravity for all harvesting times. Specific gravity value increased up to 30 DAS irrespective of varieties after that it reduced gradually and it contined up to last date 75 DAS. However, the lowest specific gravity was observed in V_5 (1.057) variety for all DAS. Sogut and Ozturk (2011) reported that cultivars reacted differently for specific gravity of potato. The highest specific gravity was found in the mid-late cultivars 'Mondial' and 'Vangogh' while the early cultivars gave the lowest specific gravity. The result was in accordance with the results obtained by Yilmaz and Tugay (1999).

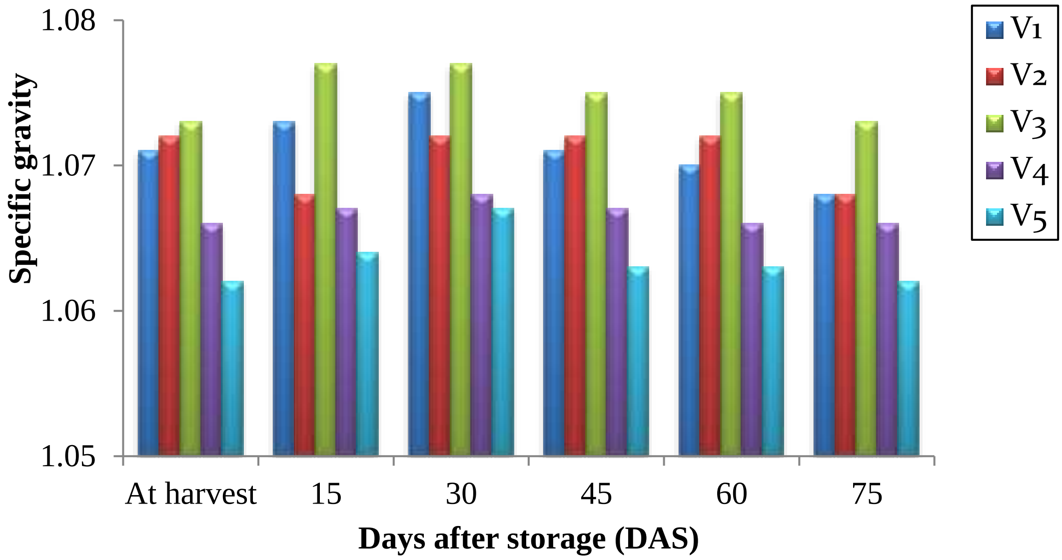


Figure 41. Effect of variety on the specific gravity of potato at different days after storage (LSD $_{0.05}$= 0.01, 0.01, 0.01, 0.01, 0.01 and NS at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets

4.3.2.2 Effect of harvesting time

Specific gravity of potato was significantly influenced by different harvesting time at all growth stages except at harvest and 75 DAS (Figure 42). The figure shows that trend of specific gravity behaved differently due to different days after planting. Early dates H_1 (80 DAP) and H_2 (90 DAP) showed lower specific gravity than delayed days after harvest H_3 (100 DAP) and H_4 (110 DAP). Harvesting at H_3 (100 DAP) and H_4 (110 DAP) showed higher specific gravity than the early harvest of H_1 80 (DAP) and H_2 (90 DAP). Result revealed that, at 15, 30, 45 and 60 DAS the maximum specific gravity (1.069, 1.070, 1.069 and 1.069, respectively) were scored by H_3 which showed similarity rest of the harvesting times except H_1 and the minimum specific gravity (1.058, 1.062, 1.059 and 1.057, respectively) was scored by both H_1 at which showed similarity with H_2 at 15, 30, 45 and 60 DAS. Specific gravity directly related to the dry matter content of potato. Potato with higher dry matter content gave the maximum specific gravity. So in present experiment the longer growth duration potato scored the maximum dry matter content and also maximum specific gravity. Similar observation was reported by Sogut and Ozturk (2011) that time of harvesting had significant effects on specific gravity.

delaying harvest until 105 DAP resulted in greater specific gravity. The findings of the experiment were also in accordance with the results obtained by Yilmaz and Tugay (1999).

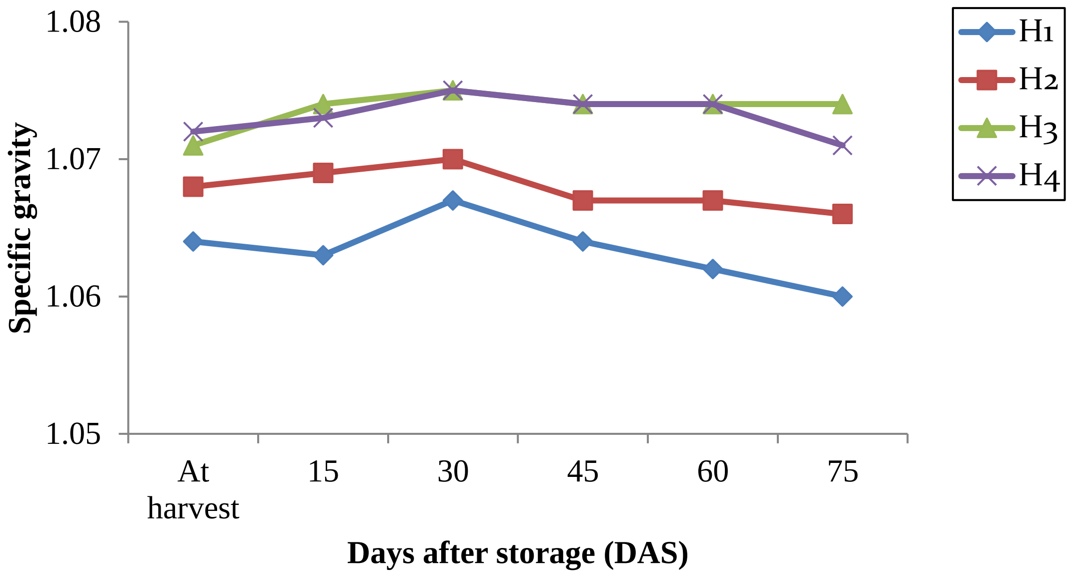


Figure 42. Effect of harvesting time on the specific gravity of potato at different days after harvesting ($LSD_{0.05}$= NS, 0.01, 0.01, 0.01, 0.01 and NS at harvest, 15, 30, 45, 60 and 75 DAS, respectively)

Here, H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), H_4 = harvesting at (110 DAP)

4.3.2.3 Interaction effect of variety and harvesting time

Specific gravity of potato was significantly influenced by interaction effect of variety and harvesting time except at 75 DAS (Table 33). Result revealed that, at harvest the maximum specific gravity (1.070) was scored by V_1H_3, V_1H_4, V_2H_3, V_2H_4, V_3H_2, V_3H_3 and V_3H_4 which showed similarity with rest of the treatment combinations except V_5H_1 and the minimum specific gravity (1.053) was scored by V_5H_1 which showed similarity with rest of the treatment combinations except V_1H_3, V_1H_4, V_2H_3, V_2H_4, V_3H_2, V_3H_3 and V_3H_4. At 15, 30, 45 and 60 DAS the maximum specific gravity (1.077, 1.077, 1.077 and 1.077, respectively) was scored by V_3H_3 which showed similarity with rest of the treatment combinations except V_1H_1, V_2H_1, V_4H_1, V_4H_3, V_5H_1, V_5H_2 and V_5H_4 at 15 DAS; with V_2H_1, V_4H_1, V_4H_3, V_5H_1, V_5H_4 and V_4H_2 at 30 DAS; with V_1H_1, V_1H_2, V_2H_1, V_3H_1, V_4H_1, V_4H_2, V_4H_3, V_5H_1, V_5H_2 and V_5H_4 at 45 and 60 DAS. The minimum specific gravity (1.047) was scored by V_2H_1 at 15 DAS which showed similarity with V_1H_1, V_4H_1, V_4H_3, V_5H_1, V_5H_2 and V_5H_4. At 30 DAS the minimum specific gravity (1.060) was scored by V_2H_1, V_4H_1, V_4H_2, V_4H_3 and V_5H_1 which showed similarity with rest of the treatment combinations except V_1H_3, V_1H_4 and V_3H_3. At 45 DAS the minimum specific gravity

(1.053) was scored by V_5H_2 which showed similarity with rest of the treatment combinations except V_1H_3, V_1H_4, V_2H_3, V_2H_4, V_3H_2, V_3H_3 and V_3H_4. At 60 DAS the minimum specific gravity (1.053) was scored by V_1H_1, V_5H_1 and V_5H_2 which showed similarity with rest of the treatment combinations except V_1H_3, V_1H_4, V_2H_3, V_2H_4, V_3H_2, V_3H_3 and V_3H_4 at 60 DAS. These results were in line with the results obtained by Sogut and Ozturk (2011) and Yilmaz and Tugay (1999) who reported that cultivars differed in their response to harvesting time as indicated by the significant interaction between harvesting time and cultivar treatments. Delaying harvest until 105 DAP resulted in greater specific gravity for mid-late maturing cultivars (mondial and vangogh), while, the early harvesting time caused a small decrease in specific gravity for the early cultivars tested.

Table 33. Interaction effect of variety and harvesting time on the specific gravity of potato at different days after storage

Interaction (variety × harvesting time)	Specific gravity of potato at different days after storage					
	At harvest	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
V_1H_1	1.060 ab	1.060 b-d	1.063 ab	1.057 cd	1.053 d	1.053 b
V_1H_2	1.063 ab	1.063 a-c	1.063 ab	1.060 b-d	1.060 b-d	1.060 b
V_1H_3	1.070 a	1.073 ab	1.077 a	1.073 ab	1.073 ab	1.070 b
V_1H_4	1.070 a	1.077 a	1.077 a	1.073 ab	1.073 ab	1.070 b
V_2H_1	1.060 ab	1.047 d	1.060 b	1.060 b-d	1.060 b-d	1.053 b
V_2H_2	1.067 ab	1.063 a-c	1.067 ab	1.067 a-d	1.067 a-d	1.067 b
V_2H_3	1.070 a	1.073 ab	1.073 ab	1.073 ab	1.070 a-c	1.067 b
V_2H_4	1.070 a	1.067 a-c	1.070 ab	1.070 a-c	1.070 a-c	1.067 b
V_3H_1	1.063 ab	1.070 ab	1.067 ab	1.060 b-d	1.060 b-d	1.060 b
V_3H_2	1.070 a	1.070 ab	1.070 ab	1.070 a-c	1.070 a-c	1.070 b
V_3H_3	1.070 a	1.077 a	1.077 a	1.077 a	1.077 a	1.073 b
V_3H_4	1.070 a	1.073 ab	1.073 ab	1.073 ab	1.073 ab	1.070 b
V_4H_1	1.060 ab	1.060 b-d	1.060 b	1.060 b-d	1.057 cd	1.053 b
V_4H_2	1.060 ab	1.063 a-c	1.060 b	1.060 b-d	1.060 b-d	1.057 b
V_4H_3	1.060 ab	1.060 b-d	1.060 b	1.060 b-d	1.060 b-d	1.230 a
V_4H_4	1.063 ab	1.063 a-c	1.070 ab	1.067 a-d	1.067 a-d	1.063 b
V_5H_1	1.053 b	1.053 cd	1.060 b	1.057 cd	1.053 d	1.053 b
V_5H_2	1.057 ab	1.060 b-d	1.063 ab	1.053 d	1.053 d	1.053 b
V_5H_3	1.060 ab	1.063 a-c	1.063 ab	1.063 a-d	1.063 a-d	1.060 b
V_5H_4	1.060 ab	1.060 b-d	1.060 b	1.060 b-d	1.060 b-d	1.060 b
$LSD_{(0.05)}$	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.10**
CV (%)	**0.28**	**0.79**	**0.45**	**0.40**	**0.45**	**6.13**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), V_4= Diamant (BARI Alu-7) and V_5= BARI TPS-1 tuberlets
H_1 = harvesting at (80 DAP), H_2 = harvesting at (90 DAP), H_3 = harvesting at (100 DAP), H_4 = harvesting at (110 DAP)

It was observed from the experiment no.3 that among the five tested varieties BARI Alu-25 (V_1), BARI Alu-28 (V_2), BARI Alu-29 (V_3) and BARI Alu-7 (V_4) showed higher yield (23.16, 23.08, 22.00 and 21.39 t ha^{-1} respectively). In case of quality, BARI Alu-29 (V_3), BARI Alu-28 (V_2) and BARI Alu-25 (V_1) gave highest tuber dry matter (%) and specific gravity. Considering the harvesting times, 110 DAP and 100 DAP gave the similar performance in respect of tuber yield (25.38, 24.56 t ha^{-1}, respectively) and other yield attributes like marketable yield, marketable tuber number percent, tuber no. $hill^{-1}$ and tuber weight (kg) $hill^{-1}$. Considering tuber quality, harvested on 110 DAP and 100 DAP contributed similar and higher dry matter (%) and specific gravity.

Experiment No. 4 : Response of organic manures and various mulch materials on growth yield and quality of selected potato varieties

This experiment was conducted to find out the effect of mulch and organic mamures on three potato varieties at SAU experimental field in Dhaka. The results obtained from the study have been presented, discussed and compared in this chapter through table(s). The results have been presented and discussed with the help of tables and possible interpretations given under the following headings.

4.1 Potato growth parameters

4.1.1 Plant height

The height of plant taken at 85 DAP was not significantly influenced by the varieties (Table 34). Effect of variety, organic manure, mulching, interaction of variety × organic manure, interaction of variety × mulchig, interaction of organic manure × mulching and interaction of variety × organic manure × mulching on plant height of potato was found non-significant (Table 34, 35 and 36).

4.1.2 Number of stems hill^{-1}

4.1.2.1 Effect of varieties

The number of stems hill^{-1} was significantly varied among the varieties at 85 DAP (Table 34). The maximum number of stems hill^{-1} (3.72) was obtained from the variety V_1 (BARI Alu-25) which was statistically similar with the variety V_3 (BARI Alu-29) (3.65 no.). The minimum number of stems hill^{-1} (3.38) was observed from the V_2 (BARI Alu-28). This might be due to varietal characters. The findings was in line with the findings of Anonymous (2009f) who found that number of stems hill^{-1} was varied among seven tested potato varieties.

4.1.2.2 Effect of organic manures

Significant variation of number of stems hill^{-1} was found due to use of different organic manures in potato (Table 34). Maximum number of stems hill^{-1} was measured (3.85 no.) from O_2 (poultry litter) which was significant by highest (3.52 no.) from O_3 (ACI organic fertilizer) and O_1 (cowdung) (3.37 no.). On the other hand, O_3 and O_1 showed statistically similar stems hill^{-1}. The highest stems number with poultry litter (O_2) may be attributed to some nutrients were added through more nutritious poultry feed in poultry litter.

Table 34. Effect of varieties, organic manures and mulch materials on the growth characteristics of potato

Treatments	Plant height at 85 DAP(cm)	Stems plant^{-1} at 85 DAP (no.)	SPAD value in leaf at 55 DAP (%)	Leaf area at 55 DAP (cm^2)	Dry matter content plant^{-1} (%)
Effect of variety					
V_1	81.05	3.72 a	52.85 b	14.31 b	10.47
V_2	78.86	3.38 b	52.56 b	14.99 ab	10.50
V_3	77.51	3.65 a	56.24 a	15.27 a	10.43
LSD $_{(0.05)}$	**4.98**	**0.22**	**2.93**	**0.88**	**0.64**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**
Effect of organic manure					
O_1	79.20	3.37 b	54.35	14.99 ab	10.69
O_2	80.20	3.85 a	54.50	14.34 b	10.42
O_3	78.02	3.52 b	52.80	15.23 a	10.30
LSD $_{(0.05)}$	**4.98**	**0.22**	**2.93**	**0.88**	**0.64**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**
Effect of mulch mateial					
M_1	79.53	3.75 a	54.19	14.90 ab	10.42
M_2	78.17	3.49 b	53.73	15.31 a	10.43
M_3	79.72	3.50 b	53.73	14.35 b	10.55
LSD $_{(0.05)}$	**4.98**	**0.22**	**2.93**	**0.88**	**0.64**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.1.2.3 Effect of mulch material

Significant variation in number of stems hill^{-1} was found due to different mulch mateiral used in potato (Table 34). Maximum number of stems hill^{-1} was measured (3.75 no.) from M_1 (water hyacinth). The minimum was shown (3.49 no.) from M_2 (rice straw) which is statistically similar with M_3 (rice husk) resulted as (3.50 no.). These may be attributed to water hyacinth had ability to add more nutrient which ultimately helped to produce more stem in potato.

4.1.2.4 Interaction effect of varieties and organic manures

Significant variation of number of stems hill^{-1} was found due to interactional effect of varieties and organic manures from this experiment. (Table 35). Maximum number of stems hill^{-1} (4.18 no.) was measured from V_3O_2 combination followed by V_1O_2 and V_1O_1 combination (3.93 and 3.88 no., respectively). The minimum number of stems hill^{-1}

(2.96 no.) was recorded from V_2O_1 followed by (3.33 no.) from V_2O_1 and (3.26 no.) from V_3O_1 combination.

4.1.2.5 Interaction effect of varieties and mulch materials

Significant variation of number of stems hill^{-1} was found due to interactional effect of varieties and mulch materials from this experiment (Table 35). Maximum number of stems hill^{-1} (4.10 no.) was measured from V_1M_1 combination followed by (3.71 no.) was found from V_3M_3 combination. The minimum number of stems hill^{-1} (3.25 no.) and (3.25 no.) were measured from V_2M_2 and V_3M_3 interaction, respectively.

4.1.2.6 Interaction effect of organic manures and mulch materials

Significant variation of number of stems hill^{-1} was found in potato due to interactional effect of organic manures and mulch materials. (Table 35). Table shows that maximum number of stems hill^{-1} (3.98 no.) was measured from O_2M_3 combination followed by O_2M_1 and O_3M_1 combination (3.97 no. and 3.85 no. respectively). The minimum statistically similar number of stems hill^{-1} was observed in O_3M_3, O_1M_1 , O_1M_2 and O_1M_3 combinations and these treatments were also measured statistically similar as O_3M_2 and O_2M_2 and only numerical variation was observed among them.

4.1.2.7 Interaction effect of variety, organic manures and mulch materials

Number of stems hill^{-1} was found significant due to interactional effect of variety, organic manures and mulch materials of potato (Table 36). The result shows that the maximum number of stems hill^{-1} (4.47 no.) was counted from $V_3O_2M_2$ combination which was followed by $V_1O_1M_1$ (4.30 no.). The minimum number of stems hill^{-1} was observed in $V_2O_2M_2$ (2.37 no.) which was close to $V_2O_1M_3$ (2.47).

4.1.3 SPAD value in leaf of potato

4.1.3.1 Effect of varieties

SPAD value of potato leaves were significantly affected by the varieties at 55 DAP (Table 34). The maximum SPAD value (56.24) was recorded from V_3 (BARI Alu-29). The minimum SPAD value (52.85) and (52.56) were counted from V_1 (BARI Alu-25) and V_2 (BARI Alu-28), respectively, which indicated that the chlorophyll content was maximum in V_3 compared to V_1 and V_2 leaves of potato.

4.1.3.2 Effect of organic manures

Non-significant variation of SPAD value in potato leaves was found due to different organic manures used in potato (Table 34). At 55 DAP numerically maximum SPAD value (54.50) was recorded from O_2 (poultry litter) and minimum SPAD value (52.80) from O_3 (ACI organic fertilizer). The SPAD value (54.35) was recorded from O_1 (cowdung).

4.1.3.3 Effect of mulch materials

Non-significant variation in SPAD value was found from different mulch materials used in potato (Table 34). At 55 DAP numerically maximum SPAD value (54.19) was recorded from water hyacinth (M_1) and minimum SPAD value was recorded from rice straw (M_2) (53.73) and rice husk (M_3) (53.73) which were shown same numerical value.

4.1.3.4 Interaction effect of varieties and organic manures

Significant variation in SPAD value was found due to interaction of varieties and organic manures in potato. (Table 35). The maximum SPAD value (56.88) was observed from the treatment V_3O_1 , which was statistically similar with all the interaction except V_1O_3 and V_2O_3 interactions. The minimum SPAD value was found from the treatment V_2O_3 (51.54) which was near to V_1O_3 (51.65).

4.1.3.5 Interaction effect of varieties and mulch materials

Non-significant variation in SPAD value was found due to interactional effect of varieties and mulch materials in potato (Table 35).

4.1.3.6 Interaction effect of organic manures and mulch materials

SPAD value in leaves was found non-significant due to interactional effect of organic manures and mulch materials in potato (Table 35).

4.1.3.7 Interaction effect of variety, organic manures and mulch materials

SPAD value in leaves exerted non-significant variation due to interational effect of variety, organic manures and mulch materials in potato plant (Table 36).

Table 35. Interaction effect of varieties, organic manures and mulch materials on the plant growth characteristics of potato

Treatment combinations	Plant height at 85 DAP (cm)	Stem plant^{-1} at 85 DAP (no.)	SPAD value in leaf at 55 DAP	Leaf area at 55 DAP (cm^2 plant^{-1})	Dry matter content plant^{-1} (%)
Interaction effect of variety and organic manure					
V_1O_1	80.75	3.88 a-c	53.96 a-c	12.49 b	10.84
V_1O_2	80.66	3.93 ab	52.96 a-c	13.82 ab	10.40
V_1O_3	81.73	3.33 ef	51.65 bc	14.48 a	10.17
V_2O_1	78.90	2.96 f	52.20 a-c	14.31 a	10.83
V_2O_2	80.23	3.43 de	53.93 a-c	13.69 ab	10.34
V_2O_3	77.46	3.74 b-d	51.54 c	14.25 a	10.35
V_3O_1	77.96	3.26 ef	56.88 a	14.97 a	10.40
V_3O_2	79.70	4.18 a	56.61 ab	14.57 a	10.52
V_3O_3	74.86	3.49 c-e	55.22 abc	14.88 a	10.38
LSD $_{(0.05)}$	**8.62**	**0.39**	**5.07**	**1.53**	**1.05**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**
Interaction effect of variety and mulch material					
V_1M_1	80.27	4.10 a	53.70	13.42 b	10.55
V_1M_2	80.34	3.53 bc	52.34	13.97 ab	10.47
V_1M_3	82.53	3.52 bc	52.52	13.40 b	10.39
V_2M_1	79.91	3.62 bc	52.56	14.12 ab	10.42
V_2M_2	78.84	3.26 c	52.14	14.42 ab	10.39
V_2M_3	77.83	3.26 c	52.98	13.71 ab	10.71
V_3M_1	78.40	3.54 bc	56.30	14.51 ab	10.30
V_3M_2	75.33	3.68 b	56.72	15.06 a	10.44
V_3M_3	78.79	3.72 ab	55.69	14.86 ab	10.56
LSD $_{(0.05)}$	**8.62**	**0.39**	**5.07**	**1.53**	**1.05**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**
Interaction effect of organic manure and mulch material					
O_1M_1	78.90	3.43 d	54.24	14.87 a	10.69
O_1M_2	77.88	3.39 d	54.51	14.78 a	10.59
O_1M_3	80.83	3.27 d	54.29	15.31 a	10.79
O_2M_1	77.52	3.97 ab	55.25	14.53 ab	10.25
O_2M_2	79.92	3.59 b-d	54.25	15.50 a	10.39
O_2M_3	83.14	3.99 a	54.00	13.00 b	10.62
O_3M_1	82.16	3.85 a-c	53.07	15.32 a	10.33
O_3M_2	76.71	3.48 cd	52.44	15.65 a	10.32
O_3M_3	75.18	3.23 d	52.91	14.74 a	10.25
LSD $_{(0.05)}$	**8.62**	**0.39**	**5.07**	**1.53**	**1.05**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.1.4 Leaf area (cm^2)

4.1.4.1 Effect of varieties

Leaf area of potato leaf was significantly affected by the varieties at 55 DAP (Table 34). At 55 DAP, the maximum leaf area plant^{-1} (15.27 cm^2) was recorded from V_3 (BARI Alu-29) which was statistically similar to (14.99 cm^2) in V_2 (BARI Alu-28). The minimum leaf area plant^{-1} (14.31 cm^2) was counted from V_1 (BARI Alu-25) which was statistically similar to V_2 (BARI Alu-28) with (14.99 cm^2).

4.1.4.2 Effect of organic manures

Leaf area of potato leaves was significantly affected by the organic manures at 55 DAP (Table 34). At 55 DAP, the maximum leaf area plant^{-1} (15.23 cm^2) was recorded from O_3 (ACI organic fertilizer) which was statistically similar to O_1 (cowdung) (14.99 cm^2). The minimum leaf area (14.34 cm^2) was measured from poultry litter which was statistically similar to (14.99 cm^2) with O_1 (cowdung).

4.1.4.3 Effect of mulch materials

Leaf area of potato leaves was significantly affected by the mulch materials at 55 DAP (Table 34). At 55 DAP, the maximum leaf area plant^{-1} (15.31 cm^2) was recorded from rice straw (M_2) which was statistically similar to water hyacinth (M_1) (14.90 cm^2). The minimum leaf area plant^{-1} (14.35 cm^2) was also measured from rice husk (M_3) which was statistically similar to (14.90 cm^2) with water hyacinth (M_1).

4.1.4.4 Interaction effect of varieties and organic manures

Leaf area of potato leaves was significantly affected by the variety and organic manures interaction at 55 DAP (Table 35). At 55 DAP, maximum leaf area plant^{-1} was recorded from the combination V_1O_3 (14.48 cm^2) which was statistically similar with all the interactions except V_2O_1 (12.49 cm^2). Beside the minimum leaf area plant^{-1} was also measured from V_1O_1 (12.49 cm^2) which was also statistically similar to V_1O_2 (13.82 cm^2) and V_2O_2 (13.69 cm^2).

4.1.4.5 Interaction effect of varieties and mulch materials

Leaf area of potato leaf was significantly affected by the variety and mulch materials at 55 DAP (Table 35). At 55 DAP, the maximum leaf area plant^{-1} was recorded from combination of V_3M_2 (15.06 cm^2) which was statistically similar to all the combinations except V_1M_1 and V_1M_3. On the other hand, the minimum leaf area plant^{-1} was also measured from V_1M_3 (13.40 cm^2) which was also statistically similar to all the combinations except V_1M_1.

4.1.4.6 Interaction effect of organic manures and mulch materials

Leaf area of potato leaf was significantly affected by the organic manures and mulch materials at 55 DAP (Table 35). At 55 DAP, the highest leaf area plant^{-1} was recorded from combination O_3M_2 (16.65 cm^2) followed by O_2M_2 (15.50 cm^2), O_3M_1 (15.32 cm^2), O_1M_3 (15.31 cm^2), O_1M_1 (14.87 cm^2) , O_1M_2 (14.78 cm^2) , O_3M_3 (14.74 cm^2) and O_2M_1 (14.53 cm^2). But the minimum leaf area plant^{-1} was measured from O_2M_3 (13.00 cm^2) which was statistically similar to O_2M_1 (14.53 cm^2).

4.1.4.7 Interaction effect of variety, organic manures and mulch materials

Significant variation of leaf area plant^{-1} was observed due to interactional effect of variety, organic manures and mulch materials in potato (Table 36). The maximum leaf area plant^{-1} was recorded from combination $V_3O_1M_3$ (17.10 cm^2) which was statistically similar to other treatments except $V_1O_1M_2$(13.52 cm^2), $V_1O_1M_3$(13.76 cm^2), $V_2O_2M_1$(14.03 cm^2), $V_2O_2M_1$(14.03 cm^2), $V_1O_1M_1$(13.03 cm^2), $V_1O_1M_2$ (12.85 cm^2) and $V_3O_2M_3$ (10.86 cm^2). The minimum leaf area plant^{-1} was measured from $V_3O_2M_3$ (10.86 cm^2) which was statistically similar to $V_1O_1M_2$ (12.85 cm^2) and $V_1O_1M_1$(13.03 cm^2).

4.1.5 Above ground dry matter content (%) of plant hill^{-1}

No significant variation was observed in potato plant dry matter content due to varieties, organic manures, mulch materials, interaction of variety × organic manure, interaction of variety × mulch material, interaction of organic manure × mulch material and interaction of variety × organic manure × mulch material (Table 34, 35 and 36).

Table 36. Interaction effect of varieties, organic manures and mulch materials on the growth characteristics of potato

Interaction of variety × organic manure × mulch material	Plant height at 85 DAP(cm)	Stem hill^{-1} at 85 DAP (no.)	SPAD value in leaf at 55 DAP	Leaf area plant^{-1} at 55 DAP (cm^2)	Dry matter content of plant hill^{-1} (%)
$V_1O_1M_1$	74.60	4.30 ab	53.74	13.03 e-g	11.16
$V_1O_1M_2$	81.97	3.67 b-g	53.76	12.85 fg	10.88
$V_1O_1M_3$	85.69	3.67 b-g	54.38	13.76 c-f	10.49
$V_1O_2M_1$	79.67	3.99 a-e	55.71	14.79 a-f	10.30
$V_1O_2M_2$	78.69	3.93 a-e	52.65	15.64 a-e	10.55
$V_1O_2M_3$	83.63	3.88 a-e	50.51	13.52 d-f	10.35
$V_1O_3M_1$	86.55	4.00 a-e	51.63	14.66 a-f	10.20
$V_1O_3M_2$	80.37	3.00 g-i	50.62	15.89 a-d	9.983
V_1O_3 M_3	78.26	3.00 g-i	52.69	14.67 a-f	10.32
$V_2O_1M_1$	80.58	3.00 g-i	53.90	16.23 a-c	10.76
$V_2O_1M_2$	79.45	3.40 e-g	51.21	15.90 a-d	10.48
$V_2O_1M_3$	76.67	2.48 hi	51.50	15.07 a-f	11.24
$V_2O_2M_1$	75.17	3.74 b-f	53.19	14.03 b-f	10.45
$V_2O_2M_2$	81.97	2.37 i	52.74	15.10 a-f	10.00
V_2O_2 M_3	83.54	4.19 a-c	55.87	14.63 a-f	10.58
V_2O_3 M_1	84.00	4.11 a-d	50.59	14.50 a-f	10.04
$V_2O_3M_2$	75.11	4.00 a-e	52.47	14.67 a-f	10.69
$V_2O_3M_3$	73.28	3.11 f-h	51.58	14.77 a-f	10.30
$V_3O_1M_1$	81.53	3.00 g-i	55.07	15.35 a-f	10.16
$V_3O_1M_2$	72.22	3.11 f-h	58.58	15.60 a-e	10.41
$V_3O_1M_3$	80.13	3.67 b-g	56.99	17.10 a	10.63
$V_3O_2M_1$	77.74	4.18 a-c	56.86	14.76 a-f	9.993
$V_3O_2M_2$	79.11	4.48 a	57.36	15.76 a-d	10.63
$V_3O_2M_3$	82.24	3.89 a-e	55.62	10.86 g	10.94
$V_3O_3M_1$	75.92	3.45 d-g	56.99	16.79 a	10.74
$V_3O_3M_2$	74.67	3.44 d-g	54.22	16.40 ab	10.27
$V_3O_3M_3$	74.00	3.59 c-g	54.46	14.78 a-f	10.11
LSD $_{(0.05)}$	**14.93**	**0.67**	**8.78**	**2.64**	**1.93**
CV (%)	**11.52**	**11.44**	**9.94**	**10.84**	**11.25**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2 Potato yield and yield parameters

4.2.1 Tuber number hill^{-1}

4.2.1.1 Effect of varieties

Significant variation was observed in tuber numbers hill^{-1} in different varieties at harvest in this experiment (Table 37). The maximum tuber number hill^{-1} was obtained from the variety V_1 (BARI Alu-25) (7.56) followed by V_2 (BARI Alu-28) (7.19) while the minimum number was found from the V_3 (BARI Alu-29) (5.70). The probable reason for variation in tuber number hill^{-1} due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site. Anonymous (2009f) conducted an experiment with seven potato varieties where it was found that number of tuber plant^{-1} varied from 5.67 to 8.07.

4.2.1.2 Effect of organic manure

Significant variation was observed on tuber number hill^{-1} influenced by the different organic manures in this experiment (Table 37). The maximum tuber number hill^{-1} was recorded from the O_2 (poultry litter) (7.18) followed by O_3 (ACI organic fertilizer) (6.98) while the minimum was found from the O_1 (cowdung) (6.29).

4.2.1.3 Effect of mulch material

Non-significant difference was observed on tuber number hill^{-1} influenced by the different mulch materials (Table 37). Only numerical variation was found among the effect of different mulch materials. The maximum tuber number hill^{-1} was recorded from the M_3 (rice husk) (6.99) whereas the minimum was found from the M_2 (rice straw) (6.67).

4.2.1.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber number hill^{-1} at harvest in this experiment (Table 38). The maximum tuber number hill^{-1} was recorded in V_1O_3 (8.08) followed by V_1O_2 (8.06) which is statistically similar to V_2O_2 (7.50) while the minimum tuber number hill^{-1} was measured from the V_3O_1 (5.43) followed by V_3O_3 (5.79) which is statistically similar to V_3O_2 (5.99).

4.2.1.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on tuber number per hill in this experiment (Table 38). The maximum tuber number hill^{-1} was recorded in V_1M_1

(8.17) which is statistically similar to V_2M_3 (7.79). The minimum tuber number hill^{-1} was obtained from the V_3M_1(5.50) followed by V_3M_3 (5.79) and V_3M_2 (5.83).

4.2.1.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interactional effect of organic manures and mulch materials on tuber number hill^{-1} (Table 38). The maximum tuber hill^{-1} was recorded in O_2M_3 (7.56) which is statistically similar to O_3M_1 (7.35) and O_2M_2 (7.17). The minimum tuber number hill^{-1} was obtained from the O_1M_2 (6.00) which is statistically similar to O_1M_1 (6.25) and O_1M_3 (6.62.).

4.2.1.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interactional effect of varieties, organic manures and mulch materials on tubers number hill^{-1} (Table 39). The maximum tubers number hill^{-1} was recorded in $V_1O_3M_1$ (9.10) which is statistically similar to $V_1O_2M_3$(8.28), $V_1O_2M_1$(8.10), $V_2O_1M_3$(8.10) and $V_2O_2M_3$(7.95). The minimum tubers number hill^{-1} $V_3O_1M_1$(5.50), $V_3O_1M_2$(5.59), $V_3O_3M_1$(5.64), $V_3O_3M_3$(5.71), $V_3O_3M_2$(5.73), $V_1O_1M_2$(5.79), $V_2O_1M_1$(5.95) and $V_3O_2M_2$(6.16)

4.2.2 Tuber weight hill^{-1} (kg)

4.2.2.1 Effect of varieties

Significant variation was observed in tuber weight hill^{-1} (kg.) in different varieties at harvest in this experiment (Table 37). The maximum tuber weight hill^{-1} was obtained from the variety V_1 (BARI Alu-25) (0.379 kg) while the minimum was found from the V_3 (BARI Alu-29) (0.297 kg). The probable reason for variation in tuber weight hill^{-1} due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site. Karim *et al.* (2011) also found that the highest total tuber weight per plant (344.60g) recorded in var. Diamant.

4.2.2.2 Effect of organic manure

Significant variation was observed on tuber weight hill^{-1} influenced by the different organic manures in this experiment (Table 37). The maximum tuber weight was recorded from the O_2 (poultry litter) (0.3459 kg.) followed by O_3 (ACI organic fertilizer) (0.3437 kg.) while the minimum was found from the O_1 (cowdung) (0.2981 kg.).

4.2.2.3 Effect of mulch materials

Non-significant difference was observed on tuber weight $hill^{-1}$ influenced by the different mulch materials (Table 37). Only numerical variation was found among the effect of mulch materials. The maximum tuber weight $hill^{-1}$ was recorded from the water hyacinth (M_1) and rice straw (M_2) (0.33 kg.) whereas the minimum was found from the rice husk (M_3) (0.32 kg.).

4.2.2.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber weight $hill^{-1}$ at harvest in this experiment (Table 38). The maximum tuber weight $hill^{-1}$ was recorded in V_1O_2(0.39 kg.) followed by V_1O_3(0.39 kg.). The minimum tuber weight $hill^{-1}$ was obtained from the V_2O_1(0.29 kg.) followed by V_3O_1(0.29 kg.) which is statistically similar to V_3O_3(0.30 kg.) and V_3O_2(0.31 kg.)

4.2.2.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on tuber weight $hill^{-1}$ in this experiment (Table 38). The maximum tuber weight $hill^{-1}$ was recorded in V_1M_1 (0.40 kg.) which is statistically similar to V_1M_2 (0.37 kg.). The minimum tuber weight $hill^{-1}$ was obtained from the V_3M_3(0.29 kg.) followed by V_3M_1(0.30 kg.) which are statistically similar to V_2M_1 (0.31 kg.) and V_3M_2 (0.31 kg.)

4.2.2.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on tuber weight $hill^{-1}$ (Table 38). The maximum tuber weight $hill^{-1}$ was recorded in O_3M_2(0.36 kg.) followed by O_2M_2(0.35 kg.), O_3M_1(0.35 kg.), O_2M_1(0.34 kg.) and O_2M_3(0.34 kg.) which are statistically similar to O_3M_3 (0.33 kg.). The minimum tuber weight $hill^{-1}$ was obtained from the O_1M_2 (0.29 kg.) followed by O_1M_3 (0.29 kg.) which are statistically similar to O_1M_1 (0.31 kg.).

4.2.2.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on tubers weight $hill^{-1}$ (Table 39). The maximum tuber weight $hill^{-1}$ was recorded in $V_1O_3M_1$(0.43 kg.) which is statistically similar to $V_1O_2M_1$(0.41 kg.), $V_1O_2M_2$(0.41 kg.) and $V_1O_3M_2$(0.40 kg.). The minimum tuber weight $hill^{-1}$ was found from

$V_2O_1M_1$(0.26 kg.) which is statistically similar to $V_3O_1M_2$(0.27 kg.), $V_3O_1M_3$(0.27 kg.), $V_2O_1M_3$(0.29 kg.), $V_3O_2M_1$(0.29 kg.), $V_3O_3M_1$(0.29 kg.), $V_3O_3M_3$(0.29 kg.), $V_1O_1M_2$ (0.30 kg.), $V_2O_1M_2$ (0.31 kg.), $V_3O_1M_1$(0.31 kg.) and $V_3O_2M_2$(0.31 kg.).

Table 37. Effect of varieties, organic manures and mulch materials on the yield and yield contributing characteristics of potato

Treatments	Tuber no. hill^{-1}	Tuber weight hill^{-1} (kg)	Potato yield (t ha^{-1})	Marketable potato (>20g) yield (t ha^{-1})	Non-marketable potato (<20g) yield (t ha^{-1})	Marketable tuber no. (%)	Marketable tuber weight (%)
Effect of variety							
V_1	7.563 a	0.3693 a	36.96 a	34.98 a	1.99 a	73.60 b	94.56
V_2	7.192 a	0.3207 b	31.92 b	30.19 b	1.73 b	78.33 a	94.51
V_3	5.703 b	0.2978 c	29.49 c	28.27 c	1.22 c	80.04 a	95.84
LSD $_{(0.05)}$	**0.38**	**0.02**	**1.78**	**1.69**	**0.10**	**4.22**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**
Effect of organic manure							
O_1	6.291 b	0.2981 b	29.71 b	28.11 b	1.60 b	76.82	94.64
O_2	7.183 a	0.3459 a	34.38 a	32.67 a	1.71 a	77.19	95.05
O_3	6.985 a	0.3437 a	34.28 a	32.65 a	1.63 ab	77.95	95.21
LSD $_{(0.05)}$	**0.38**	**0.02**	**1.78**	**1.69**	**0.10**	**NS**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**
Effect of mulch material							
M_1	6.80	0.33	33.22	31.49 ab	1.73 a	77.21	94.80
M_2	6.67	0.33	33.33	31.83 a	1.50 b	78.57	95.47
M_3	6.99	0.32	31.82	30.11 b	1.71 a	76.19	94.63
LSD $_{(0.05)}$	**0.38**	**0.02**	**1.78**	**1.69**	**0.10**	**NS**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.3 Potato tuber yield (t ha^{-1})

4.2.3.1 Effect of varieties

Variety had significant effect on the yield of tuber (Table 37). The table shows that variety V_1 (36.96 t ha^{-1}) out yielded over V_2 (31.92 t ha^{-1}) and V_3 (29.49 t ha^{-1}) by producing 15.79% and 25.33% higher tuber yield of potato, respectively. The probable reason for variation in yield due to the heredity of the variety. Similar pattern of yield performance was also reported by Hossain (2011).

4.2.3.2 Effect of organic manures

Tuber yield of potato was significantly influenced by the different organic manures (Table 37). The highest tuber yield (34.38 t ha^{-1}), which was statistically similar yield (34.28 t ha^{-1}) were recorded from the poultry litter (O_2) and ACI organic fertilizer (O_3), respectively, and the minimum yield (29.71 t ha^{-1}) was found from the cowdung (O_1). This variation might be due to change the yield contributing characteristics under different organic manures. The result corroborates with the findings of Alam *et al.* (2007) where they found that application of vermicompost and NPKS significantly influenced the growth and yield of potato.

4.2.3.3 Effect of mulch materials

Tuber yield was not affected significantly due to use of different mulch materials (Table 37). Numerically the highest tuber yield (33.33 t ha^{-1}) was recorded from the rice straw (M_2) followed by (33.22 t ha^{-1}) from the water hyacinth (M_1). The minimum (31.82 t ha^{-1}) was found from the rice husk. This variation might be due to change the yield contributing characteristics under different mulch materials. Bhuyan (2003) also found that the highest yield was obtained from rice straw mulch followed by sawdust. On the other hand, Jalil (1995) also found that black polythene and water hyacinth had no significant effect on potato yield.

4.2.3.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber yield of potato (Table 38). The maximum tuber yield (39.45 t ha^{-1}) was recorded in V_1O_3 followed by V_1O_2 (39.09 t ha^{-1}). The minimum tuber yield (28.21 t ha^{-1}) was observed in V_3O_1 which is statistically similar to V_2O_1 (28.55 t ha^{-1}), V_3O_2 (30.09 t ha^{-1}) and V_3O_3 (30.16 t ha^{-1}).

4.2.3.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on tuber yield of potato (Table 38). The maximum tuber yield (39.56 t ha^{-1}) was recorded in V_1M_1 followed by V_1M_2 (36.92 t ha^{-1}) which are statistically similar. The minimum tuber yield (28.53 t ha^{-1}) was recorded from V_3M_3 which is also statistically similar to V_3M_1 (29.63 t ha^{-1}) , V_3M_2 (30.30 t ha^{-1}) and V_2M_1 (30.48 t ha^{-1}).

4.2.3.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on tuber yield of potato (Table 38). The maximum tuber yield (35.44 t ha^{-1}) was recorded in O_3M_2 followed by O_2M_2 (35.37 t ha^{-1}), O_3M_1 (34.52 t ha^{-1}) , O_2M_1 (34.38 t ha^{-1}), O_2M_3 (33.39 t ha^{-1}) and O_3M_3 (32.88 t ha^{-1}) were measured but they are statistically similar. The minimum tuber yield was recorded (29.17 t ha^{-1}) from O_1M_3 followed by O_1M_2 (29.18 t ha^{-1}) and O_1M_1 (30.76 t ha^{-1}).

4.2.3.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interactional effect of variety, organic manures and mulch materials on tuber yield of potato (Table 39). The highest tuber yield (42.36 t ha^{-1}) was recorded in $V_1O_3M_1$ followed by $V_1O_2M_2$ (40.95 t ha^{-1}), $V_1O_2M_1$ (40.82 t ha^{-1}) and $V_1O_3M_2$ (39.74 t ha^{-1}). The minimum tuber yield was recorded (26.02 t ha^{-1}) from $V_2O_1M_1$ which was all statistically similar to $V_3O_1M_3$ (26.88), $V_3O_1M_2$(26.98) , $V_3O_3M_3$(28.26), $V_3O_2M_1$(28.82), $V_2O_1M_3$ (29.14), $V_3O_3M_1$(29.29), $V_1O_1M_2$ (30.08) , $V_3O_2M_3$(30.45), $V_3O_1M_1$(30.77) and $V_3O_2M_2$(30.99).

4.2.4 Marketable potato tuber yield (t ha^{-1})

4.2.4.1 Effect of varieties

Variety had significant effect on the marketable yield of potato tuber (Table 37). The variety V_1 (34.98 t ha^{-1}) showed its superiority by producing 15.87 % and 23.74% higher marketable potato yield than V_2 (30.19 t ha^{-1}) and V_3 (28.27 t ha^{-1}), respectively. Similar trend of yield performance was also reported by Hossain (2011). The probable reason for variation in yield due to the genetic make up of the variety.

4.2.4.2 Effect of organic manures

Marketable tuber yield exerted significant influence due to different organic manures (Table 37). O_2 (poultry litter) and O_3 (ACI organic fertilizer) performed better than O_1 (cowdung) in respect of marketable potato yield. The highest tuber yield (32.67 t ha^{-1}) was recorded from O_2 (poultry litter) which was statistically similar to (32.65 t ha^{-1}) from O_3 (ACI organic fertilizer) and the minimum yield (28.11 t ha^{-1}) was found from the O_1(cowdung). This variation might be due to change the yield contributing characteristics under different organic manures.

Table 38. Interaction effect of varieties, organic manures and mulch materials on the yield and yield contributing characteristics of potato

Interaction of Treatments	Tuber no. hill^{-1}	Tuber weight hill^{-1} (kg)	Potato yield (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})	Marketable tuber no. (%)	Marketable tuber weight (%)
Interaction effect of variety and organic manure							
V_1O_1	6.55 cd	0.32 b-d	32.35 bc	30.52 bc	1.83 b	72.21 b	94.34
V_1O_2	8.06 a	0.39 a	39.09 a	36.97 a	2.11 a	73.37 ab	94.48
V_1O_3	8.08 a	0.39 a	39.45 a	37.44 a	2.01 a	75.21 ab	94.85
V_2O_1	6.90 bc	0.29 e	28.55 d	26.79 d	1.76 bc	77.61 ab	93.85
V_2O_2	7.50 ab	0.34 b	33.97 b	32.14 b	1.83 b	77.97 ab	94.59
V_2O_3	7.18 bc	0.33 bc	33.24 b	31.62 bc	1.61 c	79.40 ab	95.09
V_3O_1	5.43 e	0.28 e	28.21 d	27.02 d	1.19 d	80.65 a	95.73
V_3O_2	5.99 de	0.31 c-e	30.09 cd	28.90 cd	1.19 d	80.22 a	96.09
V_3O_3	5.70 e	0.30 de	30.16 cd	28.89 cd	1.27 d	79.24 ab	95.70
LSD $_{(0.05)}$	**0.67**	**0.03**	**3.08**	**2.93**	**0.17**	**7.31**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**
Interaction effect of variety and mulch material							
V_1M_1	8.17 a	0.40 a	39.56 a	37.31 a	2.25 a	72.55 bc	94.28
V_1M_2	7.14 bc	0.37 ab	36.92 ab	35.27 ab	1.65 d	76.16 a-c	95.49
V_1M_3	7.39 bc	0.34 bc	34.41 bc	32.35 bc	2.06 b	72.09 c	93.91
V_2M_1	6.75 c	0.31 de	30.48 d-f	28.81 de	1.67 d	79.46 ab	94.52
V_2M_2	7.04 c	0.33 cd	32.77 cd	31.11 cd	1.66 d	78.87 a-c	94.93
V_2M_3	7.79 ab	0.33 cd	32.51 c-e	30.63 cd	1.88 c	76.65 a-c	94.08
V_3M_1	5.50 d	0.30 e	29.63 ef	28.34 de	1.29 e	79.62 ab	95.62
V_3M_2	5.83 d	0.30 de	30.30 d-f	29.11 de	1.18 e	80.67 a	96.00
V_3M_3	5.79 d	0.29 e	28.53 f	27.35 e	1.18 e	79.83 ab	95.91
LSD $_{(0.05)}$	**0.67**	**0.03**	**3.08**	**2.93**	**0.17**	**7.31**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**
Interaction effect of organic manure and mulch material							
O_1M_1	6.25 de	0.31 bc	30.76 bc	29.14 bc	1.63 bc	78.08	94.75
O_1M_2	6.00 e	0.29 c	29.18 c	27.78 c	1.40 d	77.86	95.18
O_1M_3	6.62 c-e	0.29 c	29.17 c	27.42 c	1.76 ab	74.53	93.99
O_2M_1	6.81 b-d	0.34 a	34.38 a	32.72 a	1.65 bc	76.95	95.28
O_2M_2	7.17 a-c	0.35 a	35.37 a	33.72 a	1.65 bc	77.91	95.25
O_2M_3	7.56 a	0.34 a	33.39 ab	31.57 ab	1.83 a	76.71	94.63
O_3M_1	7.35 ab	0.35 a	34.52 a	32.60 a	1.92 a	76.59	94.38
O_3M_2	6.83 b-d	0.36 a	35.44 a	34.00 a	1.43 d	79.92	95.99
O_3M_3	6.78 b-d	0.33 ab	32.88 ab	31.35 ab	1.54 cd	77.33	95.27
LSD $_{(0.05)}$	**0.67**	**0.03**	**3.08**	**2.93**	**0.17**	**NS**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.4.3 Effect of mulch materials

Significant difference was observed on marketable potato tuber yield due to different mulch materials (Table 37). The maximum marketable tuber yield (31.83 t ha^{-1}) was recorded from the M_2 (rice straw) which was statistically similar to (31.49 t ha^{-1}) from the M_1(water hyacinth). The minimum marketable tuber yield (30.11 t ha^{-1}) was found from the M_3 (rice husk) which was statistically similar to (31.49 t ha^{-1}) from the M_1 (water hyacinth). This variation might be due to change the yield contributing characteristics of potato under different mulch materials.

4.2.4.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on marketable yield of potato tuber (Table 38). The maximum marketable tuber yield (37.44 t ha^{-1}) was recorded in V_1O_3 which was followed by V_1O_2 (36.97 t ha^{-1}). The minimum tuber yield (26.79 t ha^{-1}) was observed in V_2O_1 which was statistically similar to V_3O_1 (27.02 t ha^{-1}), V_3O_3 (28.89 t ha^{-1}) and V_3O_2 (28.90 t ha^{-1}).

4.2.4.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on marketable yield of potato tuber (Table 38). The maximum marketable tuber yield (37.31 t ha^{-1}) was recorded in V_1M_1 which was statistically similar to V_1M_2 (35.27 t ha^{-1}). The minimum marketable tuber yield (27.35 t ha^{-1}) from V_3M_3 which is also statistically similar to V_3M_2 , V_3M_1 and V_2M_1 (29.11, 28.34 and 28.81 t ha^{-1}, respectively).

4.2.4.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interactional effect of organic manures and mulch materials on marketable yield of potato tuber. (Table 38). The maximum marketable potato tuber yield (34.00 t ha^{-1}) was recorded in O_3M_2 which was statistically at par with O_2M_2, O_2M_1, O_2M_1, O_2M_3 and O_3M_3 (33.72, 32.72, 32.60, 31.57 and 31.35 t ha^{-1} , respectively). The minimum marketable potato tuber yield was recorded (27.42 t ha^{-1}) from O_1M_3 which is also statistically similar with O_1M_2 and O_1M_1 (27.78 and 29.14 t ha^{-1} , respectively).

4.2.4.7 Interaction effect of varieties, organic manures and mulch materials

Interaction of varieties, organic manures and mulch materials exerted significant variation on marketable yield of potato tubers (Table 39). The table shows that the highest marketable tuber yield (40.05 t ha^{-1}) was recorded in $V_1O_3M_1$ combination which is statistically similar with $V_1O_2M_2$, $V_1O_2M_1$ and $V_1O_3M_2$ (39.19 , 38.55 and 37.92 t ha^{-1} , respectively.). The lowest marketable tuber yield was recorded (24.61 t ha^{-1}) from $V_2O_1M_1$ which is also statistically similar to $V_3O_1M_2$, $V_3O_1M_3$, $V_2O_1M_3$, $V_3O_3M_3$, $V_3O_3M_1$, $V_1O_1M_2$, $V_3O_2M_1$, $V_2O_1M_2$, $V_3O_2M_3$, $V_3O_1M_1$, $V_1O_1M_3$ and $V_3O_2M_2$ combinations.

4.2.5 Non-marketable potato tuber yield t ha^{-1}

4.2.5.1 Effect of varieties

Variety had significant effect on the non-marketable yield of potato tuber (Table 37). The highest non-marketable tuber yield (1.99 t ha^{-1}) was obtained from the variety V_1 (BARI Alu-25) while the minimum (1.22 t ha^{-1}) was found from the V_3 (BARI Alu-29). Yield differences among the potato varieties was also reported by Kundu *et al.* (2012) and Hossain (2011) which corroborates with the present result.

4.2.5.2 Effect of organic manures

Non-marketable tuber yield varied significantly due to different organic manures (Table 37). O_2 (poultry litter) showed the highest non-marketable tuber yield (1.71 t ha^{-1}) which was statistically similar to (1.63 t ha^{-1}) from O_3 (ACI organic fertilizer) and the minimum (1.60 t ha^{-1}) was found from the O_1 (cowdung) which was also statistically similar to O_3 (ACI organic fertilizer).

4.2.5.3 Effect of mulch materials

Significant difference was observed on non-marketable tuber yield as influenced by the different mulch materials (Table 37). The maximum non-marketable tuber yield (1.73 t ha^{-1}) was recorded from the M_1 (water hyacinth) which was statistically similar to (1.70 t ha^{-1}) to M_3 (rice husk). The minimum marketable yield (1.50 t ha^{-1}) was found from the M_2 **(**rice straw).

4.2.5.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on non-marketable potato tuber yield (Table 38). The result revealed that interaction of V_1O_2 showed the highest non-marketable tuber yield (2.11 t ha^{-1}) which was at par with V_1O_3 (2.01 t ha^{-1}) where as the lowest tuber yield measured from both V_3O_1 and V_3O_2 interactions (1.19 t ha^{-1}), which were at par with V_3O_3 interaction (1.27 t ha^{-1}).

4.2.5.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on non-marketable tuber yield (Table 38). Significantly highest yield was found with V_1M_1 interaction (2.25 t ha^{-1}). On the other hand, the lowest non-marketable yield was recorded from both V_3M_3 and V_3M_2 interactions (1.18 t ha^{-1}), which were at par with V_3M_1 (1.29 t ha^{-1}

4.2.5.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on non-marketable yield of tuber in the present experiment (Table 38). The maximum non-marketable tuber yield (1.92 t ha^{-1}) was recorded in O_3M_1 which was followed by O_2M_3 (1.83 t ha^{-1}) and O_1M_3 (1.76 t ha^{-1}). The minimum tuber yield was recorded (1.40 t ha^{-1}) from O_1M_2 followed by O_3M_2 (1.43 t ha^{-1}) and O_3M_3 (1.54 t ha^{-1}).

4.2.5.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on non-marketable yield of potato tubers (Table 39). The maximum non-marketable tuber yield (2.32 t ha^{-1}) was recorded in $V_1O_2M_3$ followed by $V_1O_3M_1$ (2.31 t ha^{-1}), $V_1O_2M_1$ (2.27 t ha^{-1}) , $V_2O_1M_3$ (2.23 t ha^{-1}), $V_1O_1M_1$ (2.15 t ha^{-1}) and V_2O_2 M_3 (2.04 t ha^{-1}). The minimum non-marketable tuber yield was recorded (0.90 t ha^{-1}) from $V_3O_3M_2$ which are statistically similar to $V_3O_2M_1$ (1.00), $V_3O_1M_3$ (1.06) and $V_3O_2M_3$ (1.13).

Table 39. Interaction effect of variety, organic manure and mulch material on the yield and yield contributing characteristics of potato

Interaction (variety×organic manure × mulch material)	Tuber no. $hill^{-1}$	Tuber weight $hill^{-1}$ (kg)	Potato yield (t ha^{-1})	Marketable potato yield (t ha^{-1})	Non-marketable potato yield (t ha^{-1})	Marketable tuber no. (%)	Marketable tuber weight (%)
$V_1O_1M_1$	7.30 b-f	0.36 b-e	35.49 c-e	33.33 c-e	2.15 a-c	71.93 ab	93.95
$V_1O_1M_2$	5.79 h-k	0.30 f-i	30.08 f-j	28.71 e-i	1.37 i-l	75.17 ab	95.41
$V_1O_1M_3$	6.57 f-i	0.32 d-h	31.50 d-i	29.52 d-i	1.97 b-e	69.54 b	93.65
$V_1O_2M_1$	8.10 a-c	0.41 ab	40.82 a-c	38.55 ab	2.27 ab	72.04 ab	94.37
$V_1O_2M_2$	7.80 b-d	0.41 ab	40.95 ab	39.19 ab	1.76 d-g	76.85 ab	95.66
$V_1O_2M_3$	8.28 ab	0.35 c-e	35.49 c-e	33.18 c-e	2.32 a	71.23 ab	93.42
$V_1O_3M_1$	9.10 a	0.43 a	42.36 a	40.05 a	2.31 a	73.68 ab	94.50
$V_1O_3M_2$	7.83 b-d	0.40 a-c	39.74 a-c	37.92 a-c	1.82 d-g	76.44 ab	95.41
$V_1O_3 M_3$	7.31 b-f	0.36 b-d	36.25 b-d	34.35 b-d	1.90 c-f	75.50 ab	94.65
$V_2O_1M_1$	5.95 g-k	0.26 i	26.02 j	24.61 i	1.41 h-l	81.72 ab	94.62
$V_2O_1M_2$	6.63 e-i	0.31 e-i	30.49 e-j	28.85 e-i	1.63 f-i	77.02 ab	94.64
$V_2O_1M_3$	8.10 a-c	0.29 f-i	29.14 f-j	26.91 g-i	2.23 ab	74.09 ab	92.29
$V_2O_2M_1$	6.99 c-g	0.34 d-g	33.50 d-h	31.80 d-g	1.70 e-h	78.35 ab	94.91
$V_2O_2M_2$	7.57 b-e	0.34 d-f	34.17 d-f	32.42 d-f	1.75 d-g	79.54 ab	94.84
$V_2O_2 M_3$	7.95 a-d	0.34 d-f	34.23 d-f	32.20 d-f	2.04 a-d	76.03 ab	94.01
$V_2O_3 M_1$	7.30 b-f	0.32 d-h	31.92 d-i	30.02 d-h	1.89 c-f	78.31 ab	94.02
$V_2O_3M_2$	6.92 d-h	0.34 d-f	33.64 d-g	32.06 d-f	1.58 g-j	80.06 ab	95.31
$V_2O_3M_3$	7.31 b-f	0.34 d-f	34.15 d-g	32.78 d-f	1.37 i-l	79.83 ab	95.93
$V_3O_1M_1$	5.50 i-k	0.31 e-i	30.77 e-j	29.46 d-i	1.32 j-m	80.60 ab	95.69
$V_3O_1M_2$	5.59 i-k	0.27 hi	26.98 ij	25.77 hi	1.20 k-n	81.39 ab	95.48
$V_3O_1M_3$	5.19 k	0.27 hi	26.88 ij	25.82 hi	1.06 m-o	79.95 ab	96.03
$V_3O_2M_1$	5.35 jk	0.29 g-i	28.82 g-j	27.82 f-i	1.00 no	80.46 ab	96.54
$V_3O_2M_2$	6.16 g-k	0.31 d-i	30.99 d-j	29.55 d-i	1.45 h-k	77.34 ab	95.26
$V_3O_2M_3$	6.46 e-j	0.33 d-g	30.45 e-j	29.32 d-i	1.13 l-o	82.87 a	96.47
$V_3O_3M_1$	5.64 i-k	0.29 f-i	29.29 f-j	27.74 f-i	1.56 g-j	77.80 ab	94.63
$V_3O_3M_2$	5.73 i-k	0.33 d-g	32.92 d-h	32.02 d-f	0.90 o	83.27 a	97.25
$V_3O_3M_3$	5.71 i-k	0.29 g-i	28.26 h-j	26.92 g-i	1.34 i-m	76.66 ab	95.23
LSD (0.05)	**1.15**	**0.05**	**5.33**	**5.07**	**0.30**	**12.67**	**NS**
CV (%)	**10.30**	**10.52**	**9.92**	**9.94**	**10.98**	**10.00**	**10.51**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.6 Marketable tuber number (%)

4.2.6.1 Effect of varieties

Significant effect on the marketable tuber percent by number was observed in different varieties (Table 37). The highest marketable tuber percent (80.04%) was obtained from the variety V_3 (BARI Alu-29) which was statistically similar to V_2 (BARI Alu-28) (78.33%), while the minimum (73.60%) was found from the V_1 (BARI Alu-25). The probable reason for variation in yield due to the genetic variability among the varieties which is governed by the genetic make up of the varieties.

4.2.6.2 Effect of organic manure

Marketable tuber percent by number has no significant influence by the different organic manures (Table 37).

4.2.6.3 Effect of mulch materials

Non-significant difference was observed on marketable tuber percent due to different mulch materials (Table 37).

4.2.6.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on marketable tuber percent by number in this experiment (Table 38). The maximum marketable tuber percent (80.65%) was recorded in V_3O_1 which was statistically similar with all other combinations except V_1O_1 combination (72.21%). Significantly the minimum marketable tuber percent (72.21%) was observed in V_1O_1 which was statistically similar with all other combinations except V_3O_1 and V_3O_2 combinations (80.65% and 80.22%, respectively).

4.2.6.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on marketable tuber percent by number (Table 38). The highest marketable tuber percent by number was recorded in V_2M_3 (80.67%) which was statistically similar to V_3M_3 (79.83%), V_3M_1 (79.62 %), V_2M_1 (79.46%), V_2M_2 (78.87%)), V_2M_3 (76.65%) and V_1M_2 (76.16%). The lowest marketable tuber percent by number was recorded in V_1M_3 (72.09%) which was statistically significant with V_1M_1 , V_1M_2 , V_2M_3 and V_2M_2 (72.55%, 76.16% , 76.65% and 78.87%, respectively).

4.2.6.6 Interaction effect of organic manures and mulch materials

Non-significant variation was found due to interaction effect of organic manures and mulch materials on marketable tuber percent by number in potato (Table 38).

4.2.6.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on marketable tubers percent by number in potato (Table 39). The maximum marketable tubers percent by number was observed from $V_3O_3M_2$(83.27%) which was statistically similar with all the interactions except $V_1O_1M_3$ (69.54%). The minimum marketable tuber percent by number was recorded from $V_1O_1M_3$ (69.54%) which was statistically at par with all other interactions except $V_3O_3M_2$ and $V_3O_2M_3$ combinations (83.27% and 82.87%, respectively).

4.2.7 Marketable tuber weight (%)

Effect of varieties, organic manure, mulch materials, interaction of variety × organic manure, interaction of variety × mulch materials, interaction of organic manure × mulch materials and interaction of variety × organic manure × mulch material exerted non significant variation on marketable potato tuber weight by percentage (Table 37, 38 and 39).

4.2.8 Marketable tuber (>75 g) yield (t ha^{-1})

4.2.8.1 Effect of varieties

Variety exihited significant variation in producing various sized tuber >75 g, 50-75 g, 20-50 g and chips tuber, dehydrated tuber, french fry tuber and canned tuber yield in the present experiment (Table 40). The result revealed that V_1 (BARI Alu-25) variety showed the highest yield on >75 g tuber, dehydrated tuber, french fry tuber and canned tuber (16.10, 2.67, 8.02 and 0.91 tha^{-1}, respectively). On the contrary, V_2 (BARI Alu-28) variety exhibited highest yield of 50-75g tuber, 20-50g tuber and chips tuber (8.89, 9.40 and 25.00 tha^{-1}, respectively). Significantly lowest yield was recorded from V_3 (BARI Alu-29) variety in producing 50-75 g tuber, 20-50 g tuber, dehydrated tuber and canned tuber (7.23, 6.58, 1.03 and 0.40 tha^{-1} , respectively. On the other hand V_2 showed the lowest of >75g tuber and french fry tuber (9.13 and 0.00 tha^{-1}, respectively).

4.2.8.2 Effect of organic manures

There was observed a significant variation among the tested organic manures on >75g tuber, 50-75g tuber, 20-50g tuber, chips tuber, dehydrated tuber, french fry tuber and canned tuber in the present experiment (Table 40). The result revealed that organic manure applied through O_3 (ACI organic fertilizer) exerted highest yield on >75g tuber, chips tuber, dehydrated tuber and french fry tuber yield (13.62, 23.43, 2.08 and 3.22 tha^{-1}, respectively). On the other hand, O_2 organic manure (poultry litter) exhibited highest yield on 50-75g tuber, 20-50g tuber and canned tuber (8.34, 8.40 and 0.65 tha^{-1}, respectively). The result showed that O_3 and O_2 gave the statistically similar yield on >75g tuber, 50-75g tuber, and canned tuber. However, the lowest yield was observed in potato tuber production with O_1 (cowdung) organic manure.

Table 40. Effect of variety, organic manure and mulch material on the yield of different sizes of potato tuber

Treatment	Yield of >75g tuber ($t\ ha^{-1}$)	Yield of 50-75 g tuber ($t\ ha^{-1}$)	Yield of 20-50 g tuber ($t\ ha^{-1}$)	Yield of chips tuber (45-75mm) ($t\ ha^{-1}$)	Yield of dehydrated tuber (30-45 mm) ($t\ ha^{-1}$)	Yield of french fry tuber (>75mm) ($t\ ha^{-1}$)	Yield of canned tuber (20-30mm) ($t\ ha^{-1}$)
Effect of variety							
V_1	16.10 a	8.20 b	7.484 b	18.15 c	2.67 a	8.02 a	0.90 a
V_2	9.13 c	8.89 a	9.397 a	25.00 a	1.41 b	0.00 b	0.55 b
V_3	12.10 b	7.23 c	6.579 c	22.70 b	1.03 c	0.05 b	0.40 c
LSD $_{(0.05)}$	**0.73**	**0.47**	**0.49**	**1.16**	**0.15**	**0.31**	**0.04**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**
Effect of organic manure							
O_1	10.57 b	7.79 b	7.206 c	20.45 c	1.16 c	2.09 c	0.58 b
O_2	13.15 a	8.34 a	8.402 a	21.97 b	1.88 b	2.76 b	0.65 a
O_3	13.62 a	8.19 ab	7.853 b	23.43 a	2.07 a	3.22 a	0.62 ab
LSD $_{(0.05)}$	**0.73**	**0.47**	**0.49**	**1.16**	**0.15**	**0.31**	**0.04**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**
Effect of mulch material							
M_1	12.81 a	8.26 a	7.578 b	22.01 a	1.91 a	2.70 a	0.70 a
M_2	13.13 a	8.29 a	7.501 b	23.03 a	1.85 a	3.01 a	0.56 b
M_3	11.40 b	7.76 b	8.381 a	20.81 b	1.35 b	2.36 b	0.59 b
LSD $_{(0.05)}$	**0.73**	**0.47**	**0.49**	**1.16**	**0.15**	**0.31**	**0.04**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.8.3 Effect of mulch materials

Result presented in table 40 showed significant variation on >75g tuber, 50-75g tuber, 20-50g tuber, chips tuber, dehydrated tuber, french fry tuber and canned tuber production due to different mulch materials (Table 40). M_2 (rice straw) showed the highest >75g tuber, 50-75g tuber, chips tuber and french fry tuber (13.13, 8.29, 23.03 and 3.01 tha^{-1}, repectively), but M_1 (water hyacinth) showed the highest dehydrated tuber and canned tuber (1.91 and 0.70 t ha^{-1}, respectively). Different yield recorded from M_1 and M_2 showed statistically similar yield on >75g tuber, 50-75g tuber, chips tuber, dehydrated tuber and french fry tuber. However, M_3 (rice husk) showed comparatively lowest values of different sized and types of potato tubers.

4.2.8.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the production of all the tuber sizes and tuber types in the present study (Table 41). Among the interactions V_1O_3 was found superior by producing higher sizes as well as different types of potato tubers yield on >75g tuber, dehydrated tuber, french fry tuber and canned tuber (17.10, 3.72, 9.51 and 1.00 t ha^{-1}, respectively). On the other hand, V_2O_2 showed the highest yield on 50-75g tuber, 20-50g tuber and chips tuber (9.34, 10.10 and 25.43 t ha^{-1}, respectively.). Table showed that >75g tuber yield was similar in V_1O_2 and V_1O_3 interaction, 50-75g tuber yield was statistically similar in V_1O_3 , V_2O_3 and V_2O_2 interactions. On the other hand, the lowest yield of >75g tuber was with V_2O_2 (9.76 t ha^{-1}), 50-75g tuber was with V_3O_3 (7.06 t ha^{-1}), 20-50g tuber was with V_3O_3 (6.14 t ha^{-1}), chips tuber with V_1O_1 (16.92 t ha^{-1}), dehydrated tuber with V_3O_2 (0.51 t ha^{-1}) and canned tuber with V_3O_1 (0.35 t ha^{-1}) interaction.

4.2.8.5 Interaction effect of varieties and mulch materials

Significant variation was observed due to interaction of varieties and mulch materials on different sizes of potato tuber yield (Table 41). Interaction V_1M_2 and V_1M_1 showed statistically similar values of >75g tuber yield (17.20 and 17.12 t ha^{-1}, respectively) where as lowest was observed with V_2M_3 (8.57 t ha^{-1}) which was at par with V_2M_1 (8.93 t ha^{-1}). In case of 50-75g tuber, V_1M_1, V_2M_2, V_2M_3 and V_2M_1 showed the higher statistically similar level of tuber yield, while lowest was observed with V_3M_3 (6.49 t ha^{-1}) combination. In case of 20-50g tuber, V_2M_3 gave the highest yield and that of minimum was found with V_3M_1. For chips tuber yield, V_2M_2 gave the highest yield which was at par with V_2M_1, V_2M_3 and V_3M_2 while the lowest yield was obtained from V_1M_3 interaction.

In case of dehydrated tuber yield, V_1M_2 and V_2M_1 gave significantly highest yield (3.32 and 3.14 t ha^{-1}, respectively) and that of lowest was recorded with V_2M_2 interaction. In case of french fry , V_1M_2 interaction was superior than others. However, canned tuber was significantly highest with V_1M_1 (1.26 t ha^{-1}) and that of lowest was recorded with V_3M_3 which was statistically at par with V_3M_1 combination.

4.2.8.6 Interaction effect of organic manures and mulch materials

Interaction effect of organic manures and mulch materials behaved differently in producing different sizes of tubers but were significant (Table 41). The result revealed that interaction of O_2M_2 gave the highest yield of >75g tuber (14.25 t ha^{-1}) and french fry tuber (3.58 t ha^{-1}), while O_3M_1 interaction gave the highest yield of dehydrated tuber (3.19 t ha^{-1}), french fry tuber (3.66 t ha^{-1}) and canned tuber (0.08 t ha^{-1}). On the other hand, O_3M_2 gave the highest yield of 50-75g tuber (9.21 t ha^{-1}) and chips tuber (26.25 t ha^{-1}). The result also revealed that interaction of O_2M_1, O_3M_1, O_3M_2 and O_3M_3 gave statistically similar for >75g tuber yield of potato. However, the lowest yield was found with O_1M_3 for >75g tuber, 50-75g tuber, chips tuber, dehydrated tuber and french fry tuber (9.14, 7.26, 29.09, 0.87 and 0.80 t ha^{-1}, respectively).

Table 41. Interaction effect of variety, organic manure and mulch material on the yield of different sizes of potato tuber

Treatment	Yield of >75g tuber (t ha^{-1})	Yield of 50-75 g tuber (t ha^{-1})	Yield of 20-50 g tuber (t ha^{-1})	Yield of chips tuber (45-75mm) (t ha^{-1})	Yield of dehydrated tuber (30-45 mm) (t ha^{-1})	Yield of french fry tuber (>75mm) (t ha^{-1})	Yield of canned tuber (20-30mm) (t ha^{-1})
Effect of variety and organic manure							
V_1O_1	13.71 b	7.66 cd	6.37 e	16.92 d	0.92 d	6.28 c	0.83 b
V_1O_2	17.50 a	8.33 bc	7.74 cd	18.97 c	3.38 b	8.27 b	0.89 b
V_1O_3	17.10 a	8.62 ab	8.33 bc	18.57 cd	3.72 a	9.51 a	1.00 a
V_2O_1	6.952 g	8.43 bc	9.00 b	23.03 b	0.60 e	0.00 d	0.58 d
V_2O_2	9.760 f	9.34 a	10.10 a	25.43 a	1.75 c	0.00 d	0.66 c
V_2O_3	10.69 ef	8.88 ab	9.08 b	26.55 a	1.87 c	0.00 d	0.40 ef
V_3O_1	11.06 de	7.27 d	6.24 e	21.38 b	1.96 c	0.00 d	0.35 f
V_3O_2	12.18 cd	7.35 d	7.36 d	21.52 b	0.51 e	0.00 d	0.39 ef
V_3O_3	13.07 bc	7.06 d	6.14 e	25.18 a	0.63 e	0.15 d	0.45 e
LSD $_{(0.05)}$	**1.27**	**0.81**	**0.85**	**2.01**	**0.26**	**0.54**	**0.07**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**
Effect of variety and mulch material							
V_1M_1	17.12 a	9.00 a	7.80 c	19.94 d	2.01 c	7.94 b	1.13 a
V_1M_2	17.20 a	7.73 bc	7.09 cd	19.12 d	3.32 a	9.03 a	0.85 b
V_1M_3	13.99 b	7.86 bc	7.56 c	15.39 e	2.68 b	7.08 c	0.74 c
V_2M_1	8.93 de	8.46 ab	8.85 b	25.11 a	3.15 a	0.00 d	0.53 e
V_2M_2	9.90 d	9.27 a	9.09 b	25.70 a	0.32 e	0.00 d	0.49 ef
V_2M_3	8.57 e	8.93 a	10.24 a	24.20 ab	0.75 d	0.00 d	0.62 d
V_3M_1	12.37 c	7.32 c	6.08 e	20.98 cd	0.57 de	0.15 d	0.45 fg
V_3M_2	12.29 c	7.87 bc	6.32 de	24.28 ab	1.90 c	0.00 d	0.33 h
V_3M_3	11.66 c	6.49 d	7.34 c	22.83 bc	0.63 d	0.00 d	0.40 g
LSD $_{(0.05)}$	**1.27**	**0.81**	**0.85**	**2.01**	**0.26**	**0.54**	**0.07**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**
Effect of organic manure and mulch material							
O_1M_1	11.58 c	8.33 b-d	6.64 d	23.12 bc	0.85 e	2.54 b	0.68 b
O_1M_2	11.00 c	7.77 c-e	6.47 d	19.13 e	1.75 c	2.94 b	0.49 e
O_1M_3	9.14 d	7.26 e	8.51 ab	19.09 e	0.87 e	0.80 d	0.59 cd
O_2M_1	13.13 ab	8.63 ab	7.97 a-c	20.53 de	1.69 cd	1.90 c	0.63 bc
O_2M_2	14.25 a	7.89 b-e	8.47 ab	23.71 b	1.43 d	3.58 a	0.65 b
O_2M_3	12.06 bc	8.50 a-c	8.77 a	21.68 cd	2.51 b	2.80 b	0.65 bc
O_3M_1	13.71 a	7.83 b-e	8.13 a-c	22.39 b-d	3.19 a	3.66 a	0.80 a
O_3M_2	14.13 a	9.21 a	7.57 c	26.25 a	2.35 b	2.52 b	0.52 de
O_3M_3	13.01 ab	7.52 de	7.86 bc	21.66 cd	0.68 e	3.49 a	0.54 de
LSD $_{(0.05)}$	**1.27**	**0.81**	**0.85**	**2.01**	**0.26**	**0.54**	**0.07**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.8.7 Interaction effect of varieties, organic manures and mulch materials

Interaction of varieties, organic manures and mulch materials exhibited significant difference on different types tuber yield of potato (Table 42). Interactions behaved differently in producing different size of tuber. For >75g tuber, $V_1O_2M_2$ and $V_1O_3M_1$ interaction performed the best (21.55 and 21.15t ha^{-1}); for 50-75g tuber interaction of $V_1O_2M_1$ gave the highest yield which was statistically similar with $V_1O_1M_1$, $V_1O_3M_2$, $V_2O_1M_3$, $V_2O_2M_2$, $V_2O_2M_3$ and $V_2O_3M_2$ interactions; for 20-50g tuber $V_2O_1M_3$ interaction showed the maximum yield (11.65 t ha^{-1}) which was at par with $V_2O_2M_2$ and $V_2O_3M_1$ interactions; for chips tuber $V_3O_3M_2$ gave the highest tuber yield (29.26 t ha^{-1}) which was at par with $V_2O_2M_1$, $V_2O_2M_2$, $V_2O_3M_2$ and $V_2O_3M_3$ interactions; for dehydrated tuber yield $V_1O_3M_2$ and $V_1O_2M_3$ gave the similar and highest tuber yield; for french fry tuber, interaction of $V_1O_2M_2$, $V_1O_3M_1$ and $V_1O_3M_3$ gave the statistically similar and higher yield and for canned tuber yield, interaction of $V_1O_3M_1$ gave significantly highest yield than other interactions. Lowest yield was found with different interactions in different sizes of potato tubers which was $V_2O_1M_3$ (3.62 t ha^{-1}), $V_3O_1M_3$ (5.86 t ha^{-1}), $V_1O_1M_2$ (4.67 t ha^{-1}), $V_1O_1M_2$ (14.97 t ha^{-1}), $V_2O_3M_2$ (0.17 t ha^{-1}) and $V_3O_3M_2$ (0.25 t ha^{-1}) interactions for >75g tuber, 50-75g tuber, 20-50g tuber, chips tuber, dehydrated tuber and canned tuber, respectively. For french fry tuber, the lowest (0.00 t ha^{-1}) was found with all interactions of variety V_2 and V_3 which indicated that V_1 variety was the best for french fry yield than other two varieties.

4.2.9 Marketable tuber (>75 g) number (%)

4.2.9.1 Effect of varieties

Tuber number (>75 g) percentage by number had affected significantly among the varieties (Table 43). Variety V_1 (BARI Alu-25) and V_3 (BARI Alu-29) showed the highest tubers percent of potato (23.43 and 22.47%, respectively) than V_2 (BARI Alu-28) with (15.08 %). The yield variation among the varieties may attributed to the inherent genetic characters of the cultivars that are governed by the genetic make up of the varieties.

4.2.9.2 Effect of organic manures

Marketable tuber (>75 g) number had significantly influenced by the different organic manures (Table 43). The maximum marketable tuber (>75 g) number by percent was recorded (22.00 %) from O_3 (ACI organic fertilizer) while the minimum (18.41 %) was found from the O_1 (cowdung). This variation might be due to change the yield contributing characteristics under different organic manures

Table 42. Interaction effect of variety, organic manure and mulch material on the yield of different sizes of potato tuber

Interaction of Treatments	Yield of >75g tuber ($t\ ha^{-1}$)	Yield of 50-75 g tuber ($t\ ha^{-1}$)	Yield of 20-50 g tuber ($t\ ha^{-1}$)	Yield of chips tuber (45-75mm) ($t\ ha^{-1}$)	Yield of dehydrated tuber (30-45mm) ($t\ ha^{-1}$)	Yield of french fry tuber (>75mm) ($t\ ha^{-1}$)	Yield of canned tuber (20-30mm) ($t\ ha^{-1}$)
$V_1O_1M_1$	13.82 c-f	9.31 a-c	7.18 e-i	20.63 g-j	0.68 f-j	7.63 c	0.99 b
$V_1O_1M_2$	14.50 b-e	6.92 g-j	4.67 k	14.97 l	0.49 g-k	8.82 b	0.73 e-g
$V_1O_1M_3$	12.81 e-h	6.74 h-j	7.29 e-i	15.16 l	1.58 e	2.39 e	0.76 d-f
$V_1O_2M_1$	16.40 b	10.47 a	8.15 de	20.17 h-j	0.67 f-j	5.69 d	0.98 b
$V_1O_2M_2$	21.55 a	6.16 ij	7.81 d-h	21.33 f-j	3.60 d	10.73 a	0.86 cd
$V_1O_2M_3$	14.56 b-e	8.34 c-f	7.26 e-i	15.41 l	5.86 a	8.40 bc	0.81 de
$V_1O_3M_1$	21.15 a	7.24 e-j	8.07 d-f	19.03 jk	4.68 b	10.51 a	1.40 a
$V_1O_3M_2$	15.55 b-d	10.12 ab	8.79 cd	21.06 f-j	5.88 a	7.55 c	0.95 bc
$V_1O_3 M_3$	14.60 b-e	8.49 c-e	8.14 de	15.61 kl	0.60 f-k	10.46 a	0.66 f-i
$V_2O_1M_1$	7.51 m	7.88 d-h	7.15 e-i	24.33 c-f	0.86 f-h	0.00 f	0.60 h-j
$V_2O_1M_2$	9.73 i-l	8.22 c-g	8.21 de	22.67 d-i	0.38 i-k	0.00 f	0.46 k-m
$V_2O_1M_3$	3.62 n	9.20 a-d	11.65 a	22.09 e-j	0.55 g-k	0.00 f	0.68 f-h
$V_2O_2M_1$	11.18 h-j	8.51 c-e	9.20 cd	26.12 a-d	4.02 cd	0.00 f	0.54 j -l
$V_2O_2M_2$	9.02 j-m	9.34 a-c	11.11 ab	26.00 a-d	0.43 h-k	0.00 f	0.64 g-j
$V_2O_2 M_3$	9.08 j-m	10.18 ab	10.00 bc	24.19 c-f	0.79 f-i	0.00 f	0.80 de
$V_2O_3 M_1$	8.09 lm	9.00 b-d	10.20 a-c	24.88 c-e	4.56 b	0.00 f	0.45 k-m
$V_2O_3M_2$	10.96 h-k	10.24 ab	7.96 h-g	28.44 ab	0.17 k	0.00 f	0.36 m-p
$V_2O_3M_3$	13.00 e-h	7.41 e-i	9.09 cd	26.33 a-c	0.90 fg	0.00 f	0.39 m-o
$V_3O_1M_1$	13.40 d-g	7.80 d-h	5.58 jk	24.39 c-f	1.01 f	0.00 f	0.44 l-n
$V_3O_1M_2$	8.78 k-m	8.15 c-g	6.53 g-j	19.75 ij	4.40 bc	0.00 f	0.29 op
$V_3O_1M_3$	11.00 h-j	5.86 j	6.60 f-j	20.01 h-j	0.48 g-k	0.00 f	0.32 op
$V_3O_2M_1$	11.82 f-i	6.92 g-j	6.55 g-j	15.30 l	0.36 i-k	0.00 f	0.38 m-o
$V_3O_2M_2$	12.19 f-h	8.16 c-g	6.49 g-j	23.82 c-g	0.27 jk	0.00 f	0.46 k-m
$V_3O_2M_3$	12.52 e-h	6.96 f-j	9.05 cd	25.44 b-e	0.89 fg	0.00 f	0.33 n-p
$V_3O_3M_1$	11.88 f-i	7.25 e-j	6.11 i-k	23.26 c-h	0.34 jk	0.46 f	0.54 j-l
$V_3O_3M_2$	15.88 bc	7.28 e-i	5.95 i-k	29.26 a	1.02 f	0.00 f	0.25 p
$V_3O_3M_3$	11.44 g-i	6.66 h-j	6.36 h-j	23.03 c-i	0.53 g-k	0.00 f	0.56 i-k
$LSD_{(0.05)}$	**2.20**	**1.41**	**1.48**	**3.48**	**0.45**	**0.94**	**0.12**
CV (%)	**10.76**	**10.60**	**11.52**	**9.68**	**16.12**	**21.37**	**11.75**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.9.3 Effect of mulch materials

Significant difference was observed on percentage of marketable tuber (>75 g) number as influenced by the different mulch materials (Table 43). The result revealed that mulching with M_2 (rice straw) and M_1 (water hyacinth) showed the highest tuber number (21.39 and 21.02%, respectively) while M_3 (rice husk) showed the lowest value (18.58 %) of tuber number (>75g).

4.2.9.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of marketable tuber (>75 g) number in different treatments in this experiment. (Table 44). Interaction of V_1O_2 showed the maximum marketable tuber (>75 g) percent by number (24.53%) which was statistically similar to V_3O_3 and V_1O_3 (24.25 and 23.89%, respectively) . The minimum marketable tuber (>75 g) percent by number (12.31%) was recorded in $V_2O_{1.}$ This variation might be due to the positive influence in producing higher marketable tuber (>75g) number with the V_1O_2 , V_3O_3 and V_1O_3 interactions.

4.2.9.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on marketable (>75 g) tuber percent by number in potato (Table 44). The maximum marketable (>75 g) tuber percent by number (25.56%) was observed in V_1M_2 which was statistically similar to V_1M_1 and V_3M_1 combinations (24.23 and 23.48%, respectively). The minimum marketable (>75 g) tuber percent by number (13.73%) was recorded from V_2M_3 which is statistically similar to V_2M_1 (15.35%).

4.2.9.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on the percentage of marketable tuber (>75 g) percent by number in potato (Table 44). Interaction comprised with O_3M_2 was superior in producing highest marketable tuber (>75g) percent by number (22.47%) which was at par with O_3M_1, O_2M_2, O_3M_3, O_2M_1 interactions (22.19, 21.84, 21.34, and 20.98%, respectively). The minimum marketable tuber number was obtained from O_1M_3 (15.49%).

Table 43. Effect of variety, organic manure and mulch material on the tuber characteristics of potato

Treatments	No. of tuber >75g (%)	No. of tuber 50-75 g (%)	No. of tuber 20-50 g (%)	No. of canned tuber (20-30mm) (%)
Effect of variety				
V_1	23.43 a	19.29 b	31.21 c	18.37 a
V_2	15.08 b	23.01 a	40.59 a	12.20 b
V_3	22.47 a	22.69 a	35.30 b	11.45 b
LSD $_{(0.05)}$	**1.38**	**1.46**	**2.09**	**0.98**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**
Effect of organic manure				
O_1	18.41 c	23.26 a	35.54	14.32
O_2	20.58 b	20.57 b	36.51	14.26
O_3	22.00 a	21.17 b	35.05	13.43
LSD $_{(0.05)}$	**1.38**	**1.46**	**NS**	**NS**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**
Effect of mulch material				
M_1	21.02 a	21.72 ab	34.84 b	14.68 a
M_2	21.39 a	22.66 a	34.94 b	13.30 b
M_3	18.58 b	20.61 b	37.32 a	14.03 ab
LSD $_{(0.05)}$	**1.38**	**1.46**	**2.09**	**0.98**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.9.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interactional effect of varieties, organic manures and mulch materials on the percentage of marketable tubers (>75 g) number of potato (Table 45). The maximum marketable tubers (>75 g) was recorded in $V_1O_3M_1$ (30.88 %) which is statistically similar to $V_1O_2M_2$ (29.50%), $V_3O_3M_2$ (28.63%) and $V_1O_1M_2$ (26.78 %). The minimum marketable tuber numbers (>75 g) percent was obtained from $V_2O_1M_3$ (5.13%). This variation might be due to change the yield contributing characteristics under different interactions.

4.2.10 Marketable tuber (50-75 g) number (%)

4.2.10.1 Effect of varieties

Significantly highest marketable tuber (50-75g) percent by number (23.01%) was obtained from the variety V_2 (BARI Alu-28) which was followed by V_3 (BARI Alu-29) (22.69%) while the minimum (19.29 %) was found from the variety V_1 (BARI Alu-25) (Table 43). The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.10.2 Effect of organic manures

Significantly highest marketable tuber (50-75 g) percent by number (23.26%) was found with O_1 (cowdung) which was 13.07% and 9.87% higher than O_2 (poultry litter) and O_3 (ACI organic fertilizer), respectively (Table 43).

4.2.10.3 Effect of mulch materials

M_2 (rice straw) mulch material showed its superiority by producing significantly highest (22.66%) marketable tuber (50-75g) percent by number than other mulch materials (Table 43). M_1 (water hyacinth) mulch material also showed statistically similar value with M_2. The minimum marketable tuber (50-75g) percent by number (20.61%) was obtained from M_3 (rice husk).

4.2.10.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on marketable tuber (50-75g) percent by number in this experiment (Table 44). The maximum marketable tuber (50-75g) percent by number was recorded in V_3O_1 (24.15%) while the minimum marketable tuber (50-75g) percent by number was obtained from V_1O_2 (17.34%). All other treatments are statistically similar with the maximum marketable tuber (50-75g) percent by number in the experiment except V_1O_3 (18.77%) combination.

4.2.10.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on the percentage of marketable (50-75g) tuber number in this experiment (Table 44). Interaction of V_3M_2 showed the highest marketable (50-75g) tuber percent by number (24.53%) which was statistically similar to V_2M_2 (23.84%), V_2M_1 (23.68%) and V_3M_1 (23.39%). The lowest marketable (50-75g) tuber percent by number was recorded from V_1M_1 (18.09%) which was statistically similar to V_1M_2, V_3M_3 and V_1M_3 (19.61, 20.13 and 20.17%, respectively).

4.2.10.6 Interaction effect of organic manures and mulch materials

Significantly higher and statistically similar marketable tuber (50-75g) percent by number were observed from the interactions of O_1M_1, O_1M_2 and O_3M_2 (24.96, 24.23, and 23.68%, respectively) (Table 44). On the other hand, all the interactions other than O_1M_1, O_1M_2 and O_3M_2 showed the lower level and statistically similar marketable tuber (50-75g) percent by number yield in potato.

Table 44. Interaction effect of variety, organic manure and mulch material on the tuber characteristics of potato

Treatment combinations	No. of tuber >75g (%)	No. of tuber 50-75 g (%)	No. of tuber 20-50 g (%)	No. of canned tuber 20-30 mm (%)
Interaction effect of variety and organic manure				
V_1O_1	21.87 bc	21.77 a	29.02 f	19.31 a
V_1O_2	24.53 a	17.34 b	31.82 ef	18.07 a
V_1O_3	23.89 ab	18.77 b	32.80 de	17.72 a
V_2O_1	12.31 f	23.85 a	41.70 a	13.55 b
V_2O_2	15.07 e	22.45 a	41.00 a	13.39 b
V_2O_3	17.87 d	22.73 a	39.07 ab	9.66 d
V_3O_1	21.05 c	24.15 a	35.90 b-d	10.10 d
V_3O_2	22.12 bc	21.91 a	36.72 bc	11.32 cd
V_3O_3	24.25 ab	22.00 a	33.28 c-e	12.92 bc
LSD $_{(0.05)}$	**2.39**	**2.52**	**3.50**	**1.70**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**
Interaction effect of variety and mulch material				
V_1M_1	24.23 ab	18.09 d	30.54 c	20.22 a
V_1M_2	25.56 a	19.61 cd	31.35 bc	17.49 b
V_1M_3	20.50 d	20.17 cd	31.73 bc	17.40 b
V_2M_1	15.35 ef	23.68 ab	40.75 a	11.66 cd
V_2M_2	16.17 e	23.84 ab	39.22 a	11.69 cd
V_2M_3	13.73 f	21.51 bc	41.80 a	13.24 c
V_3M_1	23.48 a-c	23.39 ab	33.22 bc	12.17 cd
V_3M_2	22.43 b-d	24.53 a	34.25 b	10.73 d
V_3M_3	21.51 cd	20.13 cd	38.44 a	11.45 d
LSD $_{(0.05)}$	**2.39**	**2.52**	**3.50**	**1.70**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**
Interaction effect of organic manure and mulch material				
O_1M_1	19.89 bc	24.96 a	33.76 c	14.63 a-c
O_1M_2	19.85 bc	24.23 a	34.21 bc	13.29 b-d
O_1M_3	15.49 d	20.58 b	38.65 a	15.04 a
O_2M_1	20.98 a-c	20.60 b	35.62 a-c	14.86 ab
O_2M_2	21.84 ab	20.07 b	36.54 a-c	13.93 a-d
O_2M_3	18.91 c	21.03 b	37.38 ab	13.99 a-d
O_3M_1	22.19 ab	19.60 b	35.13 bc	14.56 a-c
O_3M_2	22.47 a	23.68 a	34.07 bc	12.69 d
O_3M_3	21.34 ab	20.22 b	35.94 a-c	13.05 cd
LSD $_{(0.05)}$	**2.39**	**2.52**	**3.50**	**1.70**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.10.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on percentage of marketable tubers (50-75g) number of potato from this experiment (Table 45). The maximum marketable tubers (50-75g) percent by number was recorded in $V_3O_1M_2$ (27.48%) which was statistically similar to $V_2O_1M_1$(27.29%), $V_2O_3M_2$(26.83%), $V_3O_1M_1$(25.07%), $V_2O_2M_3$(23.99%) and $V_3O_2M_2$ (23.74%). The minimum marketable tuber (50-75g) numbers percent $V_1O_3M_1$ (14.02%) which was statistically similar with $V_1O_2M_2$, $V_1O_2M_1$ combinations (14.04 and 17.74%, respectively).

4.2.11 Marketable tuber (20-50 g) number (%)

4.2.11.1 Effect of varieties

The result presented in table 43 showed that V_2(BARI Alu-28) variety showed its superiority by producing significantly highest (40.59%) marketable tuber (20-50g) number than other two tested varieties V_1 (BARI Alu-25) and V_3(BARI Alu-29) (Table 43). It can also be inferred from the table that V_2 (BARI Alu-28) out yield over V_1 and V_3 by producing 30.05 and 14.99%, respectively higher marketable (20-50 g) tuber yield.

4.2.11.2 Effect of organic manures

Non-significant variation was observed on the percentage of marketable tuber (20-50g) number due to organic manures in potato tuber (Table 43).

4.2.11.3 Effect of mulch materials

Significant variation was observed on percentage of marketable tuber (20-50g) number due to different mulch materials (Table 43). M_3 (rice husk) mulch material showed highest (37.32%) marketable tuber (20-50 g) than M_1 (water hyacinth) and M_2 (rice straw) mulch materials. This indicates that M_3 showed 7.12 and 6.82% higher marketable tuber (20-50 g) yield than M_1 and M_2, respectively.

4.2.11.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of marketable tuber (20-50 g) number in potato (Table 44). The maximum marketable tuber (20-50 g) percent by number was recorded in V_2O_1 (41.70%) which was statistically similar with V_2O_2 (41.00%) and V_2O_3 (39.07%). The minimum marketable tuber (20-50 g) percent by number was obtained from V_1O_1 (29.02%) which is statistically similar with V_1O_2 (31.82%).

4.2.11.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on percentage of marketable (20-50 g) tuber number in potato (Table 44). The maximum marketable (20-50 g) tuber percent by number was recorded in V_2M_3 (41.80%) which was statistically similar with V_2M_1 (40.75%), V_2M_2 (39.22%) and V_3M_3 (38.44%). The minimum marketable (20-50 g) tuber percent by number was obtained from V_1M_1 (30.54%) which was statistically similar to V_1M_2 (31.35%), V_1M_3 (31.73%) and V_3M_1 (33.22%).

Table 45. Interaction effect of variety, organic manure and mulch material on the tuber characteristics of potato

Treatment combinations	No. of tuber >75g (%)	No. of tuber 50-75 g (%)	No. of tuber 20-50 g (%)	No. of canned tuber 20-30 mm (%)
$V_1O_1M_1$	19.35 e-i	22.52 b-f	30.72 g-i	19.68 ab
$V_1O_1M_2$	26.78 a-c	22.37 c-f	26.59 i	18.44 bc
$V_1O_1M_3$	19.50 e-i	20.43 d-g	29.74 g-i	19.81 ab
$V_1O_2M_1$	22.45 d-f	17.74 gh	31.95 f-i	19.50 ab
$V_1O_2M_2$	29.50 a	14.64 h	32.82 e-i	16.49 c-f
$V_1O_2M_3$	21.64 d-g	19.64 d-g	30.68 g-i	18.23 b-d
$V_1O_3M_1$	30.88 a	14.02 h	28.96 hi	21.47 a
$V_1O_3M_2$	20.41 e-h	21.83 c-g	34.65 d-h	17.54 b-e
$V_1O_3 M_3$	20.37 e-h	20.46 d-g	34.78 d-h	14.16 f-h
$V_2O_1M_1$	15.66 i-k	27.29 a	39.23 b-d	13.63 f-i
$V_2O_1M_2$	16.13 i-k	22.85 b-f	38.25 b-e	12.62 g-l
$V_2O_1M_3$	5.13 l	21.40 c-g	47.64 a	14.41 f-h
$V_2O_2M_1$	17.79 g-j	21.52 c-g	39.40 b-d	12.23 h-l
$V_2O_2M_2$	14.00 jk	21.84 c-g	44.14 ab	12.63 g-l
$V_2O_2 M_3$	13.42 k	23.99 a-d	39.45 b-d	15.31 d-g
$V_2O_3 M_1$	12.59 k	22.22 c-f	43.62 a-c	9.13 m
$V_2O_3M_2$	18.37 f-i	26.83 ab	35.27 d-g	9.83 lm
$V_2O_3M_3$	22.64 c-e	19.15 fg	38.32 b-e	10.01 k-m
$V_3O_1M_1$	24.67 b-d	25.07 a-c	31.33 g-i	10.60 j-m
$V_3O_1M_2$	16.64 h-k	27.48 a	37.80 d-f	8.80 m
$V_3O_1M_3$	21.83 d-g	19.90 d-g	38.58 b-e	10.91 i-m
$V_3O_2M_1$	22.68 c-e	22.54 b-f	35.52 d-g	12.85 g-k
$V_3O_2M_2$	22.02 d-f	23.74 a-e	32.65 e-i	12.67 g-l
$V_3O_2M_3$	21.67 d-g	19.46 e-g	42.00 a-c	8.45 m
$V_3O_3M_1$	23.10 c-e	22.56 b-f	32.81 e-i	13.07 g-j
$V_3O_3M_2$	28.63 ab	22.38 c-f	32.30 e-i	10.71 i-m
$V_3O_3M_3$	21.01 d-g	21.05 c-g	34.73 d-h	14.98 e-h
$LSD_{(0.05)}$	**4.14**	**4.37**	**6.28**	**2.94**
CV (%)	**12.44**	**12.32**	**10.74**	**12.80**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.11.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on marketable tuber (20-50g) numbers percentage in potato (Table 44). The maximum marketable (20-50g) tuber percent by number was obtained in O_1M_3 (38.65%) which was statistically similar to O_2M_3 (37.38%), O_2M_2 (36.54%), O_2M_1 (35.62%) and O_3M_3 (35.94%). The minimum O_1M_3 (38.65%) marketable tuber (20-50g) percent by number was recorded from O_1M_1 (33.76%) which was statistically similar to O_3M_2 (34.07%), O_1M_2 (34.21%), O_3M_1 35.13%), O_2M_1 (35.62%) and (O_2M_2 (36.54%).

4.2.11.7 Interaction effect of varieties, organic manures and mulch materials

There was observed a significant variation due to interaction effect of varieties, organic manures and mulch materials on marketable tubers (20-50g) percent by number in potato (Table 45). The highest marketable tubers (20-50g) percent by number was recorded in $V_2O_1M_3$ (47.64%) which was statistically similar with $V_2O_2M_2$ (44.14%), $V_2O_3M_1$ (43.62%) and $V_3O_2M_3$ (42.00%). The lowest marketable tuber (20-50 g) number by percent was recorded from $V_1O_1M_2$ (26.59%) which was statistically similar with $V_1O_3M_1$ (28.96%), $V_1O_1M_3$ (29.74%), $V_1O_2M_3$ (30.68%), $V_1O_1M_1$ (30.72%), $V_3O_1M_1$ (31.33%), $V_1O_2M_1$ (31.95%), $V_3O_3M_2$ (32.30%), $V_3O_2M_3$ (32.65%), $V_3O_3M_1$ (32.81%) and $V_1O_2M_2$ (32.82%).

4.2.12 Canned tuber (20-30 mm) number (%)

4.2.12.1 Effect of varieties

Significant effect on percentage of canned tuber (20-30 mm) was observed in different varieties (Table 43). The maximum canned tuber (20-30 mm) percent by number (18.37%) was obtained from the variety V_1 (BARI Alu-25) while the minimum (11.45%) was found from the V_3 (BARI Alu-29). The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.12.2 Effect of organic manure

Non-significant variation was observed on marketable tuber (20-30 mm) percent by number was influenced by the different organic manures (Table 43). The maximum marketable tuber (20-30 mm) percent by number was recorded from the cowdung (14.32%) while minimum was found from the ACI organic fertilizer (13.43%).

4.2.12.3 Effect of mulch materials

Significant difference was observed on canned tuber (20-30 mm) percent by number due to different mulch materials (Table 43). The maximum canned tuber (20-30 mm) percent by number (14.68%) was recorded from the M_1 (water hyacinth) which was statistically similar to M_3 (rice husk) while the minimum (13.30%) was obtained from the M_2 (rice straw) which was statistically similar to M_3 (rice husk).

4.2.12.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of canned tuber (20-30 mm) number in potato (Table 44). The maximum canned tuber (20-30 mm) percent by number was observed in V_1O_1 (19.31%) which was statistically similar with V_1O_2 and V_1O_3 (18.07% and 17.72%, respectively). The minimum canned tuber (20-30 mm) percent by number was obtained from the V_2O_3 (9.66%) which was statistically similar to V_3O_1 and V_3O_2 (10.10% and 11.32%, respectively).

4.2.12.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on canned (20-30 mm) percent by number in potato (Table 44). Significantly the highest canned (20-30 mm) tuber number was recorded in V_1M_1 (20.22%) while the minimum canned (20-30 mm) tuber percent by number was obtained from the treatment V_3M_2 (10.73%) which was statistically similar with V_3M_3 (11.45%), V_2M_1 (11.66%), V_2M_2 (11.69%) and V_3M_1 (12.17%).

4.2.12.6 Interaction effect of organic manures and mulch materials

Significant variation was obtained due to interaction effect of organic manures and mulch materials on the percentage of canned tuber (20-30 mm) number in potato (Table 44). Interaction of O_1M_3 showed the highest (15.04%) canned tuber (20-30 mm) number by percent which was statistically similar to O_2M_1 (14.86%), O_1M_1(14.63%), O_3M_1 (14.56%), O_2M_3(13.99%) and O_2M_2(13.93%). The lowest canned tuber (20-30 mm) percent by number was recorded from O_3M_2 (12.69%) which was statistically similar to O_3M_3 (13.05%), O_1M_2 (13.29%), O_2M_2 (13.93%) and O_2M_3 (13.99%).

4.2.12.7 Interaction effect of varieties, organic manures and mulch materials

Interactional effect of varieties, organic manures and mulch materials exerted significant effect on canned tubers (20-30 mm) number of potato (Table 45). The highest canned tubers (20-30 mm) percent by number was recorded from $V_1O_3M_1$ (21.47%) which was statistically similar with $V_1O_1M_3$, $V_1O_1M_1$ and $V_1O_2M_1$ (19.81, 19.68 and 19.50%, respectively). The lowest number was obtained from $V_3O_2M_3$ (8.45%) which was statistically similar with $V_3O_1M_2$,$V_2O_3M_1$,$V_2O_3M_2$, $V_2O_3M_3$, $V_3O_1M_1$, $V_3O_3M_2$ and $V_3O_1M_3$ (8.80, 9.13, 9.83, 10.01, 10.60, 10.71 and 10.91%, repectively).

4.2.13 Chips tuber (45-75 mm) number (%)

4.2.13.1 Effect of varieties

Significant effect was found on the percentage of marketable chips tuber number due to different varieties (Table 46). The maximum chips tuber percent (60.91%) by number was found from the variety V_2 (BARI Alu-28) which was statistically similar at par with V_3 (BARI Alu-29). The minimum chips tuber percent (40.97%) by number obtained from the variety V_1 (BARI Alu-25). The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.13.2 Effect of organic manures

Different organic manure exhibited significant variation on chips tuber percent by number in potato (Table 46). When O_1 (cowdung) used as organic manure then the highest percent by number (56.68%) was recorded. But chips tuber obtained from O_3 (ACI organic fertilizer) showed statistically similar with O_1(cowdung) while the minimum (48.92%) was found from the O_2 **(**poultry litter).

4.2.13.3 Effect of mulch materials

Significant difference was observed on chips tuber percent by number due to different mulch materials (Table 46). The result revealed that M_2 (rice straw) mulch material gave maximum marketable chips tuber percent by number (56.91%) while the minimum (52.30%) was found from the M_1 (water hyacinth) which was statistically similar with the rice husk (52.56%). The result indicated that rice straw mulch material was the best in producing chips tubers.

4.2.13.4 Interaction effect of varieties and organic manures

Interactional effect of varieties and organic manures had significant effect on chips tuber percent by number in potato (Table 47). The highest chips tuber percent by number (65.49%) was recorded in V_2O_3 combination which was statistically similar with V_3O_3, V_2O_1 and V_3O_1 combination (65.21, 64.35 and 60.40%, respectively). The lowest (37.82%) was obtained from the V_1O_3 combination which was statistically similar with V_1O_2 combination.

4.2.13.5 Interaction effect of varieties and mulch materials

Significant variation was observed on chips tuber percent by number due to interaction of varieties and mulch materials in potato (Table 47). The highest (64.91%) chips tuber percent by number was recorded in V_2M_2 which was statistically similar with V_3M_3, V_2M_1 and V_3M_2 combinations (63.04, 62.46 and 61.11%, respectively). The lowest (38.93%) was obtained from V_1M_1 combination which was statistically similar with V_1M_3..

4.2.13.6 Interaction effect of organic manures and mulch materials

Significant variation was found on chips tuber percent by number due to interaction of organic manures and mulch materials in potato (Table 47). The highest chips tuber percent by number (65.75%) was recorded in O_3M_2 combination which was statistically similar with O_1M_1 combination. The lowest chips tuber percent by number (47.11%) was found from O_2M_1 combination which was statistically similar with O_3M_1, O_2M_3 and O_2M_2 (49.29, 49.50 and 50.15%, respectively).

4.2.13.7 Interaction effect of varieties, organic manures and mulch materials

Interactional effect of varieties, organic manures and mulch materials exhibited significant effect on chips tuber percent by number in potato (Table 48). The result revealed that among the interactions the maximum chips tuber percent by number was recorded in $V_2O_3M_2$ (81.39%) which was statistically similar with $V_2O_1M_1$ (74.12%) and $V_3O_3M_2$ (73.09%). The minimum marketable chips tuber percent by number was found from $V_1O_2M_3$ (31.93%) which was statistically similar with $V_1O_3M_1$ (32.07%) and $V_1O_3M_3$ (38.65%).

4.2.14 Dehydrated tuber(30-45 mm) number (%)

4.2.14.1 Effect of varieties

Non-significant effect on the percentage of dehydrated tuber percent by number was observed in different varieties (Table 46).

4.2.14.2 Effect of organic manure

Non-significant variation was recorded on the percentage of dehydrated tuber (30-45 mm.) number which was influenced by the different organic manures (Table 46).

4.2.14.3 Effect of mulch materials

Non-significant variation was observed on the percentage of dehydrated tuber (>30 mm) number due to different mulch materials (Table 46).

Table 46. Effect of variety, organic manure and mulch material on the tuber characteristics of potato

Treatments	Chips tuber (45-75mm) no. (%)	Dehydrated tuber (30-45 mm) no. (%)	French fry (>75mm) tuber no. (%)
Effect of variety			
V_1	40.97 b	18.99	10.82 a
V_2	60.91 a	19.76	0.00 b
V_3	59.89 a	18.41	0.04 b
LSD $_{(0.05)}$	**3.21**	**NS**	**0.39**
CV (%)	**10.89**	**13.08**	**19.77**
Effect of organic manure			
O_1	56.68 a	18.74	3.794
O_2	48.92 b	19.15	3.564
O_3	56.18 a	19.26	3.510
LSD $_{(0.05)}$	**3.21**	**NS**	**NS**
CV (%)	**10.89**	**13.08**	**19.77**
Effect of mulch material			
M_1	52.30 b	18.68	3.34 b
M_2	56.91 a	19.45	3.76 a
M_3	52.56 b	19.02	3.77 a
LSD $_{(0.05)}$	**3.21**	**NS**	**0.39**
CV (%)	**10.89**	**13.08**	**19.77**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.14.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of dehydrated tuber (30-45 mm.) number in this experiment (Table 47). The highest dehydrated tuber percent by number was recorded in V_1O_3 (21.07%) which was statistically similar with V_1O_2 (20.75%), V_2O_1 (20.75%), V_3O_1 (20.33%), V_2O_2 (19.31%) and V_2O_3 (19.21%). The lowest dehydrated tuber percent by number was observed in V_1O_1 (15.14%) which was statistically similar with V_2O_2 (19.31%).

4.2.14.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on the percentage of dehydrated (30-45 mm.) tuber number in potato (Table 47). The maximum dehydrated tuber percent by number was recorded in V_2M_1 (23.73%) while the minimum was obtained in V_3M_1 (14.80%) which was statistically similar with V_2M_2 (16.71%).

4.2.14.6 Interaction effect of organic manures and mulch materials

Interactional effect of organic manures and mulch materials comprised with O_1M_2 gave the highest dehydrated (30-45 mm.) tuber percent by number (20.94%) which was statistically similar with O_2M_3(20.75%), O_3M_1(20.07%), O_3M_3 (18.91%), O_3M_2 (18.81%) and O_2M_2(18.62%) (Table 47). The lowest dehydrated tuber percent by number was recorded with O_1M_3(17.41%) which was statistically similar to O_1M_1(17.88%), O_2M_1(18.09%), O_2M_2 (18.62%), O_3M_2 (18.81%) and O_3M_3 (18.91%).

4.2.14.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on the percentage of dehydrated (30-45 mm.) tuber number in this experiment (Table 48). The maximum dehydrated tuber percent by number was recorded in the combination of $V_1O_2M_2$ (28.14%) which was statistically similar with $V_2O_1M_1$, $V_1O_3M_2$ and $V_1O_2M_3$ combinations (26.32, 25.67 and 25.05%, respectively). The minimum dehydrated tuber percent by number was recorded in the combination of $V_3O_1M_1$(12.65%) which was statistically similar to $V_1O_1M_3$, $V_2O_3M_2$, $V_3O_2M_1$ and $V_1O_1M_1$ (14.01, 14.02, 14.43 and 14.65%, respectively).

4.2.15 French fry tuber (>75 mm) number (%)

4.2.15.1 Effect of varieties

French fry tuber production among the varieties was found significant (Table 46). Among the varieties, V_1 (BARI Alu-25) variety produced the highest value (10.82%) of french fry tuber while the lowest value (0.00 %) of french fry tuber was found from V_2 (BARI Alu-28) which was statistically similar to the variety V_3 (BARI Alu-29). The probable reason for variation in tuber size due to the genetic make up of the varieties.

4.2.15.2 Effect of organic manures

Non-significant variation was observed on the percentage of french fry tuber number due to the different organic manures (Table 46).

4.2.15.3 Effect of mulch materials

Significant variation was observed on the percentage of french fry tuber number as influenced by the different mulch materials (Table 46). The french fry tuber percent by number (3.77%) was recorded from M_3 (rice husk) which was statistically similar with M_2 (rice straw) while the minimum (3.34%) was found from the M_1 (water hyacinth).

4.2.15.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures comprised with V_1O_1 produced significantly highest (11.38%) french fry tuber (>75mm) (Table 47) while the minimum french fry tuber percent by number was observed in V_1O_3 (10.40%) which was statistically similar with V_1O_2 (10.69%).

4.2.15.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on french fry tuber percent by number in potato (Table 47). The maximum french fry tuber by percent number was recorded in V_1M_3(11.30%) which was similar with V_1M_2(11.29%) while the minimum french fry tuber percent by number was recorded from V_2M_1, V_2M_2, V_2M_3, V_3M_2 and V_3M_3 (0.00%) which was statistically similar to V_3M_1 (00.13%).

Table 47. Interaction effect of variety, organic manure and mulch material on the tuber characteristics of potato

Treatment combinations	Chips tuber (45-75mm) no. (%)	Dehydrated tuber (30-45 mm) no. (%)	French fry (>75mm) tuber no. (%)
Interaction effect of variety and organic manure			
V_1O_1	45.29 c	15.14 c	11.38 a
V_1O_2	39.80 cd	20.75 a	10.69 b
V_1O_3	37.82 d	21.07 a	10.40 b
V_2O_1	64.35 a	20.75 a	0.00 c
V_2O_2	52.89 b	19.31 ab	0.00 c
V_2O_3	65.49 a	19.21 ab	0.00 c
V_3O_1	60.40 a	20.33 a	0.00 c
V_3O_2	54.07 b	17.39 bc	0.00 c
V_3O_3	65.21 a	17.51 b	0.13 c
LSD $_{(0.05)}$	**5.55**	**2.36**	**0.68**
CV (%)	**10.89**	**13.08**	**19.77**
Interaction effect of variety and mulch material			
V_1M_1	38.93 d	17.51 de	9.88 b
V_1M_2	44.72 c	20.42 bc	11.29 a
V_1M_3	39.26 cd	19.03 b-e	11.30 a
V_2M_1	62.46 a	23.73 a	0.00 c
V_2M_2	64.91 a	16.71 ef	0.00 c
V_2M_3	55.37 b	18.83 c-e	0.00 c
V_3M_1	55.52 b	14.80 f	0.13 c
V_3M_2	61.11 a	21.23 b	0.00 c
V_3M_3	63.04 a	19.20 b-d	0.00 c
LSD $_{(0.05)}$	**5.55**	**2.36**	**0.68**
CV (%)	**10.89**	**13.08**	**19.77**
Interaction effect of organic manure and mulch material			
O_1M_1	60.51 a	17.88 bc	2.94 d
O_1M_2	54.84 b	20.94 a	4.54 a
O_1M_3	54.68 b	17.41 c	3.90 a-c
O_2M_1	47.11 c	18.09 bc	3.76 bc
O_2M_2	50.15 bc	18.62 a-c	3.89 a-c
O_2M_3	49.50 bc	20.75 a	3.05 d
O_3M_1	49.29 bc	20.07 ab	3.31 cd
O_3M_2	65.75 a	18.81 a-c	2.86 d
O_3M_3	53.49 b	18.91 a-c	4.36 ab
LSD $_{(0.05)}$	**5.55**	**2.36**	**0.68**
CV (%)	**10.89**	**13.08**	**19.77**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.2.15.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on percentage of french fry percent by number in potato (Table 47). The result exhibited that the maximum french fry tuber percent by number was recorded from O_1M_2(4.54%) which was statistically similar to O_3M_3(4.36%), O_1M_3(3.90%) and O_2M_2(3.89%). The minimum french fry tuber percent by number was recorded from O_3M_2(2.86%) which was statistically similar to O_1M_1(2.94%), O_2M_3(3.05%) and O_3M_1(3.31%).

4.2.15.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on percentage of french fry tuber by number from potato (Table 48). The table showed that the maximum french fry tuber number was recorded from $V_1O_1M_2$ (13.63%) which was statistically similar to $V_1O_3M_3$ (13.08%). The minimum french fry tuber percent by number was recorded from all the possible combinaions of organic manures and mulch materials with V_2 and V_3 varieties.

Table 48. Interaction effect of variety, organic manure and mulch material on the tuber characteristics of potato

Treatment combinations	Chips tuber (45-75mm) no. (%)	Dehydrated tuber (30-45 mm) no (%)	French fry (>75mm) tuber no. (%)
$V_1O_1M_1$	42.84 lm	14.65 g-i	8.830 c
$V_1O_1M_2$	45.86 i-m	16.75 f-h	13.63 a
$V_1O_1M_3$	47.17 h-m	14.01 hi	11.69 b
$V_1O_2M_1$	41.88 lm	18.37 e-g	11.28 b
$V_1O_2M_2$	45.54 j-m	18.83 ef	11.66 b
$V_1O_2M_3$	31.97 n	25.05 a-c	9.14 c
$V_1O_3M_1$	32.07 n	19.50 d-f	9.54 c
$V_1O_3M_2$	42.75 lm	25.67 ab	8.57 c
$V_1O_3 M_3$	38.65 mn	18.03 e-h	13.08 a
$V_2O_1M_1$	74.12 ab	26.32 ab	0.00 d
$V_2O_1M_2$	63.29 de	17.91 e-h	0.00 d
$V_2O_1M_3$	55.64 d-h	18.01 e-h	0.00 d
$V_2O_2M_1$	56.06 d-h	21.46 c-e	0.00 d
$V_2O_2M_2$	50.04 g-l	18.21 e-g	0.00 d
$V_2O_2 M_3$	52.59 f-k	18.28 e-g	0.00 d
$V_2O_3 M_1$	57.20 d-g	23.40 b-d	0.00 d
$V_2O_3M_2$	81.39 a	14.02 hi	0.00 d
$V_2O_3M_3$	57.89 d-g	20.20 d-f	0.00 d
$V_3O_1M_1$	64.59 b-d	12.65 i	0.00 d
$V_3O_1M_2$	55.36 d-i	28.14 a	0.00 d
$V_3O_1M_3$	61.24 d-f	20.19 d-f	0.00 d
$V_3O_2M_1$	43.38 k-m	14.43 g-i	0.00 d
$V_3O_2M_2$	54.87 e-j	18.81 ef	0.00 d
$V_3O_2M_3$	63.94 c-e	18.93 ef	0.00 d
$V_3O_3M_1$	58.59 d-g	17.32 f-h	0.40 d
$V_3O_3M_2$	73.09 a-c	16.74 f-h	0.00 d
$V_3O_3M_3$	63.94 c-e	18.49 e-g	0.00 d
LSD $_{(0.05)}$	**9.62**	**4.08**	**1.17**
CV (%)	**10.89**	**13.08**	**19.77**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.3 Post-harvest quality of potato

4.3.1 Dry matter of potato tuber at harvest (%)

Non-significant variation on dry matter (%) of potato at harvest was observed due to the effect of single factor like organic manure and mulch material, interactions of variety and mulch material, interaction of organic manure and mulch material, interaction of (variety × organic manure × mulch material) but only variety, and (variety × organic manure) interaction varied significantly (Table 49, 50 and 51).

4.3.1.1 Effect of varieties

Significant variation on the dry matter percent was observed due to different varieties of potato (Table 49). The maximum dry matter percentage (22.77%) of potato at harvest was obtained from the variety V_3 (BARI Alu-29) which was statistically at par with V_2 (BARI Alu-28). The minimum dry matter percentage (21.04%).at harvest was found from the variety V_1 (BARI Alu-25) The probable reason for variation in dry matter (%) due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site. Variation of dry matter (%) was observed by many scientists which corroborates with the present findings. Cota and Hadzic (2013) found that dry matter content ranged from 21.80% in Romano to 22.20% in Desiree. Rainys and Rudokas (2005) also found averaged over the 3 years, the highest dry matter contents were recorded from 'Lady rosetta' (23.2-24.1%) and Saturna (23.5-23.8%).

4.3.1.2 Interaction effect of varieties and organic manures

Significant variation was observed on the dry matter (%) of potato tuber at harvest due to the different varieties and organic manures (Table 50). The highest dry matter (%) was found from the interaction of V_3O_2 (23.17%) which was statistically similar to all other interactions except V_1O_1 (20.64%).

4.3.2 Specific gravity of potato tuber at harvest

4.3.2.1 Effect of varieties

Significant variation was found on the specific gravity of potato tuber at harvest due to the effect of varieties (Table 49). The highest specific gravity (1.088) was observed from the variety V_3 (BARI Alu-29) and the lowest (1.063) was found from the variety V_1 (BARI Alu-25). The probable reason for variation in specific gravity due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.3.2.2 Effect of organic manures

Significant variation was observed on the specific gravity of potato tuber at harvest due to the effect of organic manures (Table 49). The highest specific gravity (1.084) was found from the variety V_2 (BARI Alu-28) and the lowest (1.073) was found from the variety V_1 (BARI Alu-25) which was statistically similar with V_3 (BARI Alu-29). The probable reason for variation in specific gravity due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

Table 49. Effect of variety, organic manure and mulch material on the qualitative characteristics of potato tuber at harvest

Treatments	Dry matter of potato at harvest (%)	Specific gravity	Total Soluble Solid (TSS ^{O})
Effect of variety			
V_1	21.04 b	1.063 c	5.83 b
V_2	22.51 a	1.080 b	6.91 a
V_3	22.77 a	1.088 a	6.92 a
LSD $_{(0.05)}$	**1.38**	**0.01**	**0.33**
CV (%)	**11.40**	**1.22**	**9.25**
Effect of organic manure			
O_1	21.78	1.073 b	6.45
O_2	22.54	1.084 a	6.56
O_3	21.99	1.074 b	6.66
LSD $_{(0.05)}$	**NS**	**0.01**	**NS**
CV (%)	**11.40**	**1.22**	**9.25**
Effect of mulch material			
M_1	21.95	1.075	6.49
M_2	22.23	1.079	6.58
M_3	22.14	1.078	6.59
LSD $_{(0.05)}$	**NS**	**NS**	**NS**
CV (%)	**11.40**	**1.22**	**9.25**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.3.2.3 Effect of mulch materials

Non-significant variation was observed on specific gravity of potato due to different mulch materials (Table 49).

4.3.2.4 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the specific gravity of potato at harvest (Table 50). Interaction of V_3O_2 showed the maximum specific gravity (1.09) while the minimum was found from the V_1O_1(1.057) which was statistically at par with V_1O_3(1.06).

4.3.2.5 Interaction effect of varieties and mulch materials

Interaction of varieties and mulch materials had significant effect on the specific gravity of potato at harvest (Table 50). The table showed that the highest specific gravity (1.09) of potato tuber was recorded in V_3M_1 which was statistically similar with V_3M_2 (1.089) V_3M_3 (1.086), V_2M_3 (1.083) and V_2M_2 (1.081). The minimum specific gravity of potato was obtained from the V_1M_1 (1.058) which was at par with V_1M_3 (1.064) and V_1M_2 (1.066) combinations.

4.3.2.6 Interaction effect of organic manures and mulch materials

Significant variation was found due to interaction effect of organic manures and mulch materials on the specific gravity of potato at harvest (Table 50). The maximum specific gravity of potato (1.091) was recorded in O_3M_2 which is statistically similar to O_2M_3(1.082). The minimum specific gravity of potato was obtained from the O_1M_1 and O_1M_2(1.07) which is statistically similar with O_3M_3(1.072), O_3M_2(1.074), O_3M_1(1.077), O_2M_1(1.078) and O_1M_3(1.079).

4.3.2.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of variety, organic manures and mulch materials on the specific gravity of potato at harvest (Table 51). The maximum specific gravity of potato (1.097) was recorded both the combinations of $V_3O_2M_2$ and $V_3O_2M_3$ (1.097) which were statistically similar to $V_1O_2M_2$ (1.083), $V_2O_1M_3$ (1.083), $V_2O_2M_3$ (1.083), $V_2O_3M_3$(1.083), $V_3O_1M_2$(1.083), $V_3O_1M_1$(1.087), $V_3O_1M_3$(1.087), $V_3O_3M_2$(1.087), $V_3O_3M_1$ (1.090), $V_2O_2M_2$ (1.093) and $V_3O_2M_1$(1.093). The minimum specific gravity of potato was found from $V_1O_1M_1$(1.050) which was statistically similar to $V_1O_1M_3$(1.053), $V_1O_3M_1$(1.060), $V_1O_3M_2$(1.060), $V_1O_3M_3$(1.060) and $V_1O_2M_1$(1.063).

4.3.3 Total soluble solid (TSS^o)

4.3.3.1 Effect of varieties

Significant variation was found among different varieties to total soluble solid of potato tuber at harvest (Table 49). The highest total soluble solid of tuber (6.92^{o}BRIX) exhibited by the variety V_3 (BARI Alu-29) which was statistically similar with V_2 (BARI Alu-28) while the minimum total soluble solid of tuber (5.83^{o}BRIX) was found from the variety V_1 (BARI Alu-25) The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.3.3.2 Effect of organic manure

Non-significant variation was found among the effect of different organic manures to total soluble solid of tuber at harvest (Table 49).

4.3.3.3 Effect of mulch materials

Non-significant variation was found among the effect of different mulch materials on total soluble solid of tuber at harvest (Table 49).

Table 50. Interaction effect of variety, organic manure and mulch material on the qualitative characteristics of potato tuber at harvest

Treatment combinations	Dry matter of potato at harvest (%)	Specific gravity	Total Soluble Solid (TSS ^{O})
Interaction effect of variety and organic manure			
V_1O_1	20.64 b	1.057 d	5.64 b
V_1O_2	21.58 ab	1.071 c	6.06 b
V_1O_3	20.89 ab	1.060 d	5.80 b
V_2O_1	22.03 ab	1.077 bc	6.76 a
V_2O_2	22.87 ab	1.084 b	6.80 a
V_2O_3	22.62 ab	1.080 bc	7.18 a
V_3O_1	22.67 ab	1.086 b	6.94 a
V_3O_2	23.17 a	1.096 a	6.82 a
V_3O_3	22.48 ab	1.083 b	7.00 a
$LSD_{(0.05)}$	**2.38**	**0.01**	**0.57**
CV (%)	**11.40**	**1.22**	**9.25**
Interaction effect of variety and mulch material			
V_1M_1	20.82	1.058 c	5.81 b
V_1M_2	21.15	1.066 c	5.88 b
V_1M_3	21.15	1.064 c	5.81 b
V_2M_1	22.25	1.077 b	6.76 a
V_2M_2	22.68	1.081 ab	7.03 a
V_2M_3	22.59	1.083 ab	6.95 a
V_3M_1	22.80	1.090 a	6.91 a
V_3M_2	22.85	1.089 a	6.84 a
V_3M_3	22.67	1.086 ab	7.01 a
$LSD_{(0.05)}$	**NS**	**0.01**	**0.57**
CV (%)	**11.40**	**1.22**	**9.25**
Interaction effect of organic manure and mulch material			
O_1M_1	21.77	1.070 c	6.27
O_1M_2	21.48	1.070 c	6.50
O_1M_3	22.10	1.079 bc	6.58
O_2M_1	22.07	1.078 bc	6.50
O_2M_2	23.18	1.091 a	6.47
O_2M_3	22.37	1.082 ab	6.71
O_3M_1	22.02	1.077 bc	6.71
O_3M_2	22.03	1.074 bc	6.79
O_3M_3	21.94	1.072 c	6.48
$LSD_{(0.05)}$	**NS**	**0.01**	**NS**
CV (%)	**11.40**	**1.22**	**9.25**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.3.3.4 Interaction effect of varieties and organic manures

Interaction of different varieties and organic manures had significant effect on total soluble solid of tuber at harvest (Table 50). The maximum total soluble solid of tuber was found from V_2O_3(7.18^{o}BRIX) followed by V_2O_1 (6.76^{o}BRIX), V_2O_2 (6.80^{o}BRIX), V_3O_2 (6.82^{o}BRIX), V_3O_1 (6.94^{o}BRIX) and V_3O_3 (7.00^{o}BRIX) which were statistically similar. The minimum soluble solid of tuber was found from the V_1O_1 (5.64^{o}BRIX) followed by V_1O_3 (5.80^{o}BRIX) and V_1O_2 (6.06^{o}BRIX) which are statistically similar. The probable reason for variation due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.3.3.5 Interaction effect of varieties and mulch materials

Interaction of different varieties and mulch materials had significant effect on total soluble solid of tuber at harvest (Table 50). The maximum total soluble solid of tuber was obtained from V_2M_2 (7.03^{o}BRIX) followed by V_3M_3 (7.01^{o}BRIX), V_2M_3 (6.95^{o}BRIX), V_3M_1 (6.91^o BRIX), V_3M_2 (6.84^o BRIX) and V_2M_1 (6.76^o BRIX) which were statistically similar. The minimum soluble solid of tuber was found from the V_1M_1 (5.81^o BRIX), V_1M_3 (5.81^o BRIX) and V_1M_2 (5.88^o BRIX) which were also statistically similar. The probable reason for variation due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.3.3.6 Interaction effect of organic manures and mulch materials

Interaction of different organic manures and mulch materials had non-significant effect on total soluble solid of tuber at harvest (Table 50.)

Table 51. Interaction effect of variety, organic manure and mulch material on the qualitative characteristics of potato tuber at harvest

Treatment combinations	Dry matter of potato at harvest (%)	Specific gravity	Total Soluble Solid (TSS ^{O})
$V_1O_1M_1$	20.49	1.05 i	5.53 gh
$V_1O_1M_2$	20.32	1.05 hi	5.40 h
$V_1O_1M_3$	21.11	1.07 e-h	6.00 d-h
$V_1O_2M_1$	21.18	1.06 f-i	6.10 c-h
$V_1O_2M_2$	22.29	1.08 a-d	6.23 b-h
$V_1O_2M_3$	21.28	1.07 e-h	5.83 e-h
$V_1O_3M_1$	20.77	1.06 g-i	5.80 f-h
$V_1O_3M_2$	20.83	1.06 g-i	6.00 d-h
$V_1O_3 M_3$	21.06	1.06 g-i	5.60 gh
$V_2O_1M_1$	22.13	1.07 d-g	6.43 a-g
$V_2O_1M_2$	21.65	1.07 d-g	7.00 a-c
$V_2O_1M_3$	22.32	1.08 a-d	6.83 a-d
$V_2O_2M_1$	22.15	1.08 c-f	6.67 a-f
$V_2O_2M_2$	23.86	1.09 ab	6.77 a-f
$V_2O_2 M_3$	22.60	1.08 a-d	6.97 a-d
$V_2O_3 M_1$	22.47	1.08 b-e	7.17 ab
$V_2O_3M_2$	22.54	1.08 c-f	7.33 a
$V_2O_3M_3$	22.85	1.08 a-d	7.05 a-c
$V_3O_1M_1$	22.69	1.09 a-d	6.83 a-d
$V_3O_1M_2$	22.46	1.08 a-d	7.10 ab
$V_3O_1M_3$	22.86	1.09 a-d	6.90 a-d
$V_3O_2M_1$	22.88	1.09 ab	6.73 a-f
$V_3O_2M_2$	23.39	1.10 a	6.40 a-g
$V_3O_2M_3$	23.24	1.10 a	7.33 a
$V_3O_3M_1$	22.81	1.09 a-c	7.17 ab
$V_3O_3M_2$	22.72	1.09 a-d	7.03 a-c
$V_3O_3M_3$	21.90	1.07 d-g	6.80 a-e
LSD $_{(0.05)}$	**NS**	**0.02**	**0.99**
CV (%)	**11.40**	**1.22**	**9.25**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29),
O_1= Cowdung @ 10 t ha^{-1}, O_2 = Poultry litter @ 10 t ha^{-1} and
O_3 = ACI organic fertilizer @ 10 t ha^{-1}
M_1 = Water hyacinth, M_2 = Rice straw , M_3 = Rice husk

4.3.3.7 Interaction effect of varieties, organic manures and mulch materials

Significant variation was found due to interaction effect of varieties, organic manures and mulch materials on total soluble solid of tuber at harvest (Table 51). The maximum total soluble solid of tubers (7.33^o BRIX) was recorded from both $V_2O_3M_2$ and $V_3O_2M_3$ which were statistically similar to all the combinations of organic manure and mulch material with variety V_2 (BARI Alu-28) and V_3 (BARI Alu-29). The minimum total soluble solid of tubers was obtained from the $V_1O_1M_2$ (5.40^o BRIX) which was statistically similar to all the combinations of organic manure and mulch materials with variety V_1 (BARI Alu-25).

It was observed from the experiment no.4 that among three tested varieties BARI Alu-25 showed higher yield and french fry tuber number (%) and higher french fry tuber yield. In case of quality parameter, BARI Alu-29 (V_3) and BARI Alu-28 (V_2) gave higher tuber dry matter (%) and total soluble solid. Considering the three organic manures, poultry litter (O_2) and ACI organic fertilizer (O_3) showed higher and similar yield. Considering tuber quality, cowdung (O_1) and ACI organic fertilizer provided highest chips tuber besides poultry litter (O_2) gave higher specific gravity (1.084) than other organic manures. Among three mulch materials, water hyacinth (M_1), rice straw (M_2) and rice husk (M_3) showed similar performance but numerically rice straw (M_2) gave the highest yield. Considering processing quality tuber, rice straw gave highest chips tuber (56.91 %), higher dry matter (%), specific gravity and total soluble solid (^{o} BRIX) than other mulch materials.

Experiment No. 5 : Response of organic manures on growth yield and quality of selected potato varieties in three districts of Bangladesh

The experiment was conducted to find out the effect of organic manure and mulch materials on three potato varieties at three potato growing region including SAU experimental farm in Dhaka. The results have been presented and discussed with the help of tables and possible interpretations given under the following headings.

4.1 Yield and yield components

4.1.1 Tuber number hill^{-1}

4.1.1.1 Effect of varieties

Significant variation was observed in tuber numbers hill^{-1} in different varieties at harvest in three experimental locations (Table 52). The result revealed that variety V_2 (BARI Alu-28) gave significantly highest number of tubers hill^{-1} in three locations which were 8.23, 8.43 and 8.40 for Dhaka, Rajbari and Thakurgaon locations, respectively. The lowest tuber number hill^{-1} was observed from V_2 (BARI Alu-28) for all the locations (6.00, 6.18 and 6.31 at Dhaka, Rajbari and Thakurgaon locations, respectively). On the other hand V_1 (BARI Alu-25) showed the intermediate number of tubers hill^{-1} irrespective of locations. The probable reason for variation in tuber number hill^{-1} due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.1.2 Effect of organic manures

Significant variation was observed on tuber number hill^{-1} due to different organic manures at Dhaka and Thakurgaon, but non-significant variation was found at Rajbari (Table 52). Tuber number hill^{-1} ranged 7.78-6.62 irrespective of organic manures and locations. Among the tested organic manures poultry litter (O_3) produced highest number of tubers hill^{-1} in three locations which were 7.45, 7.33 and 7.78 at Dhaka, Rajbari and Thakurgaon, respectively. No manure (O_1) gave lowest number of tubers hill^{-1} in the all tested locations.

4.1.1.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber number hill^{-1} at harvest in three experimental locations (Table 52). Interaction of V_2O_3 showed the highest tuber numbers hill^{-1} in the three tested locations (8.37, 8.80 and 8.30 for Dhaka, Rajbari and Thakurgaon locations, respectively) which was statistically similar with V_2O_1 and V_1O_3 combinations for all the locations. However, interaction of V_2O_1 showed the lowest tuber number hill^{-1} irrespective of locations.

Table 52. Effect of variety, organic manures and their interactions on yield contributing characteristics of potato in three districts of Bangladesh

Treatments	Tuber no. hill^{-1}			Tuber weight hill^{-1} (kg)		
	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon
Effect of varieties						
V_1	6.58 b	7.00 b	6.88 b	0.34	0.33	0.34
V_2	8.23 a	8.43 a	8.40 a	0.36	0.33	0.35
V_3	6.00 b	6.18 c	6.31 b	0.34	0.33	0.34
LSD $_{(0.05)}$	**0.73**	**0.74**	**0.85**	**NS**	**NS**	**NS**
CV (%)	**10.51**	**10.24**	**11.88**	**11.51**	**6.64**	**8.56**
Effect of organic manures						
O_1	6.62 b	6.80	6.87 b	0.34 ab	0.30 c	0.31 b
O_2	6.74 ab	7.48	6.94 ab	0.33 b	0.33 b	0.33 b
O_3	7.45 a	7.33	7.78 a	0.37 a	0.36 a	0.39 a
LSD $_{(0.05)}$	**0.73**	**NS**	**0.85**	**0.04**	**0.01**	**0.03**
CV (%)	**10.51**	**10.24**	**11.88**	**11.51**	**6.64**	**8.56**
Interaction effect of varieties and organic manures						
V_1O_1	6.55 b-d	6.61 de	6.60 bc	0.34	0.28 f	0.29 d
V_1O_2	6.21 cd	7.03 cd	6.71 bc	0.32	0.32 de	0.35 a-c
V_1O_3	6.99 bc	7.38 b-d	7.33 ab	0.37	0.39 a	0.38 ab
V_2O_1	7.77 ab	8.44 ab	8.28 a	0.34	0.33 cd	0.32 cd
V_2O_2	8.37 a	8.80 a	8.30 a	0.35	0.36 b	0.33 b-d
V_2O_3	8.56 a	8.04 a-c	8.62 a	0.39	0.32 de	0.39 a
V_3O_1	5.55 d	5.37 e	5.73 c	0.33	0.30 e	0.32 cd
V_3O_2	5.66 d	6.61 de	5.82 c	0.32	0.34 bc	0.32 cd
V_3O_3	6.79 b-d	6.57 de	7.38 ab	0.36	0.36 b	0.39 ab
LSD $_{(0.05)}$	**1.26**	**1.28**	**1.48**	**NS**	**0.02**	**0.05**
CV (%)	**10.51**	**10.24**	**11.88**	**11.51**	**6.64**	**8.56**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29), O_1 = Control (no manure), O_2 = cowdung @10 t ha^{-1} and O_3 = poultry litter @10 t ha^{-1}

4.1.2 Tuber weight hill^{-1} (kg)

4.1.2.1 Effect of varieties

Non-significant variation was observed in tuber weight hill^{-1} due to varieties at harvest in three experimental locations (Table 52).

4.1.2.2 Effect of organic manures

Significant variation was observed on tuber weight hill^{-1} due to different organic manures in three experimental locations (Table 52). The result revealed that irrespective of locations organic manures applied through poultry litter (O_3) showed significantly the highest tuber weight hill^{-1} in potato which were 0.37, 0.36 and 0.39 kg at Dhaka, Rajbari and Thakurgaon locations, respectively. Except Dhaka location no manure (O_1) showed the lowest tuber weight (0.30 and 0.31 kg) hill^{-1} for Rajbari and Thakurgaon, respectively. At Dhaka location cowdung (O_2) gave the lowest result.

4.1.2.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber weight hill^{-1} at harvest at Rajbari and Thakurgaon, but non-significant variation was observed at Dhaka location (Table 52). Irrespective of interaction and location tuber weight ranged 0.39 to 0.28 kg hill^{-1}. Among the interaction V_1O_3 performed best in all locations. At Thakurgaon, interaction of V_1O_2, V_1O_3, V_2O_3 and V_3O_3 showed the statistically similar tuber weight (0.35, 0.38, 0.39 and 0.39 kg hill^{-1}, respectively.).

4.1.3 Potato yield (t ha^{-1})

4.1.3.1 Effect of varieties

Variety had significant effect on the yield of tuber at Thakurgaon, but it was non-significant at Dhaka and Rajbari (Table 53). But ingeneral V_1 (BARI Alu-25) was found superior in producing highest yield in Thakurgaon, Rajbari and Dhaka locations (35.11, 33.19 and 33.15 t ha^{-1}, respectively). On the other hand V_3 (BARI Alu-29) showed the lowest in three location of Thakurgaon, Rajbari and Dhaka (31.89 , 31.19 and 29.88 t ha^{-1}, respectively). The probable reason for variation in yield due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site. The yields difference of potato cultivars were also reported by Kundu *et al.* (2012). Similar trend of yield performance was also reported by Hossain (2011) and Dhar *et al.* (2009) which supported the present findings.

4.1.3.2 Effect of organic manures

Significant variation exists on tuber yield of potato due to the different organic manures in three locations (Table 53). The result revealed that organic matter appliced through poultry litter (O_3) showed statistically highest potato yield in all the locations (37.87, 39.13 and 37.75 t ha^{-1} for Dhaka, Rajbari and Thakurgaon, respectively). The significantly lowest tuber was recorded from no manure (O_1) for all the three locations that were 26.36, 25.63 and 26.99 t ha^{-1} for Dhaka, Rajbari and Thakurgaon, respectively. At Thakurgaon, poultry litter (O_3) and cowdung (O_2) although gave the statistically similar yield but O_2 (cowdung) gave second highest potato yield. This variation might be due to change the yield contributing character under different organic manures.

4.1.3.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber yield in three locations (Table 53). The result revealed that among the interactions V_1O_3 was found best as it produced the highest potato yield in all three locations which was 42.46, 41.48 and 40.21 t ha^{-1}, at Rajbari, Dhaka and Thakurgaon respectively. Interaction of V_2O_3 showed the second highest potato yield that in all locations. The maximum tuber yield (42.46 t ha^{-1}) was recorded in V_1O_3 at Rajbari while the minimum tuber yield (22.94 t ha^{-1}) was obtained in the same location. The treatment combination of V_1O_3 was shown the highest and the treatment combination with no manure was shown the lowest tuber yield at all three locations.

4.1.4 Marketable potato yield (t ha^{-1})

4.1.4.1 Effect of varieties

Variety had significant effect on the marketable yield of tuber at Dhaka while non-significant effect was found at Rajbari and Thakurgaon (Table 53). Among the varieties V_1 (BARI Alu-25) showed the highest yield at Dhaka and Thakurgaon (31.04 and 32.84 t ha^{-1}, respectively) but at Rajbari V_2 (BARI Alu-28) variety showed the highest yield (31.09 t ha^{-1}). Variety V_3 (BARI Alu-29) showed the lowest yield in the three locations in this experiment which were 29.84, 29.12 and 27.84 t ha^{-1} for Thakurgaon, Rajbari and Dhaka locations, respectively. The probable reason for variation in yield due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site. Similar trend of yield performance was also reported by Kundu *et al.* (2012), Hossain (2011), Dhar *et al.* (2009) and DAP (2006).

Table 53. Effect of variety, organic manures and their interactions on the yield and yield contributing characteristics of potato in three districts of Bangladesh

Treatments	Potato yield (t ha^{-1})			Marketable potato (>20g) yield (t ha^{-1})			Non marketable potato(<20g) yield (t ha^{-1})		
	Dhaka	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**
Effect of varieties									
V_1	33.15	33.19	35.11 a	31.04 a	30.89	32.84	2.11 a	2.30 a	2.27 a
V_2	31.94	33.02	32.62 ab	30.07 a	31.09	30.73	1.87 b	1.93 b	1.89 b
V_3	29.88	31.19	31.89 b	27.84 b	29.12	29.84	2.04 ab	2.07 b	2.05 b
LSD $_{(0.05)}$	**NS**	**NS**	**3.22**	**2.19**	**NS**	**NS**	**0.23**	**0.19**	**0.22**
CV (%)	**10.84**	**10.19**	**9.70**	**7.27**	**9.40**	**8.39**	**11.33**	**9.28**	**10.53**
Effect of organic manures									
O_1	26.36 c	25.63 c	26.99 b	24.43 c	23.54 c	25.12 c	1.93	2.09	1.87 b
O_2	30.73 b	32.64 b	34.88 a	28.64 b	30.46 b	32.71 b	2.09	2.18	2.17 a
O_3	37.87 a	39.13 a	37.75 a	35.87 a	37.10 a	35.57 a	2.00	2.03	2.18 a
LSD $_{(0.05)}$	**3.43**	**3.31**	**3.22**	**2.19**	**2.87**	**2.59**	**NS**	**NS**	**0.22**
CV (%)	**10.84**	**10.19**	**9.70**	**7.27**	**9.40**	**8.39**	**11.33**	**9.28**	**10.53**
Interaction effect of varieties and organic manures									
V_1O_1	27.57 cd	22.94 f	27.70 cd	25.75 ef	21.64 f	25.14 e	1.69 d	2.07 b-d	1.93 b-d
V_1O_2	30.39 bc	34.17 bc	37.44 ab	30.20 cd	35.61 ab	32.47 bc	2.46 a	2.36 ab	2.24 bc
V_1O_3	41.48 a	42.46 a	40.21 a	38.73 a	39.99 a	37.45 a	2.18 ab	2.47 a	2.65 a
V_2O_1	27.12 cd	27.61 d-f	26.38 d	24.14 ef	25.95 def	25.41 de	1.95 b-d	1.97 c-e	1.70 d
V_2O_2	32.61 bc	32.61 cd	34.57 b	33.35 bc	30.30 cd	30.61 c	1.72 cd	1.84 de	1.96 b-d
V_2O_3	36.08 ab	38.82 ab	36.90 ab	33.23 bc	36.51 ab	36.14 ab	1.95 b-d	1.98 cd	2.00 b-d
V_3O_1	24.40 d	26.34 ef	26.89 d	22.37 f	24.03 ef	24.82 e	2.17 ab	2.23 a-c	1.97 b-d
V_3O_2	29.20 cd	31.14 c-e	32.63 bc	27.85 de	28.63 c-e	29.74 cd	2.09 a-c	2.34 ab	2.30 ab
V_3O_3	36.04 ab	36.10 bc	36.14 ab	35.35 ab	31.87 bc	35.70 ab	1.86 b-d	1.64 e	1.87 cd
LSD $_{(0.05)}$	**5.94**	**5.73**	**5.58**	**3.79**	**4.96**	**4.48**	**0.39**	**0.34**	**0.38**
CV (%)	**10.84**	**10.19**	**9.70**	**7.27**	**9.40**	**8.39**	**11.33**	**9.28**	**10.53**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and
O_1= Control (no manure), O_2 = cowdung @ 10 t ha^{-1} and O_3 = poultry litter @ 10 t ha^{-1}

4.1.4.2 Effect of organic manures

Significant variation was observed on marketable tuber yield due to use of different organic manures in three locations (Table 53). The result revealed that organic manures applied through poultry litter (O_3) produced significantly the highest potato yield in the three locations which were 35.87, 37.10 and 35.57 t ha^{-1}, for Dhaka, Rajbari and Thakurgaon locations, respectively. Significantly the lowest yield was observed from O_1 (no manure) and intermediate level of yield was recorded from O_2 (cowdung) for all the three locations.

4.1.4.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on marketable tuber yield at all three locations (Table 53). Data presented in the table indicated that interaction of V_1O_3 showed the highest marketable tuber yield at Dhaka, Rajbari and Thakurgaon (38.73, 39.99 and 37.45 t ha^{-1}, respectively). At Dhaka, V_3O_3 interaction showed statistically similar result with V_1O_3 , at Rajbari interaction of V_1O_2 (35.61 t ha^{-1}) and V_2O_3 (36.51 t ha^{-1}) and at Thakurgaon location V_3O_3 (35.70 t ha^{-1}) interactions were statistically at par with V_1O_3 combination.

4.1.5 Non-marketable tuber yield (t ha^{-1})

4.1.5.1 Effect of varieties

Varieties exerted significant effect on the non-marketable yield of tuber at Dhaka, Rajbari and Thakurgaon (Table 53). The highest non-marketable tuber yield was found from V_1 (BARI Alu-25) variety in the three locations which were 2.11, 2.30 and 2.27 t ha^{-1} for Dhaka, Rajbari and Thakurgaon locations, respectively. At Dhaka location V_3 (BARI Alu-29) variety showed statistically similar yield with V_1 (BARI Alu-25) variety. For all locations V_2 (BARI Alu-28) showed lowest non-marketable yield of 1.87, 1.93 and 1.89 t ha^{-1} for Dhaka, Rajbari and Thakurgaon, respectively. The probable reason for variation in yield due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site. The result corroborates with the findings of Kundu *et at* (2012), Hossain (2011) and Dhar *et al* (2009) who observed yield difference among the potato varieties.

4.1.5.2 Effect of organic manures

Non-marketable tuber yield had significant influences by the different organic manures at Thakurgaon and non-significant variation was found at Dhaka and Rajbari location (Table 53). The highest tuber yield (2.18 t ha^{-1}) was recorded from the poultry litter (O_3) at Thakurgaon which was similar with cowdung (O_2) at the same location. The lowest yield was found with O_1 (no manure) at Dhaka and Thakurgaon location. This variation might be due to change the yield contributing characteristics under different organic manures.

4.1.5.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on tuber non-marketable yield at three locations (Table 53). The result indicated that interaction of V_1O_3 showed the highest non-marketable tuber yield at Rajbari and Thakurgaon (2.47 and 2.65 t ha^{-1} , respectively), but at Dhaka location V_1O_2 interaction gave highest (2.46 t ha^{-1}) non-marketable tuber yield. At Dhaka location interaction of V_1O_3, V_3O_1 and V_3O_2 (2.18, 2.17 and 2.09 t ha^{-1} , respectively) gave statistically similar yield with V_1O_2, at Rajbari the interaction of V_1O_2 (2.36 t ha^{-1}), V_3O_1 (2.23 t ha^{-1}) and V_3O_2 (2.34 t ha^{-1}) were similar with V_1O_3 interaction and at Thakurgaon interaction V_3O_2 gave the similar yield with V_1O_3 combination. The lowest yield 1.69 t ha^{-1} from V_1O_1 at Dhaka, 1.64 t ha^{-1} from V_3O_3 at Rajbari and 1.70 t ha^{-1} from V_2O_1 at Thakurgaon were observed in this experiment.

4.1.6 Tuber (>75 g) yield (t ha^{-1})

4.1.6.1 Effect of varieties

Varieties exhibited significant variation among them in respect of producing tuber yield (>75g) for all locations (Table 54) Variety V_1 (BARI Alu-25) was superior by producing higher yield at Dhaka and Thakurgaon locations (16.03 and 16.08 t ha^{-1}, respectively), where as at Rajbari V_3 (BARI Alu-29) showed the highest yield. The table showed that V_2 (BARI Alu-28) gave the lowest tuber yield for all the three locations.

4.1.6.2 Effect of organic manures

Significantly highest tuber (>75g.) yield was observed with poultry litter (O_3) that of lowest was found with no manure (O_1) in the three tested locations (Table 54). The data revealed that O_3 produced 33.52 and 30.96% higher at Dhaka location, at Rajbari 25.02 and 39.93% higher and at Thakurgaon 28.15 and 31.23% higher yield than cowdung (O_2) and no manure (O_1), respectively.

4.1.6.3 Interaction effect of varieties and organic manure

Out of nine interactions of variety and organic manure; the highest tuber (>75g) yield was found with V_1O_3 irrespective of locations (18.68, 17.88 and 18.81 t ha^{-1} at Dhaka, Rajbari and Thakurgaon, respectively), which was statistically at par with V_3O_3 for all locations (Table 54). On the other hand, the lowest yield was recorded with V_2O_2 at Dhaka and Thakurgaon (8.43 and 8.00 t ha^{-1}, respectively) but at Rajbari it was with V_2O_1 combination (8.48 t ha^{-1}).

4.1.7 Tuber (50-75 g) yield (t ha^{-1})

4.1.7.1 Effect of varieties

Like (>75g.) tuber yield, variety V_2 (BARI Alu-28) maintained its superiority by producing highest tuber (50-75g) yield in all the tested locations (8.11, 7.82 and 8.38 t ha^{-1} , respectively at Dhaka, Rajbari and Thakurgaon) than other two varieties (Table 54). The lowest tuber (50-75g.) yield was recorded with V_1 (BARI Alu-25) variety in all locations. The result indicates that variety V_2 (BARI Alu-28) produced 7.27 and 33.61% higher at Dhaka, at Rajbari 7.12 and 29.05% higher and at Thakurgaon 7.30 and 30.53% higher yield than V_3 (BARI Alu-29) and V_1 (BARI Alu-25) , respectively.

4.1.7.2 Effect of organic manures

Organic manures applied through poultry litter (O_3) was found superior in producing 19.79 and 21.04% higher at Dhaka, at Rajbari 8.18 and 19.66% higher and at Thakurgaon 24.01 and 27.45% higher tuber (50-75g.) yield than cowdung (O_2) and no manure (O_1), respectively (Table 54). However no manure (O_1) showed the lowest tuber (50-75g.) yield for all tested locations (6.74, 6.41 and 6.85 t ha^{-1}, respectively at Dhaka, Rajbari and Thakurgaon).

4.1.7.3 Interaction effect of varieties and organic manures

Out of nine interactions V_3O_2 seems superior in producing highest tuber (50-75g.) yield than other interactions irrespective of locations (Table 54). At Dhaka location, V_2O_2 (8.74 t ha^{-1}) and V_2O_3 (8.62 t ha^{-1}) showed statistically similar yield with V_3O_3, at Rajbari V_2O_3 (8.04 t ha^{-1}), V_2O_2 (7.73 t ha^{-1}) and V_2O_1 (7.68 t ha^{-1}) gave the similar yield with V_3O_3 and at Thakurgaon V_2O_3 (8.84 t ha^{-1}) and V_2O_2 (8.83 t ha^{-1}) showed similar yield with V_3O_3. However, the lowest tuber (50-75g.) yield was found with V_1O_1 at Rajbari and Thakurgaon (4.85 and 5.64 t ha^{-1} , respectively) and at Dhaka with V_1O_2 (5.23 t ha^{-1}) combination.

4.1.8 Tuber (20-50 g) yield (t ha^{-1})

4.1.8.1 Effect of varieties

The result presented in table 54 revealed that V_2 (BARI Alu-28) variety out yielded over V_1 (BARI Alu-25) and V_3 (BARI Alu-29) by producing 70 and 74.64% higher at Dhaka location, at Rajbari 73.33 and 95.52% higher and at Thakurgaon 61.99 and 55.03% higher tuber (20-50g) yield than V_1 (BARI Alu-25) and V_3 (BARI Alu-29) , respectively. Table also shows that V_3 (BARI Alu-29) and V_1 (BARI Alu-25) variety showed statistically similar tuber (20-50g) yield for all locations.

4.1.8.2 Effect of organic manures

Tuber (20-50g.) yield varied significantly at Rajbari and Thakurgaon location, but at Dhaka location it was shown non-significant due to different organic manures (Table 54). Irrespective of locations cowdung (O_2) produced the highest tuber (20-50g) which was statistically similar with O_1. On the other hand V_3 showed the lowest tuber (20-50g.) yield for all locations.

Table 54. Effect of variety, organic manures and their interactions on the yield and yield contributing characteristics of potato in three districts of Bangladesh

Treatment	>75 g. tuber yield (tha^{-1})			50-75 g. tuber yield (tha^{-1})			20-50 g. tuber yield (tha^{-1})		
	Dhaka	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**
Effect of varieties									
V_1	16.03 a	14.39 b	16.08 a	6.07 b	6.06 c	6.42 b	6.40 b	7.05 b	7.45 b
V_2	10.40 c	9.82 c	9.149 b	8.11 a	7.82 a	8.38 a	10.88 a	12.22 a	11.55 a
V_3	14.70 b	15.62 a	14.60 a	7.56 a	7.30 b	7.81 a	6.23 b	6.25 b	7.13 b
$LSD_{(0.05)}$	**1.241**	**1.122**	**1.651**	**0.68**	**0.47**	**0.87**	**0.82**	**0.95**	**0.94**
CV (%)	**9.06**	**8.45**	**12.44**	**9.46**	**6.62**	**11.6**	**10.44**	**11.16**	**10.8**
Effect of organic manures									
O_1	12.50 b	11.32 c	11.88 b	6.75 b	6.41 c	6.85 b	7.74	9.02 a	8.57 ab
O_2	12.26 b	12.67 b	12.36 b	6.82 b	7.10 b	7.04 b	8.22	8.89 a	9.28 a
O_3	16.37 a	15.84 a	15.59 a	8.17 a	7.67 a	8.73 a	7.54	7.61 b	8.28 b
$LSD_{(0.05)}$	**1.241**	**1.122**	**1.651**	**0.68**	**0.47**	**0.87**	**NS**	**0.95**	**0.94**
CV (%)	**9.06**	**8.45**	**12.44**	**9.46**	**6.62**	**11.6**	**10.44**	**11.16**	**10.8**
Interaction effect of varieties and organic manures									
V_1O_1	13.88 cd	11.36 c	13.71 cd	5.83 de	4.85 d	5.64 d	7.15 c	7.88 c	7.15 c
V_1O_2	15.54 bc	13.94 b	15.72 bc	5.23 e	6.52 c	6.07 cd	5.98 c	7.15 cd	7.72 c
V_1O_3	18.68 a	17.88 a	18.81 a	7.14 c	6.81 c	7.55 bc	6.07 c	6.11 d	7.48 c
V_2O_1	9.50 e	8.48 d	8.32 ef	6.98 cd	7.68 ab	7.48 bc	10.21 b	12.80 a	11.55 ab
V_2O_2	8.43 e	9.70 cd	8.00 f	8.74 a	7.73 ab	8.83 ab	11.99 a	13.00 a	12.64 a
V_2O_3	13.28 d	11.27 c	11.12 de	8.62 ab	8.04 a	8.84 ab	10.43 b	10.86 b	10.45 b
V_3O_1	14.12 cd	14.13 b	13.60 cd	7.44 bc	6.70 c	7.42 bc	5.85 c	6.37 cd	7.02 c
V_3O_2	12.83 d	14.37 b	13.36 cd	6.50 cd	7.04 bc	6.21 cd	6.70 c	6.51 cd	7.47 c
V_3O_3	17.16 ab	18.37 a	16.85 ab	8.76 a	8.16 a	9.81 a	6.12 c	5.87 d	6.89 c
$LSD_{(0.05)}$	**2.15**	**1.943**	**2.86**	**1.19**	**0.81**	**1.51**	**1.41**	**1.643**	**1.63**
CV (%)	**9.06**	**8.45**	**12.44**	**9.46**	**6.62**	**11.6**	**10.44**	**11.16**	**10.8**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and
O_1= Control (no manure), O_2 = cowdung@ 10 t ha^{-1} and O_3 = poultry litter @ 10 t ha^{-1}

4.1.8.3 Interaction of varieties and organic manures

Interaction of variety and organic manure exerted significant effect of tuber (20-50g.) yield of potato at all test locations (Table 54). Interaction of V_2O_2 showed the highest tuber (20-50g.) yield in all locations (11.99, 13.00 and 12.64 t ha^{-1}, respectively at Dhaka, Rajbari and Thakurgaon) which was followed by V_2O_1 interaction. On the other hand, the lowest tuber (20-50g.) yield was found with V_3O_3 combination at Dhaka, Rajbari and Thakurgaon (6.12, 5.87 and 6.89 t ha^{-1}, respectively).

4.1.9 Chips tuber (45-75 mm) yield (t ha^{-1})

4.1.9.1 Effect of varieties

Varieties exerted significant variations on chips tuber yield in all the tested locations (Table 55). The highest chips tuber yield was found from the variety V_3 (BARI Alu-29) at all three locations. It showed that variety V_3 (BARI Alu-29) was out yielded by producing 0.92 and 6.97 t ha^{-1} , 2.21 and 9.02 t ha^{-1} , and 2.81 and 7.35 t ha^{-1} higher chips tuber yield at Dhaka, Rajbari, and at Thakurgaon respectively, over V_2 (BARI Alu-28) and V_1 (BARI Alu-25) varieties. Irrespective of locations, V_1 (BARI Alu-25) variety gave the lowest chips tuber yield.

4.1.9.2 Effect of organic manures

Chips tuber yield affected significantly due to organic manure at all the tested locations (Table 55). Organic manure applied using poultry litter (O_3) was superior by producing chips tuber yield, which was followed by cowdung (O_2) irrespective of locations. No manure (O_1) showed the lowest chips tuber yield for all locations. The result seems that location have minimum effect on chips tuber yield due to organic manures.

4.1.9.3 Interaction of varieties and organic manures

Interaction of varieties and organic manures exerted significant effect on chips tuber yield of potato at all the tested locations (Table 55). Interaction of V_3O_3 showed the highest yield at Dhaka, Rajbari and Thakurgaon locations (29.88, 28.94 and 31.09 t ha^{-1}, respectively. At Dhaka, interaction of V_3O_3 was similar with V_2O_3 , at Rajbari interaction of V_2O_2, V_3O_1 and V_3O_2 were similar with V_3O_3 interaction and at Thakurgaon V_2O_3 interaction was similar with V_3O_3. However, the lowest yield value was obtained from V_1O_2 at Dhaka and V_1O_1 (15.42 and 17.41 t ha^{-1} , respectively) at Rajbari and Thakurgaon locations.

4.1.10 Dehydrated tuber (30-45mm) yield (t ha^{-1})

4.1.10.1 Effect of varieties

Dehydrated tuber yield exhibited significant variation among the varieties in all tested locations (Table 55). The data revealed that variety V_2 (BARI Alu-28) out yielded over V_1 (BARI Alu-25) and V_3 (BARI Alu-29) by producing 36.18 and 49.44% higher at Dhaka, at Rajbari 41.25 and 71.20% higher and at Thakurgaon 42.36 and 61.37% higher dehydrated tuber yield of potato. In all the locations V_3 (BARI Alu-28) showed the lowest dehydrated yield (2.67, 2.50 and 2.77 t ha^{-1}, respectively at Dhaka, Rajbari and Thakurgaon). Out of the three locations Thakurgaon seems better for all varieties in producing dehydrated tuber.

4.1.10.2 Effect of organic manures

The result revealed that highest dehydrated tuber yield was recorded with cowdung (O_2) organic manure which was statistically similar with no manure (O_1) for all the three tested locations (Table 55). The lowest dehydrated tuber yield was found with poultry litter (O_3) for all the tested locations. Irrespective of organic manure Thakurgaon showed the higher yield than other locations.

4.1.10.3 Interaction of varieties and organic manures

The result of dehydrated tuber yield due to interaction of variety and organic manure has been presented in table 55. The table indicated that V_2O_1 interaction was superior in producing dehydrated tuber which was followed by V_2O_2 interaction irrespective of locations . It was also observed that Thakurgaon location seems better for producing dehydrated tuber irrespective of interactions. However, the lowest tuber yield was found with V_3O_1 interaction for all locations.

4.1.11 French fry tuber (>75mm) yield (t ha^{-1})

4.1.11.1 Effect of varieties

Significantly highest french fry tuber was obtatined from V_1 (BARI Alu-25) variety for all tested locations (6.38, 6.74 and 6.20 t ha^{-1}, respectively at Dhaka, Rajbari and Thakurgaon.) (Table 55). In V_2 (BARI Alu-28) and V_3 (BARI Alu-29) varieties no yield was recorded in any location in this experiment.

4.1.11.2 Effect of organic manures

Significant variation was observed on french fry tuber production due to organic manure application in all the locations (Table 55). Organic manue applied through cowdung (O_2) gave the highest french fry tuber which was followed by poutry litter (O_3) for all locations. No manure (O_1) showed the lowest french fry tuber at all locations.

4.1.11.3 Interaction of varieties and organic manures

In producing french fry tuber, the interaction of V_1O_2 showed the highest yield (7.24, 8.12 and 7.07 t ha^{-1}, respectively at Dhaka, Rajbari and Thakurgaon whch was followed by V_1O_3 interaction irrespective of locations. On the other hand all interactions with O_1, O_2 and O_3 with V_2 and V_3 showed the lowest (zero) yield for all locations (Table 55).

4.1.12 Canned tuber (20-30 mm) yield (t ha^{-1})

4.1.12.1 Effect of varieties

Variety V_2 (BARI Alu-28) maintained its superiority by producing 0.16 and 0.57 t ha^{-1} higher at Dhaka location, at Rajbari 0.15 and 0.52 t ha^{-1} higher and at Thakurgaon 0.15 and 0.47 t ha^{-1} higher canned tuber yield than V_1 (BARI Alu-25) and V_3 ((BARI Alu-29), respectively (Table 55). However, Dhaka location showed little bit higher canned tuber yield than other locations.

4.1.12.2 Effect of organic manures

Yield of canned tuber exhibited significant variation at Dhaka and Thakurgaon location but non-significant variations was observed at Rajbari location due to different organic manure application (Table 55). Organic manure applied through poultry litter (O_3) produced maximum canned tuber than other organic manure at Dhaka and Thakurgaon (0.96 and 0.84 t ha^{-1}, respectively.) However, the lowest canned tuber yield was recorded with no manure (O_1).

Table 55. Effect of variety, organic manures and their interactions on the yield and yield contributing characteristics of potato in three districts of Bangladesh

Treatments	Chips tuber (45-75mm) yield (t ha^{-1})			Dehydrated tuber (30-45mm) yield (t ha^{-1})			French fry tuber (>75mm) yield (t ha^{-1})			Canned tuber (20-30mm) yield (t ha^{-1})		
	Dhaka	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**	**Dhaka**	**Rajbari**	**Thakurgaon**
Effect of varieties												
V_1	19.46 b	18.32 c	19.78 b	2.93 b	3.03 b	3.14 b	6.38 a	6.74 a	6.20 a	0.95 b	0.91 b	0.85 b
V_2	25.51 a	25.13 b	24.32 a	3.99 a	4.28 a	4.47 a	0.00 b	0.00 b	0.00 b	1.11 a	1.06 a	1.00 a
V_3	26.43 a	27.34 a	27.13 a	2.67 b	2.50 c	2.77 c	0.00 b	0.00 b	0.00 b	0.54 c	0.54 c	0.53 c
$LSD_{(0.05)}$	**1.86**	**1.85**	**2.86**	**0.28**	**0.38**	**0.33**	**0.47**	**0.43**	**0.38**	**0.10**	**0.10**	**0.10**
CV (%)	**7.82**	**7.84**	**12.04**	**8.48**	**11.39**	**9.58**	**21.98**	**19.29**	**18.41**	**11.03**	**10.72**	**11.71**
Effect of organic manures												
O_1	22.26 b	21.48 b	21.83 b	3.27 a	3.51 a	3.64 a	1.74 b	1.97 b	1.67 b	0.77 b	0.82	0.73 b
O_2	22.47 b	23.78 a	21.78 b	3.34 a	3.42 a	3.66 a	2.41 a	2.71 a	2.36 a	0.88 a	0.85	0.81 ab
O_3	26.67 a	25.52 a	27.62 a	2.98 b	2.88 b	3.08 b	2.23 a	2.06 b	2.18 a	0.96 a	0.84	0.84 a
$LSD_{(0.05)}$	**1.859**	**1.848**	**2.856**	**0.28**	**0.38**	**0.33**	**0.47**	**0.43**	**0.38**	**0.10**	**NS**	**0.10**
CV (%)	**7.82**	**7.84**	**12.04**	**8.48**	**11.39**	**9.58**	**21.98**	**19.29**	**18.41**	**11.03**	**10.72**	**11.71**
Interaction effect of varieties and organic manures												
V_1O_1	18.47 e	15.42 d	17.41 e	3.06 cd	3.64 b	3.42 bc	5.22 b	5.92 b	5.00 b	0.77 b	0.85 b	0.71 b
V_1O_2	17.91 e	16.66 d	17.83 de	2.94 cd	3.00 bc	3.15 cd	7.24 a	8.12 a	7.07 a	1.00 a	0.88 b	0.88 a
V_1O_3	21.99 d	22.87 c	24.09 bc	2.78 d	2.45 cd	2.85 c-e	6.69 a	6.18 b	6.54 a	1.09 a	1.00 ab	0.97 a
V_2O_1	24.43 cd	23.06 c	22.61 cd	4.63 a	4.73 a	5.03 a	0.00 c	0.00 c	0.00 c	1.12 a	1.12 a	1.00 a
V_2O_2	23.96 cd	27.57 ab	22.67 cd	4.06 b	4.61 a	4.55 a	0.00 c	0.00 c	0.00 c	1.06 a	1.09 a	1.00 a
V_2O_3	28.14 ab	24.76 bc	27.67 ab	3.29 c	3.52 b	3.82 b	0.00 c	0.00 c	0.00 c	1.15 a	0.97 ab	1.00 a
V_3O_1	23.88 cd	25.97 a-c	25.48 bc	2.12 e	2.18 d	2.45 e	0.00 c	0.00 c	0.00 c	0.42 d	0.48 c	0.48 c
V_3O_2	25.53 bc	27.11 ab	24.83 bc	3.02 cd	2.67 cd	3.27 bc	0.00 c	0.00 c	0.00 c	0.57 cd	0.58 c	0.56 bc
V_3O_3	29.88 a	28.94 a	31.09 a	2.87 cd	2.67 cd	2.58 de	0.00 c	0.00 c	0.00 c	0.64 bc	0.55 c	0.56 bc
$LSD_{(0.05)}$	**3.22**	**3.2**	**4.946**	**0.48**	**0.64**	**0.57**	**0.81**	**0.75**	**0.66**	**0.16**	**0.16**	**0.16**
CV (%)	**7.82**	**7.84**	**12.04**	**8.48**	**11.39**	**9.58**	**21.98**	**19.29**	**18.41**	**11.03**	**10.72**	**11.71**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and
O_1= Control (no manure), O_2 = cowdung @ 10 t ha^{-1} and O_3 = poultry litter @ 10 t ha^{-1}

4.1.12.3 Interaction of varieties and organic manures

There observed significant variation on canned tuber yield of potato due to interaction of variety and organic manure for all tested locations (Table 55). Among the interactions, V_1O_2, V_1O_3, V_2O_1, V_2O_2 and V_2O_3 interaction showed statistically similar and higher level of canned tuber yield irrespective of locations except V_1O_2 at Rajbari location. However, V_3O_1 interaction gave the lowest canned tuber yield irrespective locations.

4.1.13 Marketable tuber number (%)

4.1.13.1 Effect of varieties

Significant effect on the marketable tuber number by percent was observed due to different varieties at three locations (Table 56). Irrespective of varieties and locations marketable tuber number by percent ranged 84.07-69.53 % . However, V_3 (BARI Alu-29) variety alongwith V_2 (BARI Alu-28) were found superior in producing higher level of marketable tuber number by percent in the three tested locations. On the other hand V_1 (BARI Alu-25) variety gave the lowest yield in all the locations (69.81, 69.53 and 72.49%) for Dhaka, Rajbari and Thakurgaon, respectively. The probable reason for variation in yield due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.13.2 Effect of organic manures

Marketable tuber number by percent had non-significant influences due to different organic manures in all three locations (Table 56).

4.1.13.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on marketable tuber number by percent was observed at Dhaka and Rajbari, but non-significant variation was observed at Thakurgaon. (Table 56). It can be inferred from the table that although Thakurgaon location showed non-significant variation among the interactions, but it produced higher yield than Dhaka and Rajbari. For all locations interaction of V_3O_3 prduced the highest marketable tuber number by percent which was 84.27, 84.27 and 85.38% for Dhaka, Rajbari and Thakurgaon, respectively. At Dhaka location all the interactions except V_1O_1 and V_1O_2 were similar with V_3O_3 combination and at Rajbari all interactions except V_1O_1, V_1O_2 and V_1O_3 showed the statistically similar yield with V_3O_3 combination. The lowest yield was found with V_1O_1 interactions for all locations.

Table 56. Effect of variety, organic manures and their interactions on the yield and yield contributing characteristics of potato in three districts of Bangladesh

Treatments	Marketable tubers no. (%)			Marketable tuber weight (%)		
	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon
Effect of varieties						
V_1	69.81 b	69.53 b	72.49 b	93.88	96.23	93.78
V_2	77.28 a	78.04 a	80.07 ab	93.51	96.22	94.18
V_3	82.84 a	83.52 a	84.07 a	95.57	98.33	95.63
LSD $_{(0.05)}$	**7.20**	**7.63**	**8.85**	**NS**	**NS**	**NS**
CV (%)	**9.40**	**9.91**	**11.22**	**9.66**	**10.57**	**11.23**
Effect of organic manures						
O_1	75.13	76.14	78.21	93.58	97.71	94.49
O_2	76.49	76.92	79.08	94.12	101.7	94.90
O_3	78.31	78.03	79.33	95.26	91.42	94.19
LSD $_{(0.05)}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**9.40**	**9.91**	**11.22**	**9.66**	**10.57**	**11.23**
Interaction effect of varieties and organic manure						
V_1O_1	67.30 c	68.84 c	70.32	92.42	94.09 ab	93.76
V_1O_2	68.44 bc	69.79 bc	73.48	94.04	91.02 ab	94.85
V_1O_3	73.68 a-c	69.97 bc	73.66	95.18	103.6 a	92.72
V_2O_1	74.91 a-c	75.59 a-c	78.96	92.65	103.3 a	93.96
V_2O_2	79.95 ab	77.53 a-c	79.13	93.91	107.1 a	94.74
V_2O_3	76.98 a-c	80.99 a-c	82.12	93.97	78.27 b	93.83
V_3O_1	81.09 a	82.84 ab	81.47	94.42	95.72 ab	95.76
V_3O_2	83.17 a	83.43 a	85.35	95.67	106.9 a	95.10
V_3O_3	84.27 a	84.27 a	85.38	96.63	92.42 ab	96.03
LSD $_{(0.05)}$	**12.47**	**13.22**	**NS**	**NS**	**17.74**	**NS**
CV (%)	**9.4**	**9.91**	**11.22**	**9.66**	**10.57**	**11.23**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and O_1= Control (no manure), O_2 = cowdung@ 10 t ha^{-1} and O_3 = poultry litter@ 10 t ha^{-1}

4.1.14 Marketable tuber weight (%)

4.1.14.1 Effect of varieties

Non-significant effect on the percentage of marketable tuber weight was observed due to different varieties in all three locations. (Table 56).

4.1.14.2 Effect of organic manures

The percentage of marketable tuber weight had non-significant influences due to different organic manures in all the three locations (Table 56). This variation might be due to change the yield contributing characteristics under different organic manures in different agro ecological zone.

4.1.14.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures on marketable tuber weight by percent had significant effect at Rajbari while non-significant effect was found at Dhaka and Thakurgaon location (Table 56). The maximum marketable tuber weight by percent was recorded in V_2O_2 (107.1%) at Rajbari which was statistical similar with all the interactions except V_2O_3 (78.27%). The minimum marketable tuber weight by percent was observed in V_2O_3 (78.27%) at the same location. This variation might be due to improvement of yield contributing character under different organic manures in different agro ecological zone.

4.1.15 Marketable tuber (>75 g) number (%)

4.1.15.1 Effect of varieties

Significant effect on the marketable tuber (>75 g) number by percent was observed in different varieties in three locations (Table 57). The maximum marketable tuber (>75 g) number by percent was obtained from the variety V_3 (BARI Alu-29) at Dhaka, Rajbari and Thakurgaon (26.69, 24.46 and 24.32%, respectively) while the minimum was found from V_2 (BARI Alu-28) at the three locations (14.12, 12.11 and 12.79%, respectively at Dhaka, Rajbari and Thakurgaon locations). The probable reason for variation in yield due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.15.2 Effect of organic manures

Again poultry litter (O_3) proved its superiority by providing significantly highest marketable tuber number by percent irrespective of locations (Table 57). No manure (O_1) used as organic manure gave the lowest tuber number by percent for all locations. The result revealed that poultry litter out yielded by producing 24.52 and 29.46% higher at Dhaka, 29.25 and 34.24% higher at Rajbari and 22.79 and 24.33% higher yield at Thakurgaon, respectively from O_2 and O_1 organic manure. This variation might be due to change the yield contributing characteristics under different organic manures in different agro ecological condition.

4.1.15.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect to marketable tuber (>75 g) percent by number due to effect of different treatments at all three locations in this experiment (Table 57). The result indicated that irrespective of locations, the highest marketable tuber number at percent was recorded from the interaction of V_3O_3 (34.62, 31.13 and 28.29%, respectively for Dhaka, Rajbari and Thakurgaon locations).

4.1.16 Marketable tuber (50-75 g) number (%)

4.1.16.1 Effect of varieties

Significant effect on the percentage of marketable tuber (50-75 g.) number was observed in different varieties at three locations in this experiment (Table 57). The result revealed that V_3 (BARI Alu-29) showed its superiority by producing highest tuber (50-75g) number by percent than V_2 (BARI Alu-28) and V_1 (BARI Alu-25) at all locations. It can be inferred from the result that V_3 (BARI Alu-29) produced 21.84 and 39.02% higher at Dhaka, 26.03 and 40.70% higher at Rajbari and 18.38 and 30.17% higher at Thakurgaon tuber number (50-75 g) from V_2 (BARI Alu-28) and V_1 (BARI Alu-25), respectively. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.16.2 Effect of organic manures

Non-significant variation was observed on marketable tuber (50-75 g.) number by percent due to use of different organic manures in three locations (Table 57).

4.1.16.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on marketable tuber (50-75g.) number by percent in the three locations of Dhaka, Rajbari and Thakurgaon (Table 57). Data presented in the table indicated that interaction of V_3O_2 gave highest tuber (50-75g) at Dhaka and Rajbari locations (23.66 and 23.58 %, respectively), but at Thakurgaon interaction of V_3O_3 produced the maximum (23.55%). However, ingeneral interactions of O_1, O_2 and O_3 with V_3 seems promising in producing 50-75g sized tuber for all locations. On the other hand, V_1O_1 and V_1O_2 interactions gave lower level of tuber for all locations. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

Table 57. Effect of variety, organic manures and their interactions on the yield and yield contributing characteristics of potato in three districts of Bangladesh

Treatments	Tuber numbers >75 g (%)			Tuber numbers 50-75 g (%)			Tuber numbers 20-50 g (%)		
	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon
Effect of varieties									
V_1	21.45 b	19.51 b	20.03 b	15.89 c	15.21 b	16.87 b	33.58 b	33.97 b	36.25 b
V_2	14.12 c	12.11 c	12.79 c	18.13 b	16.98 b	18.55 b	45.74 a	50.17 a	48.94 a
V_3	26.69 a	24.46 a	24.32 a	22.09 a	21.40 a	21.96 a	36.85 b	35.71 b	38.99 b
LSD $_{(0.05)}$	**2.21**	**1.86**	**2.32**	**2.01**	**2.20**	**1.95**	**4.59**	**4.55**	**4.97**
CV (%)	**10.68**	**9.93**	**12.21**	**10.76**	**12.32**	**10.21**	**11.85**	**11.40**	**12.00**
Effect of organic manures									
O_1	18.67 b	16.59 b	17.55 b	18.29	17.41	17.86	34.06 b	34.87 c	36.50 b
O_2	19.41 b	17.23 b	17.77 b	18.87	17.48	19.71	41.18 a	40.19 b	44.73 a
O_3	24.17 a	22.27 a	21.82 a	18.95	18.69	19.81	40.92 a	44.80 a	42.96 a
LSD $_{(0.05)}$	**2.21**	**1.86**	**2.32**	**NS**	**NS**	**NS**	**4.59**	**4.55**	**4.97**
CV (%)	**10.68**	**9.93**	**12.21**	**10.76**	**12.32**	**10.21**	**11.85**	**11.40**	**12.00**
Interaction effect of varieties and organic manures									
V_1O_1	20.32 c	16.95 c	19.57 cd	15.57 d	17.08 c	15.42 d	29.72 f	28.73 d	33.61 cd
V_1O_2	22.20 bc	19.32 bc	18.09 de	15.65 d	12.30 d	17.55 cd	33.22 d-f	31.82 d	35.23 cd
V_1O_3	21.82 bc	22.25 b	22.43 bc	16.46 d	16.24 c	17.63 b-d	37.79 c-e	41.37 bc	39.93 bc
V_2O_1	14.73 de	11.50 d	12.44 f	18.77 b-d	16.39 c	16.45 d	41.23 bc	41.01 bc	44.84 ab
V_2O_2	11.55 e	11.42 d	11.20 f	17.32 cd	16.54 c	20.95 ab	49.26 a	45.62 ab	52.70 a
V_2O_3	16.07 d	13.43 d	14.73 ef	18.30 cd	18.00 c	18.24 b-d	46.72 ab	52.87 a	49.29 a
V_3O_1	20.95 bc	21.31 b	20.65 b-d	20.53 a-c	18.77 bc	21.69 a	31.22 ef	30.25 d	31.05 d
V_3O_2	24.48 b	20.94 b	24.03 b	23.66 a	23.58 a	20.63 a-c	41.06 b-d	35.88 cd	46.27 ab
V_3O_3	34.62 a	31.13 a	28.29 a	22.09 ab	21.84 ab	23.55 a	38.26 c-e	52.01 a	39.66 bc
LSD $_{(0.05)}$	**3.84**	**3.21**	**4.02**	**3.48**	**3.81**	**3.38**	**7.94**	**7.89**	**8.60**
CV (%)	**10.68**	**9.93**	**12.21**	**10.76**	**12.32**	**10.21**	**11.85**	**11.40**	**12.00**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and
O_1 = Control (no manure), O_2 = cowdung@ 10 t ha^{-1} and O_3 = poultry litter @ 10 t ha^{-1}

4.1.17 Marketable tuber (20-50 g) number (%)

4.1.17.1 Effect of varieties

Significant effect on marketable tuber (20-50 g.) number by percent was observed in different varieties in three locations (Table 57). The variety V_2 (BARI Alu-28) was found superior in producing potato tuber (20-50g) number by percentage than other two varieties V_3 (BARI Alu-29) and V_1 (BARI Alu-28) irrespective of locations, which were 24.13 and 36.21% higher at Dhaka location, 47.69 and 40.49% at Rajbari location and 35.00 and 25.52 % at Thakurgaon location, respectively. However, the lowest and statistically similar tuber number were recorded from V_3 and V_1 variety for all locations. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.17.2 Effect of organic manures

Significant variation was observed on the percentage of marketable tuber (20-50 g.) number by percent due to different organic manures in three locations (Table 57). Organic manure behaved differently due in producing (20-50g.) sized tuber number by percent in different locations. At Dhaka, poultry litter (O_3) and cowdung (O_2) produced the statistically similar number by percent, at Rajbari poultry litter (O_3) produced the highest number by percent (44.80%) and at Thakurgaon cowdung (O_2) produced the highest number by percent. The maximum marketable tuber (20-50 g) number by percent was recorded from the poultry litter (44.80%) at Rajbari while the minimum was found from the no manure (34.06%) at Dhaka. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.17.3 Interaction effect of varieties and organic manures

Different interactions of varieties and organic manures behaved differently on the percentage of marketable tuber (20-50 g) number in three locations (Table 57). Interaction V_2O_2 and V_2O_3 seems superior in producing tuber number (20-50 g.) by percentage for all the locations. At Rajbari, the highest tuber (20-50 g.) number was found with V_2O_3 (52.87%) which was statistically similar with V_3O_3 and V_2O_2 (52.01 and 45.62%, respectively) and that of lowest 28.73% was observed with V_1O_1 at Rajbari. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.18 Chips tuber number (%)

4.1.18.1 Effect of varieties

Significant effect was observed on the percentage of chips tuber number due to varieties in three locations (Table 58). Irrespective of varieties and locations chips tuber number ranged was recorded between 66.95% to 43.08%. Among the tested varieties V_3 (BARI Alu-29) was superior in producing highest chips tuber number by percent in all the tested locations (66.95, 62.29 and 64.48%, respectively at Dhaka, Rajbari and Thakurgaon location). The lowest values of chips tuber was found with V_1 (BARI Alu-25) variety irrespective of locations. It can be inferred that variety V_3 (BARI Alu-29) produced 18.70 and 47.44 % higher at Dhaka, 17.79 and 44.59% higher at Rajbari and 12.47 and 40.54% higher chips tuber at Thakurgaon than V_2 and V_1 variety, respectively. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.18.2 Effect of organic manures

Significant variation was observed on chips tuber number by percent due to different organic manures only in Rajbari location (Table 58). Irrespective of locations, maximum chips tuber number by percent (58.40%) was recorded from the poultry litter (O_3) at Thakurgaon while the minimum chips tuber number by percent (50.19%) was found from no manure at Rajbari. Although Dhaka and Thakurgaon location showed non-significant variation, but irrespective of locations poultry litter (O_3) showed the highest values of chips tuber (58.33, 56.13 and 58.40%, respectively at Dhaka, Rajbari and Thakurgaon), while the lowest was recorded from no manure (O_3) (54.63, 50.19 and 52.90%, respectively at Dhaka, Rajbari and Thakurgaon locations). The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.18.3 Interaction of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of chips tuber number in three locations (Table 58). Irrespective of locations, interaction of V_3O_3 produced highest percent of chips tuber which was closely followed by V_3O_2 interaction. The lowest percent of chips tuber was found with V_1O_1 interaction for all locations (41.51, 38.60 and 44.49%, respectively at Dhaka, Rajbari and Thakurgaon locations). The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

Table 58. Effect of variety, organic manures and their interactions on the qualitative characteristics of potato in three districts of Bangladesh

Treatments	Chips tuber (45-75mm) no. (%)			Dehydrated tuber (30-45mm) no. (%)			French fry tuber (>75mm) no.(%)			Canned tuber (20-30 mm) no.(%)		
	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon
Effect of varieties												
V_1	45.41 c	43.08 c	45.88 c	22.43 a	23.63 a	24.39 a	6.92 a	6.04 a	6.59 a	14.7 9 a	14.44 a	15.21 a
V_2	56.40 b	52.88 b	57.33 b	19.44 b	18.23 b	21.09 b	0.00 b	0.00 b	0.00 b	14.33 a	13.32 a	13.41 b
V_3	66.95 a	62.29 a	64.48 a	20.34 ab	18.34 b	19.53 b	0.00 b	0.00 b	0.00 b	9.65 b	9.60 b	9.46 c
$LSD_{(0.05)}$	**5.81**	**5.09**	**5.85**	**2.68**	**2.18**	**2.68**	**0.40**	**0.40**	**0.43**	**1.59**	**1.55**	**1.59**
CV (%)	**10.33**	**9.65**	**10.46**	**12.92**	**10.89**	**12.36**	**17.50**	**20.07**	**19.81**	**12.30**	**12.44**	**12.56**
Effect of organic manures												
O_1	54.63	50.19 b	52.90	22.57 a	22.66 a	24.58 a	1.98 b	1.80 b	1.91 b	13.61	12.78	12.99
O_2	55.82	51.92 ab	56.40	22.43 a	20.64 a	22.70 a	2.70 a	2.38 a	2.59 a	13.13	12.45	12.76
O_3	58.33	56.13 a	58.40	17.21 b	16.89 b	17.73 b	2.25 b	1.86 b	2.09 b	12.02	12.13	12.32
$LSD_{(0.05)}$	**NS**	**5.09**	**NS**	**2.68**	**2.18**	**2.68**	**0.40**	**0.40**	**0.43**	**NS**	**NS**	**NS**
CV (%)	**10.33**	**9.65**	**10.46**	**12.92**	**10.89**	**12.36**	**17.50**	**20.07**	**19.81**	**12.30**	**12.44**	**12.56**
Interaction effect of varieties and organic manures												
V_1O_1	41.51 f	38.60 f	44.49 e	27.56 a	26.33 a	26.68 a	5.94 c	5.39 b	5.72 b	15.28 a	14.45 a	16.36 a
V_1O_2	48.40 d-f	42.96 ef	45.12 e	23.05 a-c	24.79 a	25.91 ab	8.10 a	7.15 a	7.78 a	15.31 a	15.18 a	14.36 a-c
V_1O_3	46.32 f	47.66 de	48.03 de	16.67 e	19.77 bc	20.57 cd	6.74 b	5.58 b	6.27 b	13.77 ab	13.70 a	14.90 ab
V_2O_1	56.77 b-d	49.16 c-e	52.93 c-e	21.45 b-d	23.20 ab	23.85 a-c	0.00 d	0.00 c	0.00 c	14.25 a	13.69 a	12.09 cd
V_2O_2	53.85 c-e	54.47 b-d	58.63 bc	19.27 c-e	17.93 c	21.89 b-d	0.00 d	0.00 c	0.00 c	14.27 a	12.86 ab	14.99 ab
V_2O_3	58.60 bc	55.00 b-d	60.44 bc	17.60 de	13.55 d	17.52 de	0.00 d	0.00 c	0.00 c	14.46 a	13.41 a	13.13 b-d
V_3O_1	65.60 ab	57.78 a-c	55.58 cd	25.39 ab	18.46 c	25.17 a-c	0.00 d	0.00 c	0.00 c	11.28 bc	10.19 bc	10.52 de
V_3O_2	65.20 ab	62.81 ab	66.71 ab	18.28 de	19.21 c	18.33 de	0.00 d	0.00 c	0.00 c	9.82 cd	9.30 c	8.94 e
V_3O_3	70.06 a	66.27 a	71.15 a	17.36 de	17.35 c	15.10 e	0.00 d	0.00 c	0.00 c	7.83 d	9.29 c	8.92 e
$LSD_{(0.05)}$	**10.06**	**8.81**	**10.12**	**4.64**	**3.78**	**4.64**	**0.70**	**0.70**	**0.75**	**2.75**	**2.68**	**2.76**
CV (%)	**10.33**	**9.65**	**10.46**	**12.92**	**10.89**	**12.36**	**17.50**	**20.07**	**19.81**	**12.30**	**12.44**	**12.56**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and O_1 = Control (no manure), O_2 = cowdung@ 10 t ha^{-1} and O_3 = poultry litter@ 10 t ha^{-1}

4.1.19 Dehydrated (30-45mm) tuber number (%)

4.1.19.1 Effect of varieties

Significant effect on the percentage of dehydrated tuber number was observed in different varieties in three locations in this experiment (Table 58). Among the tested varieties V_1 (BARI Alu-25) gave significantly highest percent of dehydrated tuber for all locations (22.43, 23.63 and 24.39%, respectively at Dhaka, Rajbari and Thakurgaon). Except Thakurgaon V_2 (BARI Alu-28) variety showed the lowest percent of dehydrated tuber (19.44 and 18.23% at Dhaka and Rajbari, respectively). At Thakurgaon V_3 (BARI Alu-29) showed the lowest (19.53%) dehydrated tuber number by percent.

4.1.19.2 Effect of organic manures

Significant variation was recorded on the percentage of dehydrated tuber number due to different organic manures in three locations (Table 58). No manure (O_1) showed the highest dehydrated tuber percent which was statistically similar with cowdung (O_2) for all locations. The lowest dehydrated tuber was produced from poultry litter (O_3). The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.1.19.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of dehydrated tuber number in three locations (Table 58). The result revealed that irrespective of locations, interaction of V_1O_1 showed highest (27.56%) dehydrated tuber number. At Dhaka location V_1O_2 (23.05%), V_3O_1 (25.39%) showed similar tuber with V_1O_1, at Rajbari V_1O_2 (24.79%) and V_2O_1 (23.20%) gave similar tuber with V_1O_1 and at Thakurgaon V_1O_2 (25.91%), V_2O_2 (23.85%) and V_3O_1 (25.17%) interaction showed statistically similar dehydrated tuber with V_1O_1. On the other hand, lowest number was observed with V_1O_3 (16.67%) at Dhaka, V_2O_3 (13.55%) at Rajbari and V_3O_3 (15.10%) at Thakurgaon location.

4.1.20 French fry tuber number (%)

4.1.20.1 Effect of varieties

Significant effect on the percentage of french fry tuber number was observed due to varieties in three locations in this experiment (Table 58). The maximum french fry tuber number by percent was obtained from the variety V_1 (BARI Alu-25) for all test locations which were 6.92, 6.04 and 6.59%, respectively at Dhaka, Rajbari and Thakurgaon. On the other hand, lowest french fry tuber was observed with V_2 (BARI Alu-28) and V_3 (BARI Alu-29) varieties. The highest french fry tuber number by percent (6.92%) at Dhaka followed by (6.59%) at Thakurgaon was found from the variety V_1 (BARI Alu-25) while the minimum was from the combination of variety V_3 (BARI Alu-28) (0.00%) and V_2 (BARI Alu-29) (0.00%) which were found in three locations. The probable reason for variation in tuber size due to the heredity of the variety.

4.1.20.2 Effect of organic manures

The results on the french fry tuber number presented in table 58 shows that significantly highest percentage of french fry tuber were produced with cowdung (O_2) organic manure for all locations that were 2.70, 2.38 and 2.59%, respectively at Dhaka, Rajbari and Thakurgaon locations (Table 58). The lowest percent of french fry tuber was obtained from no manure (O_1) for all locations.

4.1.20.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of french fry tuber number in three locations (Table 58). Among the interactions V_1O_2 combination showed the highest french fry tuber irrespective of locations that were (8.10, 7.15 and 7.78%, respectively at Dhaka, Rajbari and Thakurgaon) which was followed by V_1O_3 interaction. On the other hand, all the combinations of V_2 and V_3 with O_1, O_2 and O_3 showed lowest (0.00%) french fry tuber for all locations.

4.1.21 Canned tuber (20-30 mm) number (%)

4.1.21.1 Effect of varieties

Significant effect on percentage of canned tuber (20-30 mm) was observed in different varieties in three experimental locations; (Table 58). The maximum canned tuber (20-30 mm) number by percent was obtained from the variety V_1 (BARI Alu-25) at three locations (14.79, 14.44 and 15.21% respectively at Dhaka, Rajbari and Thakurgaon). Variety V_2 (BARI Alu-28) showed the second highest canned tuber for all locations. On the other hand V_3 (BARI Alu-29) showed the lowest percent of canned tuber at all tested locations (9.65, 9.60 and 9.46%, respectively) at Dhaka, Rajbari and Thakurgaon locations.

4.1.21.2 Effect of organic manures

There was observed non-significant variation on canned tuber (20-30 mm) number by percent due to different organic manures in three locations (Table 58).

4.1.21.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the percentage of canned tuber (20-30 mm) number in three locations (Table 58). Irrespective of interactions, the highest canned tuber (16.36%) was found with the combination of V_1O_1 at Thakurgaon and the minimum (7.83%) V_3O_3 interaction at Dhaka location. Although V_1O_1 interaction showed highest canned tuber at all locations (15.28, 14.45 and 16.36% respectively,) for Dhaka, Rajbari and Thakurgaon, but V_1O_2, V_1O_3, V_2O_2 and V_2O_3 interaction seems promising irrespective of locations. On the other hand, interaction of V_3O_2 and V_3O_3 showed the lower level of canned tuber irrespective of locations. The probable reason for variation in tuber size due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2 Post-harvest quality of potato

4.2.1 Dry matter (%) of potato at harvest

4.2.1.1 Effect of varieties

Significant effect on the dry matter percent was observed in different varieties at Dhaka and non-significant variation was found at Rajbari and Thakurgaon (Table 59). Although non-significant variation observed in two locations, but numerically V_3 (BARI Alu-29) variety produced the highest dry matter content of potato and that of lowest from V_1 (BARI Alu-25) variety for all locations. V_2 (BARI Alu-28) variety showed the intermediate level of dry matter content irrespective of locations. The probable reason for variation in dry matter percent due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.1.2 Effect of organic manures

Significant variation on the dry matter percent was observed at harvest due to different organic manures in three experimental locations (Table 59). Irrespective of locations poultry litter (O_3) showed the highest dry matter which was statistically similar with cowdung (O_2). No manure (O_1) showed the lowest dry matter percent for all locations. The probable reason for variation in dry matter percent due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.1.3 Interaction effect of varieties and organic manures

Interaction of varieties and organic manures had significant effect on the dry matter percentage of potato at harvest in three experimental locations (Table 59). Interaction comprised with V_3O_3 gave highest dry matter content in Dhaka and Thakurgaon locations but at Rajbari V_2O_2 interaction showed highest dry matter content. At Dhaka location interaction of V_1O_3, V_2O_2, V_3O_2 gave statistically similar dry matter content with V_3O_3, at Rajbari V_1O_1, V_1O_2, V_1O_3, V_2O_3 and V_3O_2 gave similar dry matter with V_2O_2 and at Thakurgaon all the interaction showed similar dry matter content with V_3O_3 except V_1O_1 , V_2O_1 and V_2O_2 interactions. The probable reason for variation in dry weight percent due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.2 Specific gravity of potato

4.2.2.1 Effect of varieties

Significant effect was observed on specific gravity of potato in different varieties at harvest at Dhaka and Rajbari locations while non-significant variation was found at Thakurgaon location in this experiment (Table 59). At Dhaka location, maximum specific gravity (1.09) was observed with V_3 (BARI Alu-29) but at Rajbari V_2 (BARI Alu-28) showed the highest specific gravity (1.10). On the other hand, V_1 (BARI Alu-25) showed the lowest (1.08) specific gravity and that of at Thakurgaon (1.09) with V_3 (BARI Alu-29) variety. The probable reason for variation in due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.2.2 Effect of organic manures

Significant variation was observed on the specific gravity of potato due to different organic manures at harvest in three experimental locations (Table 59). Among the organic manures used as poultry litter (O_3) and cowdung (O_2) showed higher level of specific gravity at all the three locations and that of lowest was found with cowdung (O_2) which was (1.07, 1.08 and 1.08 at Dhaka, Rajbari and Thakurgaon, respectively).

4.2.2.3 Interaction effect of varieties and organic manures

Interaction effect of varieties and organic manures behaved differently on producing specific gravity in different locations which showed significant variation (Table 59). At Dhaka location, V_3O_3 showed the highest and V_1O_1 showed the lowest specific gravity, at Rajbari V_2O_2 , V_3O_2 and V_3O_3 showed the similar and higher specific gravity and lowest was observed with V_2O_1 (1.07) which was statistically similar with V_1O_2 , V_2O_3 and V_3O_1 , and at Thakurgaon V_3O_2 (1.11) combination showed the highest and V_2O_1 showed the lowest (1.07) specific gravity of potato tuber after harvest.

4.2.3 Total Soluble Solid (TSS^o)

4.2.3.1 Effect of varieties

Significant variation was found among different varieties for total soluble solid of tuber at harvest in three experimental locations except Dhaka (Table 59). Varieties behaved differently in producing total soluble solid in different locations. Variety V_3 (BARI Alu-29) and V_2 (BARI Alu-28) showed higher and similar total soluble solid at three locations than V_1 (BARI Alu-25) variety. The probable reason for variation in due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

4.2.3.2 Effect of organic manure

Significant variation was found among the effect of different organic manures on total soluble solid of tuber at harvest in three experimental locations (Table 59). The highest total soluble solid (7.01^o Brix) of tuber was found by the poultry litter (O_3) at Thakurgaon while the minimum (5.37^{o}Brix) was obtained with the no manure (O_1) at Rajbari. Among the organic manures used in this experiment, poultry litter (O_3) gave highest total soluble solid which was followed by cowdung (O_2) for all experimental locations. No manure (O_1) showed the lowest level of total soluble solid in all three locations. The probable reason for variation due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

Table 59. Effect of variety, organic manures and their interactions on the qualitative characteristics of potato in three districts of Bangladesh

Treatments	Dry matter of potato (%)			Specific gravity			Total Soluble Solid (TSS ^{O})		
	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon	Dhaka	Rajbari	Thakurgaon
Effect of varieties									
V_1	20.32 b	21.33	21.18	1.08 b	1.09 ab	1.09	6.09	5.63 b	6.11 b
V_2	21.36 ab	23.02	22.28	1.08 b	1.08 b	1.09	6.19	6.47 a	6.19 b
V_3	22.45 a	23.32	22.33	1.09 a	1.10 a	1.09	6.52	6.26 a	7.04 a
LSD $_{(0.05)}$	**1.71**	**NS**	**NS**	**0.01**	**0.01**	**NS**	**NS**	**0.49**	**0.70**
CV (%)	**8.02**	**9.78**	**8.60**	**0.73**	**1.10**	**2.05**	**11.44**	**7.98**	**10.93**
Effect of organic manures									
O_1	19.62 b	19.88 b	18.60 b	1.072 b	1.08 c	1.08 b	5.46 b	5.37 b	5.64 b
O_2	22.23 a	23.97 a	23.00 a	1.084 a	1.10 a	1.09 a	6.58 a	6.48 a	6.68 a
O_3	22.29 a	24.49 a	23.56 a	1.089 a	1.09 b	1.09 a	6.77 a	6.52 a	7.01 a
LSD $_{(0.05)}$	**1.71**	**2.16**	**1.97**	**0.01**	**0.01**	**0.01**	**0.72**	**0.49**	**0.70**
CV (%)	**8.02**	**9.78**	**8.60**	**0.73**	**1.10**	**2.05**	**11.44**	**7.98**	**10.93**
Interaction effect of varieties and organic manures									
V_1O_1	18.00 d	21.80 a-c	19.07 d	1.06 c	1.09 b-d	1.07 d	5.47 bc	5.27 c	5.50 c
V_1O_2	21.13 bc	21.95 a-c	24.07 ab	1.08 bc	1.08 c-e	1.10 a-c	6.53 ab	5.57 c	6.10 c
V_1O_3	21.83 a-c	22.24 a-c	23.40 a-c	1.08 b	1.09 cd	1.10 a-c	6.27 a-c	6.07 bc	6.67 a-c
V_2O_1	20.04 cd	19.05 c	21.77 b-d	1.07 bc	1.07 e	1.07 d	5.67 bc	5.43 c	5.60 c
V_2O_2	23.43 ab	25.53 a	20.34 cd	1.09 b	1.11 a	1.08 cd	6.27 a-c	6.93 a	6.43 bc
V_2O_3	20.61 b-d	24.47 ab	24.73 ab	1.08 bc	1.08 de	1.10 ab	6.63 ab	7.03 a	6.53 bc
V_3O_1	20.80 b-d	18.79 c	22.87 a-c	1.08 bc	1.08 de	1.09 b-d	5.23 c	5.40 c	5.83 c
V_3O_2	22.30 a-c	24.43 ab	24.60 ab	1.09 b	1.11 a	1.11 a	6.93 a	6.93 a	7.47 ab
V_3O_3	24.23 a	20.76 bc	25.53 a	1.11 a	1.10 a-c	1.08 cd	7.40 a	6.45 ab	7.83 a
LSD $_{(0.05)}$	**2.97**	**3.75**	**3.41**	**0.02**	**0.02**	**0.02**	**1.24**	**0.85**	**1.22**
CV (%)	**8.02**	**9.78**	**8.60**	**0.73**	**1.10**	**2.05**	**11.44**	**7.98**	**10.93**

Here, V_1= Asterix (BARI Alu-25), V_2= Lady rosetta (BARI Alu-28), V_3= Courage (BARI Alu-29) and
O_1 = Control (no manure), O_2 = cowdung@ 10 t ha^{-1} and O_3 = poultry litter@ 10 t ha^{-1}

4.2.3.3 Interaction effect of varieties and organic manures

Interaction of different varieties and organic manures had significant effect on total soluble solid of tuber at harvest in three locations (Table 59). Among the combination of variety and organic manure, V_3O_3 and V_3O_2 produced higher level of total soluble solids which were followed by V_2O_3, V_2O_2 and V_1O_3 combinations irrespective of locations. The lowest value was found at Dhaka and Rajbari with V_3O_1 combination (5.23 and 5.40 ^oBrix, respectively) and at Thakurgaon that was with V_2O_1 combination (5.60). The probable reason for variation in due to the heredity of the variety, difference in agro-ecological condition and soils of the experimental site.

It was observed from the experiment no.5 that variety V_1 (BARI Alu-25) was found superior in producing highest yield in Thakurgaon, Rajbari and Dhaka locations. Organic manures applied through poultry litter (O_3) showed statistically highest potato yield in all the three locations. . Considering processing quality tuber, BARI Alu-29 gave highest chips tuber yield, highest chips tuber number (%) at Rajbari, Thakurgaon and Dhaka. In case of tuber dry matter content (%) and specific gravity, BARI Alu-29 (V_3) showed highest at all three locations and it also gave higher at Rajbari location. The highest total soluble solid (TSS^o) was found from BARI Alu-29 at Thakurgaon. Considering french fry tuber and french fry tuber number by percent, BARI Alu-25 gave highest french fry tuber yield at Rajbari, Dhaka and Thakurgaon location. On the contrary, the lowest french fry tuber yield and tuber number (by %) were given by BARI Alu-28 and BARI Alu-29 in all three locations. Among the interaction of (variety × organic manure), the highest tuber yield, marketable yield, >75g tuber yield were given by V_1O_2 (BARI Alu-25 × poultry litter) interaction. Considering processing quality tuber, the highest chips tuber yield was obtained from the interaction of V_3O_2 (BARI Alu-29 × poultry litter) at Thakurgaon. The highest french fry tuber yield was provided by V_1O_1 (BARI Alu-25 × cowdung) at Rajbari. The highest tuber dry matter, specific gravity content was found from V_2O_1 (BARI Alu-28 × cowdung) at Rajbari. Considering TSS^o of tuber, the highest was obtained from the interaction of V_3O_2 (BARI Alu-29 × poultry litter) at Thakurgaon.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary

Five experiments were conducted at agronomy field laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh and two others potato growing regions of Rajbari and Thakurgaon district of Bangladesh during the period of three consequtive years 2014-2015 to 2016-2017 potato growing seasons. First four experiments were conducted at the SAU experiment field which belongs to Tejgaon series under Modhupur tract (AEZ-28) and general soil type is shallow red brown Terrace soil. The fifth experimemnt was conducted in three locations including SAU experimental field, Dhaka. Other two locations were Baliakandi upazila at Rajbari district and Sadar upazila at Thakurgaon district. The site of Rajbari belongs to Low Ganges River Floodplain (AEZ-12) and soil of this region is silt loams and silt clay-loams on the ridges and silty clay loam to heavy clays on lower sites. Thakurgaon site is belongs to Old Himalayan Piedmont Plain (AEZ-1) and the soil of this region is deep, rapidly permeable sandy loams and sandy clay loams are predominant which strongly acidic in topsoil and moderately acidic in subsoil. The experiments were conducted to evaluate the performance of growth, yield and tuber quality of different cultivars of potato and find out the appropriate agronomic practices to improve their yield and quality.

The **first experiment** was conducted to find out the suitable mulch materials that contributing the highest yield and good quality of potato. Two factors experiment included 5 potato varieties *viz.* BARI Alu-25 (V_1), BARI Alu-28 (V_2) , BARI Alu-29 (V_3), BARI Alu-7 (V_4) and (V_5) BARI TPS-1 tuber lets and 4 mulch materials *viz.* no mulch (M_0), water hyacinth (M_1), rice straw (M_2) and rice husk (M_3) which were outlined with 3 replications. The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. All the potato varieties (certified seed) were collected from Bangladesh Agricultural Development Corporation (BADC) except BARI TPS-1 and it was collected from Tuber Crop Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur. Fertilizers used for the experiment as prescribed by

BARI, 2014. Cultivation technique and other management practices were followed as prescribed by TCRC, BARI and BARC. Among the five tested varieties BARI Alu-25 (V_1), BARI Alu-28 (V_2) and BARI Alu-7 (V_4) showed the higher yield (28.64, 27.58 and 26.74 t ha^{-1}, respectively) along with higher yield attributes like tuber weight (0.31, 0.30 and 0.29 kg $hill^{-1}$, respectively), marketable yield (25.48, 25.48 and 24.49 t ha^{-1}, respectively) and others. In case of quality parameter, BARI Alu-29 (V_3) and BARI Alu-28 (V_2) showed higher tuber dry matter (by %) and specific gravity in different days after harvest. Among the four mulching treatments, rice straw (M_2) and rice husk (M_3) produced higher tuber yield (29.13, 27.26 t ha^{-1}, respectively) which showed 40.25 and 31.25 % higher over no mulch. These two mulch material (rice straw and rice husk) also gave higher yield contributing parameters like tuber number (7.23 and 6.78 $hill^{-1}$, respectively) and tuber weight (0.32 and 0.31 kg $hill^{-1}$, respectively). Besides, rice straw (M_2), rice husk (M_3) and water hyacinth (M_1) gave the highest dry matter content (by %) and specific gravity in different days after harvest which was higher than no mulch (M_0). Interaction of V_1M_2 (BARI Alu-25 × rice straw) and V_3M_2 (BARI Alu-29 × rice straw) showed highest tuber yield (31.26 and 30.90 t ha^{-1}, respectively). But highest marketable tuber yield was given by V_2M_2 (BARI Alu-28 × rice straw) and V_1M_1 (BARI Alu-25 × cowdung) combination (29.74 and 28.69 t ha^{-1}, respectively) which were statistically similar to V_1M_2 (BARI Alu-25 × rice straw) and V_3M_2 (BARI Alu-29 × rice straw) combination (26.31 and 25.95 t ha^{-1}, respectively). Other yield contributing characters, like tuber number $hill^{-1}$ was found highest with the interactions of V_1M_2 (BARI Alu-25 × rice straw), V_1M_3 (BARI Alu-25 ×rice husk) and V_3M_2 (BARI Alu-29 × rice straw) combination which were 8.21, 7.36 and 7.30 no. $hill^{-1}$, respectively. Considering tuber weight, the interaction of BARI Alu-25 × rice straw (V_1M_2), BARI Alu-29 × rice straw (V_3M_2) contributed the highest (0.35, 0.35 kg $hill^{-1}$, respectively). In case of quality parameter, the interaction of BARI Alu-29 × water hyacinth (V_3M_1), BARI Alu-29 × rice straw (V_3M_2), BARI Alu-29 × rice husk (V_3M_3), and BARI Alu-28 × rice straw (V_2M_2) showed the highest dry matter content (by %) and specific gravity of potato tuber in different days.

The **second experiment** was conducted to find out the suitable organic manures for maximum yield and quality of potato. This was a two factors experiment where the varieties were same as first experiment but the organic manure treatments were - no manure (O_0), cowdung (O_1), poultry litter (O_2) and ACI organic fertilizer (O_3). The experiment was conducted following RCBD design with 3 replications. Other cultivation practices were similar with experiment 1. Considering the five tested varieties BARI Alu-7 (V_4), BARI Alu-25 (V_1) showed the higher yield (29.40 and 27.95 t ha^{-1}, respectively) along with higher yield attributes like tuber weight (0.30 and 0.31 kg $hill^{-1}$, respectively), marketable yield (25.02 and 24.67 t ha^{-1}, respectively) and others. For quality parameter, BARI Alu-29 (V_3), BARI Alu-25 (V_1) and BARI Alu-28 (V_2) gave higher tuber dry matter content (by %) and specific gravity after harvest in different days. Among the four organic manure treatments, cowdung (O_1) and ACI organic fertilizer (O_3) produced higher tuber yield (28.89, 27.94 t ha^{-1}, respectively) which was 23.51 and 19.46 % higher over no organic manure treatment, along with higher yield parameter like marketable yield (25.33 and 24.85 t ha^{-1} , respectively) and tuber weight (0.30 and 0.31 kg $hill^{-1}$, respectively). Considering tuber quality, cowdung (O_1), poultry litter (O_2) and ACI organic fertilizer (O_3) gave higher dry matter content (by %) and specific gravity in different days after harvest than no organic manure (O_0) treatment. Interaction of BARI Alu-7 and cowdung (V_4O_1), BARI Alu-7 and ACI organic fertilizer (V_4O_3), BARI Alu-7 and poultry litter (V_4O_2), BARI Alu-25 and cowdung (V_1O_1), BARI Alu-25 and ACI organic fertilizer (V_1O_3), BARI Alu-25 and poultry litter (V_1O_2) showed higher tuber yield (31.98, 30.17, 29.95, 29.95, 29.36 and 28.84 t ha^{-1}) over the combinations of no manure with all varieties. The highest marketable tuber yield was also given by the varieties BARI Alu-7 and BARI Alu-25 when interaction with cowdung, poultry litter and ACI organic fertilizer. On the other hand, all the varieties with no manure gave the lowest marketable yield. Considering tuber weight, it is interesting that the highest was contributed by the V_3O_2 (BARI Alu-29 × poultry litter), V_3O_1 (BARI Alu-29 × cowdung) and V_3O_3 (BARI Alu-29 × ACI organic fertilizer) interaction (0.34, 0.33 and 0.33 kg $hill^{-1}$, respectively) which was statistical similar with the interaction of V_4O_3 (BARI Alu-7 × ACI organic fertilizer), V_4O_2 (BARI Alu-7 × poultry litter), V_4O_1 (BARI Alu-7 × cowdung) which gave (0.33, 0.31 and 29 kg $hill^{-1}$, respectively) and V_1 O_2 (BARI Alu-25 × poultry litter), V_1 O_3 (BARI Alu-25 × ACI organic fertilizer) and V_1 O_1 (BARI Alu-25 × cowdung) interaction contributed (0.33, 0.33 and 0.32 kg $hill^{-1}$, respectively). The combination of BARI Alu-29 × poultry litter (V_3O_2), BARI Alu-29 × cowdung (V_3O_1) and

BARI Alu-29 × ACI organic manure (V_3O_3) provided the highest dry matter content (by %) and specific gravity of potato tuber in different days which were statistical similar with the combination of BARI Alu-28 and BARI Alu-25 with all organic manures.

The **third experiment** was conducted to find out an appropriate harvesting time for achieving higher yield and quality of potato. This was a two factors experiment where the varieties were same as first experiment but the harvesting times were - harvesting at 80 days after planting (80 DAP), harvesting at 90 days after planting (90 DAP), harvesting at 100 days after planting (100 DAP) and harvesting at 110 days after planting (110 DAP). The experiment was conducted following RCBD design with 3 replications. Cultivation practices were similar with experiment 1. Among the five tested varieties BARI Alu-25 (V_1), BARI Alu-28 (V_2), BARI Alu-29(V_3) and BARI Alu-7 (V_4) showed statistical higher yield (23.16, 23.08, 22.00 and 21.39 t ha^{-1}, respectively). These varieties also showed highest tuber weight $hill^{-1}$ 0.26, 0.26, 0.24 and 0.24 kg, respectively for BARI Alu-25 , BARI Alu-28 , BARI Alu-29 and BARI Alu-7. In case of quality, BARI Alu-29 (V_3), BARI Alu-28(V_2) and BARI Alu-25(V_1) gave highest tuber dry matter content and specific gravity. Considering the harvesting times, 110 DAP and 100 DAP gave the highest tuber yield (25.38, 24.56 t ha^{-1}, respectively) and other yield attributes like marketable yield and marketable tuber number percent, tuber no. $hill^{-1}$ and tuber weight kg $hill^{-1}$. Considering tuber quality harvested on 110 DAP and 100 DAP contributed highest dry matter content and specific gravity. The interaction of BARI Alu-25 × 110 DAP (V_1H_4), BARI Alu-25 × 100 DAP (V_1H_3), BARI Alu-28 × 110 DAP (V_2H_4), BARI Alu-28 × 100 DAP (V_2H_3), BARI Alu-29 × 110 DAP (V_3H_4), BARI Alu-29 × 100 DAP (V_3H_3) showed higher tuber yield (28.44, 28.40, 27.88, 26.84, 26.16 and 24.89 t ha^{-1}, respectively), marketable tuber yield (25.40, 25.44, 24.88, 23.84, 22.59, 22.15 t ha^{-1} , respectively) and higher tuber weight (0.31, 0.31, 0.31, 0.30, 0.28 and 0.28 kg $hill^{-1}$, respectively), along with the similar higher tuber weight (0.29 kg $hill^{-1}$) was shown by also BARI Alu-7 and 100 DAP (V_4H_3). In case of quality, BARI Alu-29 × 110 DAP (V_3H_4), BARI Alu-29 × 100 DAP (V_3H_3), BARI Alu-28 × 110 DAP (V_2H_4), BARI Alu-28 × 100 DAP (V_2H_3) and BARI Alu-25 × 110 DAP (V_1H_4), BARI Alu-25 × 100 DAP (V_1H_3) combination showed higher tuber dry matter content (%) and specific gravity.

The **fourth experiment** was conducted to find out the best variety and suitable organic manure and mulch material along with their combination effects that contributes the highest yield and quality of potato. The three factors experiment was conducted at experimental field of SAU, Dhaka during 2015-2016 season which was laid out in RCBD design with 3 replications. The three factors were factor A: variety-3 : BARI Alu-25(V_1), BARI Alu-28(V_2) and BARI Alu-29(V_3), factor B: three organic manures: cowdung (O_1), poultry litter (O_2) and ACI organic fertilizer (O_3) and factor C: three mulch materials: water hyacinth (M_1), rice straw (M_2) and rice husk (M_3). The three varieties were selected on the basis of the performance of the first-year's experiments (Expt. No.1, Expt. No.2 and Expt No.3). The crop was harvested at 100 days after planting, which was selected from the results of the third experiment. Crop cultivation procedure was similar as experiment 1.

Considering the three tested varieties BARI Alu-25 showed higher yield (36.96 t ha^{-1}), marketable yield (34.98 t ha^{-1}), tuber number (7.56 no $hill^{-1}$), tuber weight (0.37 kg $hill^{-1}$), >75g tuber no. (23.43%), canned tuber no. (18.37%.) and french fry tuber no. (10.82%) along with higher quality yield attributes like - >75g weight tuber, dehydrated tuber, french fry tuber (16.10, 2.67 and 8.02 t ha^{-1}, respectively). In case of quality parameter, BARI Alu-29 (V_2) and BARI Alu-28 (V_2) gave higher tuber dry matter content (22.77 and 22.51 %, respectively) and total soluble solid (6.92 and 6.91^{o}Brix, respectively) at harvest. The highest specific gravity was contributed by BARI Alu-29 (1.088). Among the three organic manures, poultry litter (O_2) and ACI organic fertilizer (O_3) showed higher and statistical similar yield (34.38 and 34.28 t ha^{-1} , respectively), marketable yield (32.67 and 32.65 t ha^{-1}, respectively), tuber number $hill^{-1}$ (7.18 and 6.98, respectively), tuber weight $hill^{-1}$ (0.35, 0.35 kg , respectively), along with higher quality yield attributes like - >75g weight tuber, 20-50g weight tuber (13.15 and 13.62 t ha^{-1}, respectively. Considering tuber quality, cowdung (O_1) and ACI organic fertilizer (O_3) provided highest chips tuber number (56.68 and 56.18 % respectively). Besides, the higher and similar yield was provided by poultry litter and ACI organic fertilizer on quality yield contributes like - >75g (13.15 and 13.62 t ha^{-1}, respectively) and 50-75g tuber (8.34, 8.19 t ha^{-1}, respectively). In case of quality parameters, poultry litter (O_2) gave higher specific gravity (1.084) than other organic manures, besides it was showed non-significant variation on tuber dry matter content (by %) and total soluble solid among the three organic manures at harvest. Considering three mulch materials, water hyacinth (M_1), rice straw (M_2) and rice husk (M_3) gave non-significant yield but numerically rice straw (M_2) gave the highest yield (33.33 t ha^{-1}) and highest marketable yield (31.83 t ha^{-1}). Besides rice straw (M_2) contributed the highest tuber percent of >75g tuber and 20-50g tuber size (21.39 and 22.66 %, respectively) and the lowest canned tuber number (13.30%). Considering processing quality tuber, rice straw gave highest chips tuber (56.91 %). On the other hand rice straw showed statistical similar french fry tuber with rice husk. In case of quality parameter, rice straw (M_2) gave numerically higher dry matter content (by %), specific gravity and total soluble solid (22.23, 1.079 and 6.58, respectively) than other mulch materials. Among the interaction, $V_1O_3M_1$ (BARI Alu-25 × ACI organic fertilizer × water hyacinth) and $V_1O_2M_2$ (BARI Alu-25 × poultry litter × rice straw) gave higher and statistical similar yield (42.36 and 40.95 t ha^{-1}, respectively), marketable yield (40.05 and 39.19 t ha^{-1}, respectively), tuber weight (0.43 and 0.41 kg $hill^{-1}$), >75g tuber number (30.88 and 29.50 %, respectively), >75g size tuber yield (21.15 and 21.55 t ha^{-1}, respectively). It is interesting that the highest marketable tuber number (by %) was deserved by $V_3O_3M_2$ (BARI Alu-29 × ACI organic fertilizer × rice straw) interaction (83.27 t ha^{-1}) which was statistically similar with $V_1O_3M_1$ (BARI Alu-25 × ACI organic fertilizer × cowdung) and $V_1O_2M_2$ (BARI Alu-25 × poultry litter × rice straw) interactions. Considering processing quality tuber, highest chips tuber yield was found with $V_3O_3M_2$ (BARI Alu-29 × ACI organic fertilizer × rice straw) interaction (29.26 t ha^{-1}) which was statistical similar yield with $V_2O_2M_2$ (BARI Alu-28 × poultry litter × rice straw) interaction. Regarding dehydrated tuber yield, $V_1O_3M_2$ (BARI Alu-25 × ACI organic fertilizer × rice straw) and $V_1O_2M_3$ (BARI Alu-25 × poultry litter × rice husk) interaction gave the highest dehydrated tuber yield (5.88 and 5.86 t ha^{-1}, respectively). In case of french fry tuber yield, $V_1O_2M_2$ (BARI Alu-25 × poultry litter × rice straw), $V_1O_3M_1$ (BARI Alu-25 × ACI organic fertilizer × water hyacinth) and $V_1O_3M_3$ (BARI Alu-25 × ACI organic fertilizer × rice husk) interactions contributed statistical similar and highest tuber yield (10.73, 10.51 and 10.46 t ha^{-1}, respectively). The highest and the lowest canned tuber yield (1.40 and 0.25 t ha^{-1}, respectively) were found with $V_1O_3M_1$ (BARI Alu-25 × ACI organic fertilizer × cowdung) and $V_3O_3M_2$ (BARI Alu-29 × ACI organic fertilizer × rice straw) interactions, respectively. Besides, in case of chips tuber, dehydrated tuber and french fry tuber number (81.39, 28.14 and 13.63 %, respectively) were provided by $V_2O_3M_2$ (BARI Alu-28 × ACI organic fertilizer × rice straw), $V_3O_1M_2$ (BARI Alu-29 × cowdung × rice straw) and $V_1O_1M_2$ (BARI Alu-25 × cowdung × rice straw) interactions, respectively. Besides most important processing quality parameter like - dry matter content (23.86 and 23.39%, respectively) was found the highest from $V_2O_2M_2$ (BARI Alu-28 × poultry litter × rice straw) and $V_3O_2M_2$ (BARI Alu-29 × poultry litter × rice straw) interactions. The highest specific gravity (1.097 and 1.097) was found by $V_3O_2M_2$ (BARI Alu-29 × poultry litter × rice straw) and $V_3O_2M_3$ (BARI Alu-29 × poultry litter × rice husk) interactions. The highest total soluble solid (7.33 and 7.33^o Brix, respectively) was provided by $V_2O_3M_2$ (BARI Alu-28 × ACI organic fertilizer × rice straw) and $V_3O_2M_3$ (BARI Alu-29 × poultry litter × rice husk) interactions.

The **fifth experiment** was conducted to find out the varietal performance in different locations and suitable organic manure with their combination effects that contributes the highest yield and quality of potato (similar to expt no.4). This experiment was conducted for validation and refinement of the results of the second year's experiment. The two factors experiment was conducted in three potato growing regions of SAU campus, Dhaka, Rajbari district and Thakurgaon district covering three AEZ (AEZ-28, AEZ-12 and AEZ-1, respectively) during 2016-2017 potato growing season which were laid out in RCBD design with 3 replications. The treatments were - Factor A: variety-3 : BARI Alu-25 (V_1), BARI Alu-28 (V_2) and BARI Alu-29 (V_3), Factor B: three organic manures: no manure (O_1), cowdung (O_2) and poultry litter (O_3). In previous experiments mulch materials like- water hyacinth, rice straw and rice husk showed non-significant differences on potato. So rice straw was used as mulch material in this experiment for wider availability. Crop cultivation procedure and other management were similar as experiment 4.

Among the varieties BARI Alu-25 (V_1) showed highest yield at all locations but at Thakurgaon location the yield was 5.92 and 5.79% higher than Dhaka and Rajbari locations, respectively. The lowest yield was found from BARI Alu-29 (V_3) at Dhaka location which was 4.20 and 6.31% lower than Rajbari and

Thakurgaon location, respectively. Besides, BARI Alu-28 (V_2) gave second highest yield at all locations. Considering marketable yield and > 75 g sized tuber yield, the highest (32.84 and 16.08 t ha^{-1}, respectively) was produced by (V_1) BARI Alu-25 at Thakurgaon location and the lowest (27.84 and 9.15 t ha^{-1}, respectively) was found from BARI Alu-29 at Dhaka and BARI Alu-28 at Thakurgaon . But it is interesting that BARI Alu-28 (V_2) gave the highest tuber number $hill^{-1}$ and tuber weight $hill^{-1}$ in all three locations. Considering processing quality tuber, BARI Alu-29 gave highest chips tuber yield (27.34, 27.13 and 26.43 t ha^{-1}, respectively) at Rajbari, Thakurgaon and Dhaka which were showed (8.76, 11.56 and 3.61%) higher chips tuber yield t ha^{-1} than BARI Alu-28 (V_2) and (49.24, 37.16 and 35.82%) higher chips tuber yield than BARI Alu-25 (V_1), respectively at those locations.

Besides, BARI Alu-29 variety produced highest chips tuber number (66.95, 64.48 and 62.29%, respectively) at Dhaka, Thakurgaon and Rajbari locations which were also showed (18.71, 17.79 and 12.48%) higher tuber number (by %) than BARI Alu-28 (V_2) and (47.44, 44.60 and 40.50%) higher chips tuber number (by %) than BARI Alu-25 (V_1), respectively at those locations. The highest marketable tuber number (82.84, 83.52 and 84.07%, respectively) was obtained from BARI Alu-29 at Dhaka, Rajbari and Thakurgaon locations. The highest tuber dry matter content (23.32 %) and specific gravity value (1.10) were given by BARI Alu-29 at Rajbari. The highest total soluble solid (TSS^{o} Brix) was found from BARI Alu-29 at Thakurgaon. Considering french fry tuber, BARI Alu-25 gave highest french fry tuber yield (6.74, 6.38 and 6.20 t ha^{-1}, respectively) at Rajbari, Dhaka and Thakurgaon location. BARI Alu-25 gave highest french fry tuber number (by %) in all three locations. On the contrary, the lowest french fry tuber yield and tuber number (by %) was given by BARI Alu-28 and BARI Alu-29 in all three locations. Besides, BARI Alu-25 contributed highest dehydrated tuber number percent.

Among the three tested organic manures, poultry litter (O_2) showed highest yield in all three locations like Rajbari, Dhaka and Thakurgaon (39.13, 37.87 and 37.75 t ha^{-1}, respectively) which was 52.68, 43.67 and 39.87 %, respectively higher yield over control or no manure treatment. Poultry litter (O_3) gave highest tuber number $hill^{-1}$ and tuber weight $hill^{-1}$ (7.78 no. and 0.39 kg, respectively). Considering marketable yield, poultry litter (O_3) gave highest (37.10 t ha^{-1}) yield and highest tuber number hill^{-1} (79.33 %). In case of tuber quality yield like - >75g tuber and (50-75g tuber), poulty litter gave the highest yield (16.37 and 8.73 t ha^{-1}, respectively). In case of >75g tuber number and 20-50g tuber number, the highest percentage (24.17 and 44.80 %, respectively) were found with poultry litter (O_3). Considering processing tuber quality, the highest chips tuber number (%) was contributed by poultry litter (O_3) at Thakurgaon, Dhaka and Rajbari (58.40, 58.33 and 56.13 %, respectively) which was 10.40, 6.78 and 11.83%, respectively higher tuber number percent over no manure. Poultry litter gave the lowest dehydrated tuber percent (17.73, 17.21 and 16.89%, respectively at Thakurgaon, Dhaka and Rajbari location). Considering french fry tuber number, cowdung showed the highest tuber number percent in all three locations which was estimated as 2.70, 2.59 and 2.38 %, respectively at Dhaka, Thakurgaon and Rajbari location. Considering chips tuber yield , poultry litter (O_3) gave the highest at Thakurgaon, Dhaka and Rajbari location (27.62, 26.67 and 25.52 t ha^{-1}, respectively). The lowest dehydrated tuber yield was showed (2.88 t ha^{-1}) by poultry litter (O_3). Considering processing tuber quality, the highest dry matter content (%) of potato tuber was given by (O_3) poultry litter (24.49, 23.56 and 22.29%, respectively) at Rajbari, Thakurgaon and Dhaka . The highest specific gravity, total soluble solid were contributed by (O_3) poultry litter which was similar with (O_2) cowdung. Among the interaction of (variety × organic manure), the highest tuber yield, marketable yield, >75g tuber yield (42.46, 39.99, 18.81 t ha^{-1}, respectively) were given by V_1O_3 (BARI Alu-25 × poultry litter) interaction. The highest tuber weight hill^{-1} (0.39 kg) was found from V_1O_3 (BARI Alu-25 × poultry litter) interaction.

The yield of 50-75g tuber, the highest was (9.81 t ha^{-1}) found by the interaction of V_3O_3 (BARI Alu-29 × poultry litter) at Thakurgaon. In case of 20-50g tuber yield, the interaction of V_2O_2 (BARI Alu-28 × cowdung) gave the highest (13.00 t ha^{-1}). Considering tuber number (by %) of >75g sized tuber, the interaction V_3O_3 (BARI Alu-29 × poultry litter) gave the highest (34.62%) at Dhaka. In case of 50-75g sized tuber yield, interaction of V_3O_2(BARI Alu-29 × cowdung) gave highest tuber (23.66 %). The interaction V_2O_3 (BARI Alu-28 × poultry litter) gave highest tuber (52.87%) in 20-50g sized tuber. Considering processing quality tuber, the highest chips tuber yield (31.09 t ha^{-1}) was obtained from the interaction of V_3O_3 (BARI Alu-29 x poultry litter) at Thakurgaon. Dehydrated tuber yield (5.03 t ha^{-1}) was obtained from V_2O_1 (BARI Alu-28 × no manure) interaction at Thakurgaon. The highest french fry tuber yield (8.12 t ha^{-1}) was provided by V_1O_2 (BARI Alu-25 × cowdung) at Rajbari. But the highest (1.12 t ha^{-1}) canned tuber yield was obtained from V_2O_1 (BARI Alu-28 × no manure) at Dhaka and Rajbari. In respect of chips tuber number (by %), the highest yield (71.15 t ha^{-1}) was obtained from V_3O_3 (BARI Alu-29 × poultry litter) interaction at Thakurgaon and the highest dehydrated tuber number by percent (27.56 %) was contributed by V_1O_1 (BARI Alu-25 × no manure). In case of french fry tuber number (by %), the highest (8.10 %) was obtained from V_1O_2 (BARI Alu-25 × cowdung) at Dhaka. The highest tuber dry matter content (25.53%) was found from V_2O_2 (BARI Alu-28 × cowdung) at Rajbari. In case of specific gravity, the highest value (1.11) was also shown by V_2O_2 (BARI Alu-28 × cowdung) at Rajbari which was similar to V_3O_2 (BARI Alu-29 × cowdung) at Rajbari and Thakurgaon, and V_3O_3 (BARI Alu-29 × poultry litter) at Dhaka. Considering total soluble solid (TSS^o) of tuber, the highest (7.83^o Brix) was obtained from the interaction of V_3O_3 (BARI Alu-29 × poultry litter) at Thakurgaon.

5.2 Conclusion

1. Among the tested five varieties, BARI Alu-25, BARI Alu-7 were found superior regarding yield purpose, and BARI Alu-28 and BARI Alu-29 were given best for processing quality tuber like- chips purpose, and BARI Alu-25 for french fry tuber purpose which may be cultivated.

2. The tested three mulch materials like- water hyacinth, rice straw and rice husk mulch, among these rice straw mulch was superior than other mulch material which may be used for it's wider availability throughout the country in potato cultivation.

3. Among the tested three organic manures, poultry litter and ACI organic fertilizer gave similar performance , so that poultry litter may be used for potato cultivation. But for processing quality purpose, poultry litter and cowdung may be used as organic manures.

4. Thakurgaon location is the best for potato production but for processing quality purposes Rajbari and Dhaka region may be considered.

Some sugessions and recommendations for future research:

1. Further research may be conducted taking more potato varieties including industrial or processing quality characters.

2. More mulch materials like polythene, other synthitex can be used for further research work with potato.

3. Other organic manures like compost, vermi compost, quick compost etc. can be included for further research.

4. More potato growing regions in different AEZs may be targeted to conduct further research emphasizing industrial quality potato tubers.

5. Other chemical tests can be included in future research for evaluating processing quality of potato tubers.

6. An economic analysis of such studies should be undertaken to assess the profitability of the work.

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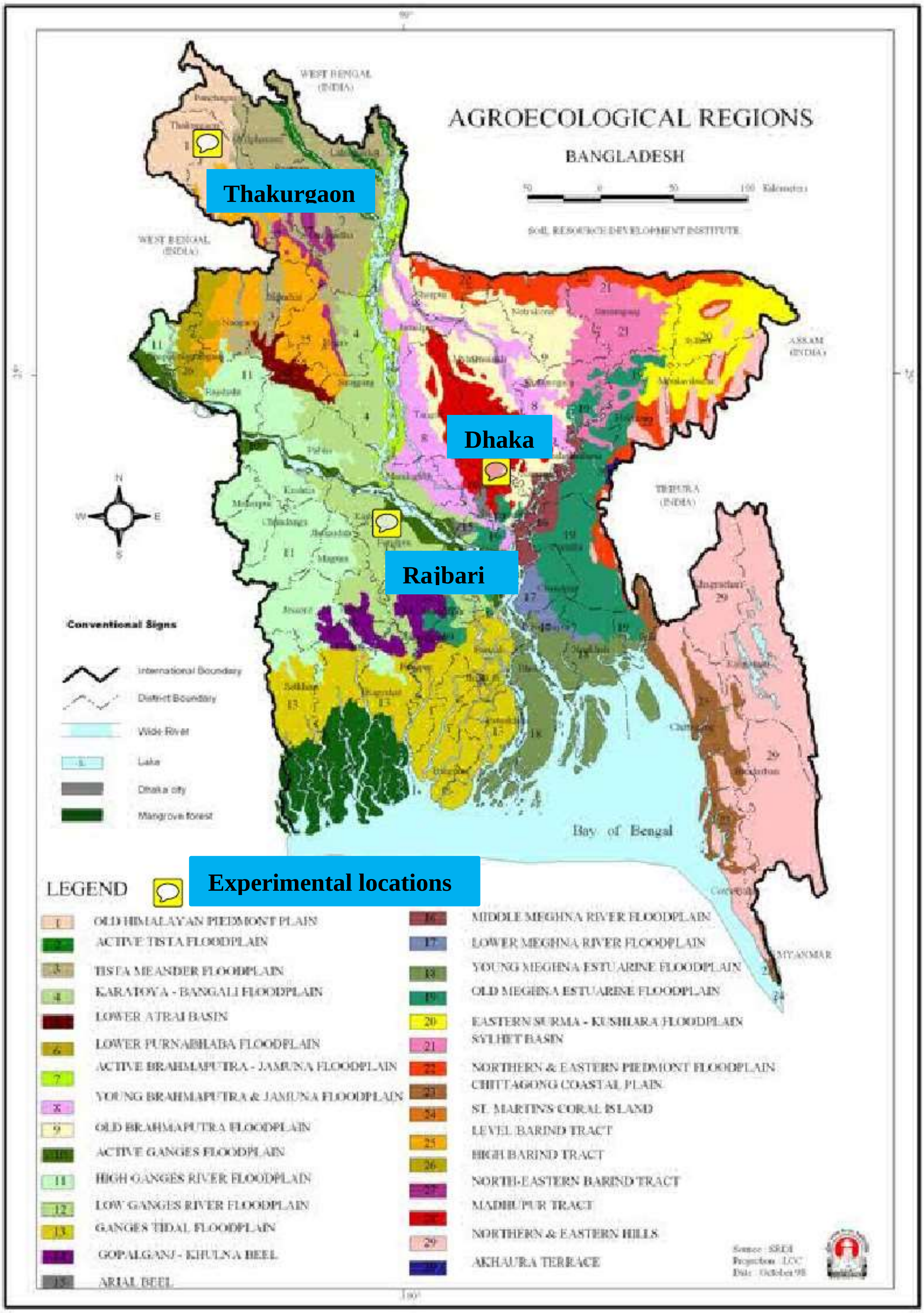
Appendix I. Map showing the experimental locations covering Dhaka, Rajbari and Thakurgaon districts for the present study



Appendix II. Chemical properties of the soil of experimental field at three locations before planting

CHARACTERISTICS	LOCATIONS & VALUE		
	SAU experimental field, Dhaka	Baliakandi Upazilla in Rajbari district	Sadar Upazilla in Thakurgaon district
P^H	5.70	6.8	6.01
Organic matter (%)	2.35	2.01	2.10
Total N (%)	0.12	0.12	0.32
K (meq/100g soil)	0.17	0.18	0.16
P (mg/g soil)	8.90	17.5	15
S (mg/g soil)	30.55	4.1	27
B (mg/g soil)	0.62	0.38	0.53
Zn (mg/g soil)	4.82	0.68	3.78

Source: Soil Resource Development Institute (SRDI), Krishi Khamar Sharak, Dhaka.

Appendix III. Monthly meteorological information during the period from November, 2016 to March, 2017 at Dhaka, Rajbari and Thakurgaon locations.

Location: SAU experimental field, Agargaon, Dhaka

Month	RH(%)	Air temperature (^{O}C)			Rainfall (mm)
		Max.	Min.	Mean	
November,2016	56.75	28.60	8.52	18.56	14.40
December,2016	54.80	25.50	6.70	16.10	0.0
January,2017	46.20	23.80	11.70	17.75	0.0
February,2017	37.90	22.75	14.26	18.51	0.0
March.2017	52.44	35.20	21.00	28.10	20.4

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212

Location: Baliakandi Upazilla, District: Rajbari

Month	RH(%)	Air temperature (^{O}C)			Rainfall (mm)
		Max.	Min.	Mean	
November,2016	80	30.2	18.8	24.5	28
December,2016	82	27.3	15.1	21.20	0
January,2017	76	26.2	12.2	19.20	0
February,2017	70	29.9	15.4	22.65	0
March.2017	72	31.4	19.6	25.50	83

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212

Location: Sadar Upazilla, District: Thakurgaon

Month	RH(%)	Air temperature (^{O}C)			Rainfall (mm)
		Max.	Min.	Mean	
November,2016	77	30.4	16.70	23.55	0
December,2016	83	26.1	13.30	19.70	11
January,2017	79	24.8	10.90	17.85	5
February,2017	71	27.8	13.40	20.60	0
March.2017	72	28.6	16.70	22.65	102

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212

Appendix IV. Monthly meteorological information during the period from November, 2015 to March, 2016 at Dhaka location.

Location: SAU experimental field, Agargaon, Dhaka

Month	RH(%)	Air temperature (^{O}C)			Rainfall (mm)	Total sunshine per day(hrs.)
		Max.	Min.	Mean		
November,2015	65	29.70	20.10	24.90	5.0	6.4
December,2015	68	26.90	15.80	21.35	0.0	7
January,2016	66	24.60	12.50	18.70	0.0	5.5
February,2016	83	36.00	24.60	30.30	37.0	4.1
March.2016	81	36.00	23.60	29.80	45.0	3.9

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212

Appendix IV. Monthly meteorological information during the period from November, 2014 to March, 2015 at Dhaka location.

Location: SAU experimental field, Agargaon, Dhaka

Month	RH(%)	Air temperature (^{O}C)			Rainfall (mm)
		Max.	Min.	Mean	
November,2014	71.15	26.98	14.88	20.93	0.0
December,2014	68.30	25.78	14.21	19.99	0.0
January,2015	69.53	25.00	13.46	19.23	0.0
February,2015	50.31	29.50	18.49	23.99	0.0
March.2015	44.95	33.80	20.28	27.04	0.0

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1212

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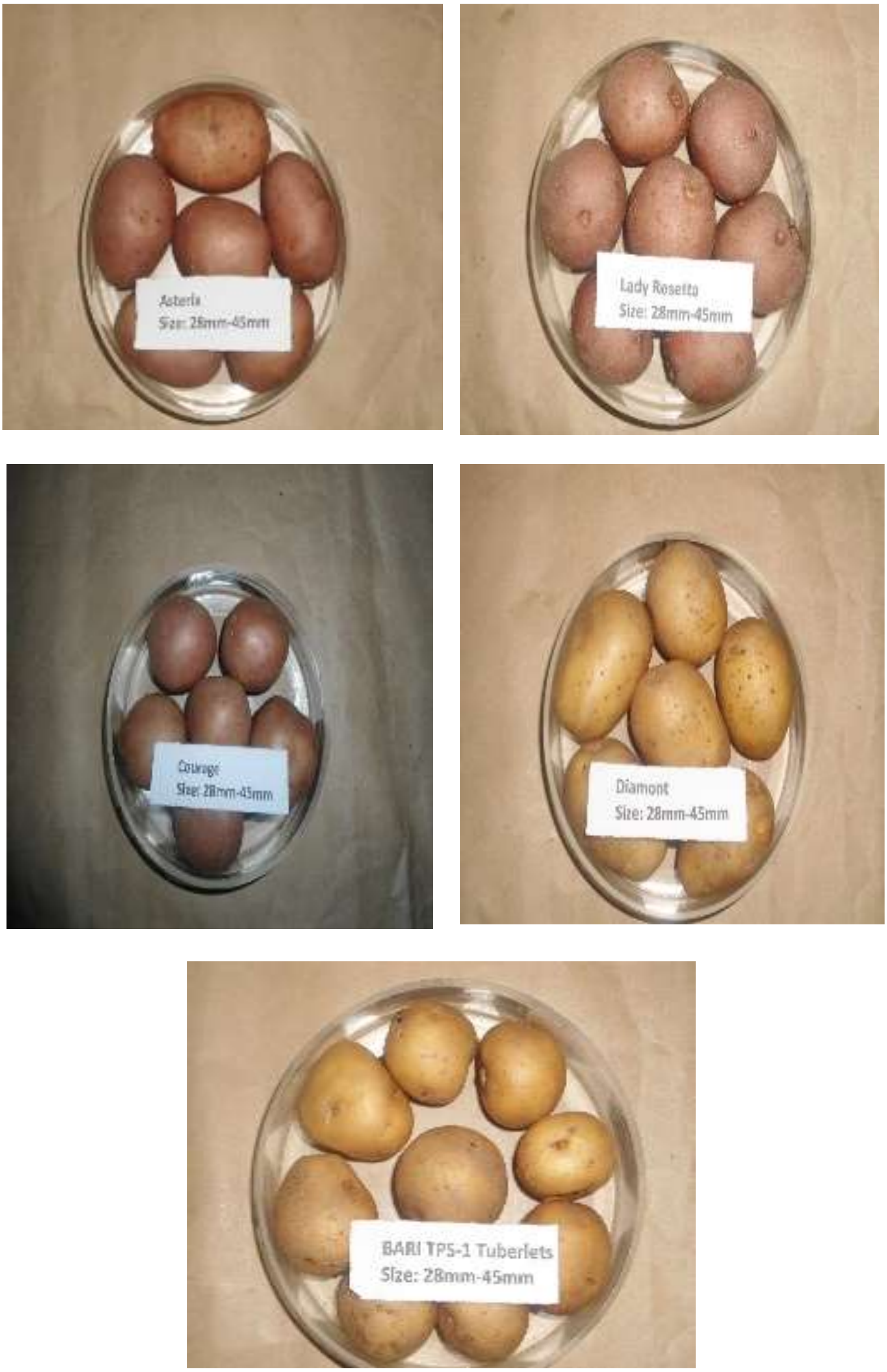

Plate-1. Potato seed tuber of five experimental varieties

Plate-2. Cross section of processing quality potato after harvest at Dhaka, Rajbari and Thakurgaon location

Grading of ' BARI Alu-25' (Asterix) under expt.3 at SAU, Dhaka

Grading of ' BARI Alu-28' (Lady Rosetta) under expt.3 at SAU, Dhaka

Grading of ' BARI Alu-29' (Courage) under expt.3 at SAU, Dhaka

Plate-3. Grading of three processing quality potato after harvest

Plate- 4. Experimental different view at field in three locations; Dhaka, Rajbari and Thakurgaon

Plate- 5. Vegetative growth of different varieties of potato plant at 55 DAP (location: Experimental field at SAU), Dhaka

Plate- 6. A view of vegetative growth of potato plant at 55 DAP (location: Experimental field at SAU), Dhaka





Plate-6. General view of experimental plots at 25, 40, 55, 70 and 85 DAP at experimental field (Expt.4 in SAU, Dhaka

Plate-7. Data Collection during conducting experiment at field and after harvest at SAU, Dhaka