GROWTH, YIELD AND QUALITY OF BARI TPS -I AS INFLUENCED BY NITROGEN AND VERMICOMPOST

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MY

BELOVED PARENTS

CERTIFICATE

This is to certify that the thesis entitled *" GROWTH, YIELD AND QUALITY OF BARI TPS -I AS INFLUENCED BY NITROGEN AND VERMICOMPOST"* ***submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of*** *MASTER OF SCIENCE (M.S.)* ***in*** *AGRONOMY,* ***embodies the results of a piece of bona fide research work carried out by*** *Auditi Mondal,* ***Registration. No.*** *08-02737* ***under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.***

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

Dated:

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ABSTRACT

Nitrogen and vermicompost may affect the yield and quality (dry matter, specific gravity and TSS) of potato. In Bangladesh quality of potato is the main constraint for expansion of potato industry. To partially overcome this constraint an experiment was carried out in the research field, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2013 to February, 2014 to find out the growth, yield and quality of BARI TPS-I as influenced by nitrogen and vermicompost. The experiment was laid out in a split plot design with three replications. The experiment comprised with two factors viz. (i) nitrogen dose and (ii) vermicompost level. Four nitrogen doses (N_0= 0 kg N ha^{-1}, N_1= 100 kg N ha^{-1}, N_2= 150 kg N ha^{-1}, N_3= 200 kg N ha^{-1}) and four vermicompost level (Vm_0= 0 t ha^{-1}, Vm_1= 5 t ha^{-1}, Vm_2= 10 t ha^{-1}, Vm_3= 15 t ha^{-1}). Nitrogen dose was placed along the main plot and vermicompost level was placed along the sub plot. The data on crop growth parameters like days to emergence, plant height, leaves plant $^{-1}$, SPAD value of leaves and stem diameter were recorded at different growth stages. Yield and quality parameter of tuber were recorded after harvest. Results revealed that, different levels of nitrogen had significant effect on most of the growth, yield and quality contributing parameters of BARI TPS-I. The treatment N_2 (150 kg N ha^{-1}) produced maximum yield (26.70 t ha^{-1}) whereas, N_0 (0 kg N ha^{-1}) showed minimum yield (18.53 t ha^{-1}). Vermicompost levels also had significant effect on most of the growth, yield and quality contributing parameters of BARI TPS-I. The results showed that most of the parameters were increased with the increasing vermicompost levels. The treatment Vm_3 (15 t ha^{-1}) produced maximum yield (26.03 t ha^{-1}) which was statistically similar with Vm_2 (10 t ha^{-1}) treatment whereas, Vm_0 (0 t ha^{-1}) showed minimum yield (19.75 t ha^{-1}).Treatment N_3 (200 kg N ha^{-1}) along with Vm_2 (vermicompost 10 t ha^{-1}) performed the best results in terms of growth, most of the yield and quality parameters.

LIST OF CONTENTS

LIST OF CONTENTS (cont'd)

LIST OF CONTENTS (cont'd)

LIST OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREBIATIONS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BADC	=	Bangladesh Agricultural Development Corporation
LAI	=	Leaf area index
ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MoP	=	Muriate of Potash
G	=	Gypsum
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
TSS	=	Total Soluble Solids
kg	=	Kilogram
q	=	Quintal
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Non significant
cm	=	Centimeter
mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) popularly known as alu 'The king of vegetables', It is the fourth most important food crop in the world after rice, wheat and maize. Bangladesh is the 7th potato producing country in the world. In Bangladesh, it ranks second after rice in production (FAOSTAT, 2014). The total area under potato crop, national average yield and total production in Bangladesh are 444534.41 hectares, 19.37 t ha^{-1} and 8603000 metric tons, respectively (BBS, 2013). 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).

Potato has acquired great importance in rural economy in Bangladesh. It is not only a cash crop but also an alternative of food crop against rice and wheat. Bangladesh has a great agro-ecological potential of growing potato. The area and production of potato in Bangladesh has been increasing during the last decades but the yield per unit area remains more or less static. The yield is very low in comparison to that of the other leading potato growing countries of the world, 47.15 t ha^{-1} in USA, 43.11 t ha^{-1} in Denmark and 30.09 t ha^{-1} in UK (FAOSTAT, 2014). The reasons responsible for such a low yield of potato in Bangladesh are use of imbalance chemical fertilizer. Available reports indicated that potato production in Bangladesh can be increased by improving cultural practices among those optimization of manure and fertilizer are important which influences the yield of potato (Divis and Barta, 2001).

Development of true potato seed (TPS) technology has opened a new era in potato cultivation. True potato seed (TPS) is a sexual seed of potato crop. Recently the use of TPS is increasing for the production of high quality seed potatoes. This is due to low transmission of disease, high multiplication rate and good tuber yield (Siddique and Rashid, 2000). But our farmers are producing low quality products with an excess use of chemical fertilizer. To make potato business profitable the quality of potato it should be improved in addition to higher yield. The increase of total tuber yield, dry matter content, qualitative and quantitative is reported for the suitable application of N fertilizer in potato (Zalalem *et al*., 2009).

Low soil fertility is one of the most important constraints limiting potato production in Bangladesh and also nitrogen (N) is deficient in most Bangladeshi soils and thus application of N could significantly increase crop yields. Nitrogen has greater influence on growth and yield of crop plants than any other essential plant nutrient. The general recommended N fertilization for all potato varieties in Bangladesh is 160 kg N ha^{-1} (Chowdhury and Hassan, 2013). However, research has demonstrated that the optimal response to N fertilizer differs by cultivar and soil fertility (Arsenault *et al.*, 2001). Many experiments have shown that total tuber yield and size of potato tubers increase with N (Sanderson and White, 1987). Zabihi-e-Mahmoodabad *et al.* (2011) also reported that increase in N application raised tuber number, but that too much nitrogen has the opposite effect. Increasing N application up to a definite point increased tuber yield, but beyond this point decreased (Jamaati-e-Somarin *et al.,* 2010). One of the main problems on potato productivity in this area is improper (non optimal) use of N fertilization.

The use of organic manures has long been considered as an effective means of improving the structure and fertility of soil (Hadi *et al*., 2011). Vermicompost can be a good organic manure substitute for chemical fertilizers to overcome their adverse effects. Vermicompost is finely-divided mature peat-like materials which are produced by a non-thermophylic process involving Combined s between earthworms and microorganisms (Edwards and Burrows, 1988).They have greatly increased surface areas, providing more micro sites for microbial decomposing organisms, and strong adsorption and retention of nutrients (Shi-wei and Fu-zhen, 1991). 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 a 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 favorable influence on all yield parameters and has a property of binding mineral particles like calcium.

Growth, yield and quality of potato depend on nutrient availability in soil, which is directly related to the judicious application of manures and fertilizers. Using of vermicompost is now a global movement for the second green revolution that emphasizes on composting. The application of recommended dose of fertilizers and vermicompost indicated maximum yield in potato (Asumus and Gorlitz, 1986; Patil, 1995; Saikia and Rajkhowa, 1998). Considering the above facts, the present study was undertaken with the following objectives:

1. To study the effect of nitrogen on yield and quality of BARI TPS-I,
2. To evaluate the role of vermicompost on growth of BARI TPS-I and
3. To find out the combined effect of nitrogen and vermicompost on growth, yield and quality of BARI TPS-I.

CHAPTER II

REVIEW OF LITERATURE

Potato is the most important tuber crop in the world as well as in Bangladesh. Numerous experiments have been conducted throughout the world on potato crop but information regarding growth and of BARI TPS-I as influenced by nitrogen and vermicompost parameters are still inadequate. Brief reviews of available literature pertinent to the present study have been reviewed in this chapter.

2.1 Effect on nitrogen

Nitrogen (N) plays a great role on different yield contributing characters and yield of potato. Both excess and under-doses of N hamper its yield. So, for higher yield, judicious amount of N should be applied to the plant.

Getie *et al.* (2015) investigated the effect of N fertilizer and planting density on yield and yield components of potato crop. Treatments included quantity of N fertilizer (0, 110, 165 and 220 kg N ha^{-1}) and planting density (4.17 plant m^{-2} (80 cm x 30 cm), 4.44 plant m^{-2} (75 cm x 30 cm), 5.56 plant m^{-2} (60 cm x 30 cm), 6.67 plant m^{-2} (60 cm x 25 cm) and 8 plant m^{-2} (50 cm x 25 cm). Increasing N level up to110 kg N ha^{-1} lead to more tuber yield, highest stem number, plant height, total dry biomass, total tuber number, large-sized tuber yield (59.01%) and marketable tuber yield. The highest foliar N concentration was recorded at 165 kg N ha^{-1}. Highest foliar N concentration was found at the lower planting densities of 4.17 and 4.44 plant m^{-2}. The results of the experiment revealed that 110 kg N ha^{-1} and planting density of 6.67 plant m^{-2} resulted in optimum total (35.50 and 35.66 t ha^{-1}, respectively) and marketable tuber yields of the Bubu variety in Haramaya, Eastern Ethiopia during the rainy season.

Bashir and Qureshi (2014) conducted an experiment during the *Rabi* seasons 2004-05 on sandy clay loam to study the effect of N fertilizers and farmyard manure on yield, nutrient content and quality of potato (*Solanum tuberosum* L).The yield and quality of potato tubers were influenced by the rate of nitrogen and farmyard manure. Application of 180 kg N ha^{-1} along with 24 t FYM ha^{-1} gave significantly higher yield. The concentration of N, P and K in tubers increased with increasing levels of N and FYM. Addition of N and FYM significantly enhanced the quality of potato. Maximum carbohydrate, crude protein and ascorbic acid were recorded in the treatment combination of $N_{180}F_{24}$.

Kolodziejczyk (2014) conducted a field trial to find the effect of nitrogen fertilization and microbial preparations on yielding and development of potato tuber yield components. The factors of the experiment were nitrogen fertilization levels: 0, 60, 120 and 180 kg N ha^{-1} and the following preparations: Bacto Fil B10, effective microorganisms and UG_{max} soil fertilizer. Nitrogen fertilization caused a significant increase in marketable yield of potato tubers. Yield increments on individual fertilizer treatments ranged from 66% to 140%. An evident effect of this factor was also visible regarding the yield components values. Increase in the number of main stems per m^2 under the influence of growing nitrogen doses occurred from the fertilization level 120 kg N ha^{-1}, whereas the number of tubers per stem increased only to the level of 60 kg N ha^{-1}. Each nitrogen dose applied within the range to 180 kg N ha^{-1} caused a marked increase in an average tuber weight.

Najm *et al.* (2013) conducted a trial to study the influence of N fertilizer and cattle manure on the vegetative growth and tuber production of potato. Treatment groups consisted of the administration of nitrogen fertilizer at three concentration levels (50, 100 and 150 kg h^{-1}) and cattle manure at four levels (5, 10, 15 and 20 t ha^{-1}). Results showed that, in all sampling times, plant height and LAI were increased significantly by increasing N fertilizer. The integrated use of nitrogen fertilizer and cattle manure increased LAI significantly (at the 45th, 75th and 90th DAE). Also, the combined effects of cattle manure and N fertilizer on plant heights were significant at the 60th, 75th, 90th and 105th DAE. Furthermore, results of tuber yield showed that, Nitrogen fertilizer, Cattle manure and their combination had highly significant effects on tuber yield. In this experiment maximum amount of tuber yield (36.8 tons ha^{-1}) was obtained by 20 t ha^{-1} Cattle manure+150 kg N ha^{-1}.

Singh and Lal (2012) conducted a field trial to find suitable dose of potassium for potato cultivar Kufri Pukhraj for optimum yield, quality and nutrient use efficiency under different N levels. There was significant positive Combined between N and K. At each level of N, increasing levels of K application increased the tuber yield, N and K uptake by potato at harvest. Potassium and N application improved tuber size by increasing the large and medium grade yield and decreasing the small and very small sized tuber. Maximum yield of 39.83 t ha^{-1} was obtained when N and K was applied @ 225 kg ha^{-1} and 150 kg K_2O ha^{-1} against a tuber yield of only 14.36 t ha^{-1} without N and K application. The recovery efficiencies of K and N fertilizer on potato increased at 100 kg K_2O and 150 kg N ha^{-1}.

Yassen *et al.* (2011) were carried out two field experiments in El-Kassasin region, Ismailia Governorate during 2009 and 2010 seasons to study the effect of both N fertilizer (at 0,150,200 and 250 kg N fed^{-1} rates) and selenium (Se) spray (at 0, 20, and 40g fed^{-1} rates) on the vegetative growth, tuber yield and chemical composition of potato plants. Results showed that nitrogen application resulted in an increase in the vegetative growth, tuber yield and quality parameters as compared with the untreated plants. The Combined effects between different nitrogen rates and selenium application significantly promoted growth parameters compared with nitrogen and/or Se alone treatments, with respect to all growth and quality characters.

Effects of N on the leaf chlorophyll yield and yield attributing characters of potato as tuber number and mean tuber weight were studied by Guler (2009). Correlation coefficients between the investigated characters were determined. Five nitrogen rates (0, 150, 200, 250 and 300 kg ha^{-1}) and four potato cultivars (Burren, Slaney, Anna and Emma) were used in the study. First, second, third class tuber yields and total tuber yield, tuber number per plant, and leaf chlorophyll were significantly influenced by both nitrogen rate and cultivar, whereas mean tuber weight was affected only by cultivar. Maximum total yield was obtained at 200 kg N ha^{-1}. There was significant linear relationship between leaf chlorophyll and N applied (R^2=0.91). There were significant correlations between chlorophyll and yield and yield related characters. Total yield significantly correlated with leaf chlorophyll. Correlations between first class yield and total yield as well as total yield and tuber number $plant^{-1}$ were highly significant.

Majic *et al.* (2007) conducted a field trial on farming household in Jasenica (area of Bosnia and Herzegovina) with three potato varieties *Solanum tuberosum* L. (cv. Liseta, Cleopatra and Adora). For side dressing they used three nitrogen doses (100, 200 and 300 kg N ha^{-1}) plus control plots (N 0 kg ha^{-1}). Data were being collected during two years 2004 and 2005. The objective of this research was to estimate influence of different nitrogen doses on optimal tuber yield. Results show that nitrogen nutrition affects on the yield and other traits of potato crop. This research shows that timing and application of correct quantity of nitrogen nutrition results in yield increments.

Yenagi *et al.* (2004) conducted a field experiment during kharif-1999 at MARS, Dharwad revealed that nitrogen significantly increased tuber number and weight per plant. Total and different grade tuber yield increased up to 150 kg N per ha (15.68 t ha^{-1}). However net income (Rs.41906 ha^{-1} and B:C ratio of 2.84 was higher with treatment combination of June 3rd week planting with 45 cm row spacing supplied with 150 kg N per ha.

Sud *et al.* (1999) carried out an experiment in 1991-92 at Kufri, Himachal Pradesh, India to investigate the effect of nitrogen and sulphur. Potato cv. (Kufri Jyoti was fertilized with 0, 60, 120 or 180 kg N ha^{-1} and 0, 20 or 40 kg S ha^{-1}. Tuber yield was increased by application of S and increased with increasing N rate. Combined between N and S was not found significant. They noticed that combined application of N and S had a positive effect on tuber quality.

Arsenault and Malone (1999) conducted an experiment to investigate the response of three potato varieties viz., AC Novachip, Norwis, and Norchip to applied nitrogen viz., 90, 134 and 179 kg ha^{-1}. They found that nitrogen application had no effect on yield of AC Novachip. Similarly increasing the rate of applied N more than 134 kg ha^{-1} resulted in little or no increase in yields of Norwis.

Sujatha and Krishnappa (1996) observed higher tuber yield at l20:l00:l20 kg NPK + 50 t FYM ha^{-1}. In another experiment, Dixit (1997) noticed better vegetative growth and higher yield at 150 kg N + 20 t FYM along with 100 kg P_20_5 + 50 kg K_20 ha^{-1}.

Zrust and Juzl (1996) conducted an experiment with potatoes cv. Krystala, Koruna, Impala and Ukama to investigate the response of nitrogen at 60 or 120 kg N ha^{-1}. Ukama gave the highest net photosynthetic rate of 20 mg DM h^{-1} with 60 kg N ha^{-1} in 1995 and Krystala the lowest (8 mg DM h^{-1}) with 60 kg N in 1994. Crop growth rate was increased with the higher rates of N. All cultivars gave higher yields at higher rates of N.

Gagro (1996) carried out an experiment on potatoes cv. Jaerla and Desiree, where they applied 0, 100, 150 or 200 kg N ha^{-1} and observed that number of tubers, tuber size and yield were increased with increasing N rates.

Chowdhary *et al.* (1996) reported that highest tuber yield (l2.60 t ha^{-1}) was recorded when the crop was fertilized with l20 kg N ha^{-1}.

Trehan and Grewal (1995) conducted an experiment on deep alluvial soil at the Central Potato Research Station, Jalandhar with six doses of N (0, 60, 120, 180, 240 and 300 kg ha^{-1}) and five doses each of P_20_5 and K_20 (0, 50, 100, 150 and 200 kg ha^{-1}), and found the highest tuber yield at 240 kg N and 150 kg K_20 ha^{-1}. Phosphorus gave little response.

Chaurasia and Singh (1995a) carried out an experiment in 1986-88 at Varanasi, Uttar Pradesh, on potatoes cv. Kufri Bahar where 0, 50, 100 or 150 kg N ha^{-1} were given and haulms were cut 80, 90, 100, 110 or 120 days after planting. Tuber yield was increased with rate of N application and with delay in haulm cutting; uptake of N, P and K in tubers was increased with N application rate and with delay in haulm cutting date except uptake of K which was the highest with 100 kg N ha^{-1}. Uptake of N, P and K in leaves and stems was increased with range of N application; uptake of N and P in leaves and stems and K in stems was highest when haulms were cut 90 days after planting whereas uptake of K in leaves was the highest when haulms were cut 80 days after planting.

Under Bangladesh condition, Hussain (1995) recommended a dose of 275 kg urea, 185 kg triple super phosphate and 250 kg muriate of potash for seed potato production.

Sharma *et al.* (1995) reported that the optimum sowing date was 25 October and the tuber yield was the highest with 160 kg N ha^{-1}.

Hossain *et al.* (1995) worked on nitrogen requirement for raising cut- shoot of potato crop and found that high rate of nitrogen application increased the number of leaves/plant, leaf length, foliage coverage and delayed tuberization and plant maturity. Tuber yield was increased significantly up to l20 kg N ha^{-1} and decreased the percentage of small tuber.

Reust (1995) reported that the maximum yield was generally afforded at 120 kg ha^{-1} nitrogen application. Nitrogen application increased the percentage of large tuber.

Chaurasia and Singh (1995b) carried out a field experiment during rabi season of I986-87 at Varanasi, Uttar Pradesh, with potatoes cv. Kufri Bahar and Kufri Lalima. Nitrogen was applied at 0-150 kg ha^{-1} and the haulms were cut between 80 and 120 days after planting. In both cultivars, tuber yields were significantly increased with up to 100 kg N while the net returns were highest with the application of 150 kg N. Tuber yields were progressively increased as the haulm cutting date was delayed. Kufri Lalima gave higher tuber yields than Kufri Bahar.

Krefft *et al.* (1995) analyzed effectiveness of applying N fertilizer to five potato cultivars using the results of field trials in 1977-92. Without applied N, yields ranged from 27.09 t ha^{-1} in cv. Kora to 38.53 t in Rys and 39.27 t in Janka. The biological and economic optimum N rates averaged 122 and 116 kg ha^{-1}, respectively. The response to N was greatest in Leda and Rys. The mean effectiveness of N fertilizer was 79.61 kg tubers kg^{-1} N.

Schonaberger and Erichsen (1994) observed that growth and development are related to nutrient uptake. Again, higher N rates promoted general vegetative growth (Borin and Magrini, 1989).

Mohammad *et al.* (1993) reported that tuber diameter and weight per plant were highest at 25 cm spacing and application of 148 kg N ha^{-1}. Tuber number $plant^{-1}$ was increased with increasing spacing and N rates. Similar result was found by Singh *et al.* (1993).

Mollerhagen (1993) observed that the tuber yield was increased with increasing N rates. The dry matter content was decreased with increasing N application. Application of high doses of N resulted in the largest tuber. Similar result was found by Proba-Bialczyk (1993) and Juzl (1993).

Chandachan *et al.* (1993) observed that tuber yield of Kufri Chandramukhi was the highest with 200 kg N + 150 kg ha^{-1} (14.5 t ha^{-1}) and Kufri Jyoti was the highest with 200 kg N + 200 kg K ha^{-1} (13.3 t ha^{-1}).

Juzl (1993) assessed the tuber yields in potatoes cv. Prior and Impala in field trials on an alluvial loam to clay loam soil (pH 6.9, total N 0.17%) in 1990 and 1992. The crop was gown with 60, 120 or 180 kg N applied per hectare with 50 kg P ha^{-1} and 130 kg K ha^{-1}. Tuber yield was increased with increasing fertilizer N application, with lmpala (27.02-36.03 t ha^{1}) yielding more than Prior (22.05-29.04 t ha^{-1}).

Mollerhagen (1993) reported that the tuber yield of cv. Beate was increased with increasing levels of N, while for cv. Danva and Matilda it increased with up to 100 kg N ha^{-1}. The DM content of all cultivars was decreased with increasing N application although Beate was less influenced by N than other cultivars. Application of high levels of N resulted in the largest tubers, highest percentage of green colored tubers and poorest quality of table potatoes.

Porter and Sisson (1993) conducted an experiment with potatoes cv. Russet Burbank and Shepody to investigate their response to applied nitrogen. Nitrogen was applied at planting followed by an additional 90 kg side dressed after tuber initiation, or 90 kg at planting followed by an additional 45 kg side dressing. Side dressed N increased total yields relative to the 90 kg N at planting treatment by an average of 5.0 t ha^{-1} in 3 of 9 experiments. Comparing with a single application of 180 kg N at planting, split application of 90 kg N at planting followed by a 90 kg side dressing significantly reduced total yields in 1 of 9 experiments and did not affect yields in the remaining 8 experiments. Tuber uniformity was improved in 3 of 9 experiments by the split-N treatment.

Santosa (1992) carried out an experiment with cv. Granola and Temate grown on alluvial soil in 1992 with a nitrogen dose of 0-250 kg N ha^{-1} as urea. It was found that yield without applied N was 3.7 and 4.9 t ha^{-1} in Granola and Temate, respectively and increased to 17.9 t ha^{-1} in Granola given 150 kg N and 16.1 t ha^{-1} in Temate given 200 kg N.

Zrust and Mica (1992) conducted an experiment on nitrogen requirement using two varieties viz., Karim and Kamyk. They observed that application of nitrogen increases stolon number and extends growth period. They also found that higher nitrogen rates retarded tuber initiation early in the growing season.

Mondal *et al.* (1992) reported that plant height of potato was increased significantly with the application of nitrogen.

Leaf number on main stem and total number of nodes on branches were increased with increasing N fertilizer as reported by Osaki *et al.* (1992).

In a study Jenkins and Nelson (1992) found that tuber dry matter (DM) percentage was reduced in one experiment with increasing N rate and in the second experiment final DM percentage was the highest following application of 240 kg N ha^{-1}.

Osaki *et al.* (1992) reported that the mean dry weight of tuber was increased after flowering and was in the order of <300<l 50 kg N ha^{-1}. Again Anand and Krishnappa (1989) reported that application of 120 and 180 kg N ha^{-1} increased the total dry matter significantly over 60 kg N ha^{-1} and the control.

Bhowmik and Dandapat (1991a) carried out an experiment on potatoes where they applied 90, 120 and 150 kg N ha^{-1} and found that tuber number, volume and yield $plant^{-1}$ were increased with increasing nitrogen rates.

Bhowmik and Dandapat (1991b) conducted an experiment on potatoes. The potato varieties Kufri Chandramukhi, Kufri Jyoti and Punjab Special were grown in farmer's field in Midnapore district, West Bengal, in the 1988/89 during rabi (winter) season at 90, 120, or 150 kg N ha^{-1}. Tuber number, volume and yield $plant^{-1}$ were increased with increasing N rates.

Porter and Sission (1991) conducted an experiment at Presque Isle, Maine during 1986-89. Nitrogen at 0-270 kg ha^{-1} was applied as half ammonium-N and half nitrate-N to potatoes cv. Russet Burbank and Shepody grown after Trifolium pratense or small gains (wheat or Oats). Total yields and tuber size were increased by N on most sites where potatoes followed small's gains, while tuber specific gravity was decreased with increased N following T. Pratense. Total yields averaged 88% of maximum with 45 kg N ha^{-1} after T. pratense compared with 77% of maximum after small gains. Generally US No. 1 yields were highest at 45-90 kg ha^{-1} and tuber size at 90-135 kg N ha^{-1} following T. pratense. Total yields following small gains were highest at 196 and 211 kg N ha^{-1} for Russet Burbank and Shepody, respectively, while after T. pratense yields were best at 126 and 136 kg N ha^{-1}, respectively. The highest N rates tested reduced total yields of Russet Burbank, a late season indeterminate cultivar, by approximately 9%.

Soaud *et al.* (l990) mentioned that nitrogen did not give significantly higher yields, but adversely affected tuber quality and led to increased residual nitrate in the soil profile.

Shvirberga (1990) reported that application of nitrogen at the rate of 175 kg ha^{-1} increased tuber yield, but yield was not further increased with 350 kg ha^{-1}.

Anand and Krishnappa (1990) carried out an experiment in I984-85 where they applied 0, 60, 120 or I80 kg N ha^{-1} and 0, 50, I50 kg ha^{-1} and they obtained the highest yield of 26.08 t ha^{-1} with 180 kg N + I50 kg ha^{-1}.

Juzl (1990) carried out an experiment during 1986-88 at Zabcice, Czechoslovakia with potatoes cv. Resy and Klara. The crops were grown at 62.5 x 30 cm or 75 x 25 cm spacing and given 60, 120 or l80 kg N ha^{-1} + 50 kg P and 130 kg K. Tuber growth and LAI followed similar trends at the different N rates. Tuber yields were higher in Resy than Klara but were not affected by spacing. Highest yields of cv. Resy were 42.00 t ha^{-1} in 1986 and 4l.85 t in 1987 with 120 kg N and 46.20 t with 180 kg N in 1988. Highest yields of cv. Klara were 31.79 t in 1986 and 40.75 t in 1988 with 180 kg N and 33.38 t with 100 kg N in 1987.

Obeirne and Cassidy (1990) stated that tuber dry matter (DM) content was significantly diminished by the application of more than 150 kg N ha^{-1}. The tuber DM was decreased with increasing N application (Krishnappa, 1989).

Anand and Krishnappa (1989) worked on dry matter accumulation and nutrient uptake by potato cv. Kufri Badshah where 0-180 kg N ha^{-1} and 0-150 kg K ha^{-1} were applied. They reported that application of N and K increased DM accumulation in roots, tubers and total plant.

A field trial conducted by Anand and Krishnappa (1989) in red sandy loam soil of Bangalore to assess the effect of four levels of nitrogen (0, 60, 120, and 180 kg ha^{-1}) found that the number of shoot per hill was not increased significantly due to the application of different levels of N and K as well as their Combined .

Dorobantu *et al.* (1989) carried out a field experiment where they found that plant height, leaf area and total biomass were maximum with 200 kg N + 60 kg $P_2 0_5$ + l00 kg $K_2 0$ + 40 t FYM or 300 kg N + 80 kg $P_2 0_5$ + 300 kg $K_2 0$.

Anand and Krishnappa (1988) reported that increased application of N and K increased the yield of A, B and C grades tuber. Similarly, nitrogen application increased the percentage of large tuber had been reported by Castro (1988).

Sharma and Sharma (1988) observed that N-use efficiency had a highly significant correlation with the K composition. Besides K composition, responsiveness of the varieties to N has been related to the capacity of a particular variety to produce large-grade tubers. The varieties like 'Kufri Badshah' and 'Kufri Lalima' producing major faction of large-sized tubers and more responsive to N than 'Kufri Bahar', producing major fraction of medium and small-sized tubers. A promising hybrid 'JH 222' which had been released as 'Kufri Jawahar' was reported to respond significantly up to 240 kg N ha^{-1} in the alluvial soil of Jalandhar. It was also observed that the old varieties were generally less responsive to N than the present-day ones. The older varieties had a better capacity to yield in the absence of N whereas the present ones in use are better yielders in the presence of N.

Ciecko *et al.* (1988) reported the differential response of potato varieties to applied nitrogen. The optimum N rate was 100 kg ha^{-1}, except in cv. Liwia, for which 50 kg ha^{-1} was adequate. Applying optimum N rates increased tuber yields by 13% in cv. Liwia and Cisa and 22-23% in the other cultivars. Tuber DM and starch contents were highest at those N rates.

Ostgard and Andersen (1988) conducted an experiment with potato cv. Gullauge and Ottar during 1979-85 in 18 fields in Troms and Finnmark (N. Norway) with 600, 750 or 900 kg 13-6-l6 NPK fertilizer ha^{-1}. Gullauge yielded 27.93 total tubers and 22.26 t marketable tubers ha^{-1} (22.0%) at 600 kg fertilizer rate; corresponding yields for Ottar were 25.85 and 19.96 t ha^{-1} (22.5% DM).

Sharma *et al.* (1988) observed the differential response of applied nitrogen on the yield of seed and ware potato in variety Kufri Chandramukhi. The dose of applied nitrogen depends upon the purpose of potato production. The yield of seed sized tubers of 'Kufri Chandramukhi'showed response up to 120 kg N ha^{-1} whereas the yield of ware-sized tubers showed response up to 180 kg N ha^{-1}.

Saini and Singh (1988) reported highest yield of seed-sized tubers of Kufri Chandramukhi with 120 kg N ha^{-1} at Jalandhar and of Kufri Bahar with 150 kg N ha^{-1} at Modipuram. Likewise highest yield of seed-sized tubers of 'Kufri Lalima' was obtained with 150 kg N ha^{-1} at Patna (Kushwah, 1989). At Jalandhar, optimum N for ware-sized tuber production varied from 224 to 231 kg N ha^{-1} whereas for seed-sized tuber production it varied from 130 kg to 146 kg N ha^{-1}. Thus N need of potato crop grown for seed purpose was 30-40% lower than that of ware-tuber production.

Sharma and Arora (1987) noticed that increase in the applied nitrogen from 0 to 250 kg N ha^{-1} decreased the small number of tubers m^{-2} and increased medium and large grades.

Singh and Sharma (1987) observed in a trial during 1984-85 on an acidic soil (pH 4.8) with one potato cultivar and two advance hybrids with 0-180 kg N ha^{-1} showed that increasing N rates increased average tuber yields from 10.21 to 22.03 t ha^{-1} in hybrid SS/C 562, from 10.58 to 21.51 t in hybrid SS/C 1101 and from 11.10 to 22.81 tin cv. Kufri Jyoti. At 120 kg N ha^{-1}, the 2 hybrids and Kufri Jyoti gave yields of 18.95, 17.54 and 22.10 t, respectively. The hybrids were shorter than Kufii Jyoti and superior in number of compound leaves and tuber m^{-2}.

Upadhayay and Sharma (1987) carried out an experiment to find out the chemical basis for differential response of the varieties to N. They found that 'Kufri Lalima' was more responsive because of its higher K composition than in ‘Kufri Bahar’ or Kufri Chandramukhi’. The nitrogen- use efficiency, i.e. increase in tuber yield with unit N, was highly correlated with the K composition of tubers.

Singh and Sharma (1987) in an experiment noticed that plant height was increased significantly with the application of nitrogen up to 120 kg per hectare.

Sahota and Perumal (1986) observed in trials during 1980-81 at Shillong with 2 potato varieties that a delay in planting from 25 February to 25 March increased the vegetative growth but decreased the tuber yield. The variety Kufri Khasigaro was superior to variety Kufri Jyoti in vegetative growth, number of tubers plant^{-1}, tuber dry weight, N content and N uptake in tubers. Nitrogen at 80 kg ha^{-1} significantly increased the yield; 120 kg N ha^{-1} gave no further increase.

Singh *et al.* (1986) reported that application of 120 kg N + 80 kg P_20_5 + 80 kg K_20 + 2 kg Agromin (a mixture of trace elements) ha^{-1} to potato cv. Kufri Badshah, Kufii Bahar and Kufri Sindhuri gave tuber yields of 26.3, 16.3 and 15.2 t ha^{-1} respectively; omitting one of the nutrients from this treatment decreased yields.

Sahota and Singh (1986) observed that plant height was increased progressively as the levels of nitrogen increased up to 160 kg per hectare. Singh and Grewal (1984) reported that average plant height was increased from 44.5 to 51.5 cm with an increase in dose from 120 to 180 kg ha^{-1}.

Sahota and Grewal (1979) reported that different doses of nitrogen significantly affected the number of tubers per plant when the dose of nitrogen was increased from 80 to 120 kg ha^{-1}; there was no increase in the number of tubers per plant.

Sharma and Grewal (1978) reported that higher dose of urea affected or delayed the germination due to accumulation of free ammonia and nitrites in the soils. They stated that heavy doses of urea killed the seed tuber sprouts and checked the root growth.

In a field trial under Bangladesh conditions Islam and Siddique (1978) observed that application of different doses of nitrogen from 0 to 224.55 kg per hectare had no significant effect on emergence. Similar result was found (up to 120 kg ha^{-1}) by Grewal *et al.* (1979).

Pushkarnath (1976) carried out an experiment on indigenous potato varieties during the fifties at Patna, India and found that 'Darjeeling Red Round' (DRR) was more responsive to N than Phulwa. The work done on other varieties showed that the nitrogen response of varieties/hybrid, namely 'O.N.45', 'Up-to-Date', 'Kufri Red', 'Kufri Safed', 'O,N.l337', 'O.N.2287' were 13, 18, 26, 30, 30 and 43%, respectively.

The work done on alluvial soil of Daurala (Uttar Pradesh) showed that 'Kufri Sheetman', a frost-resistant variety was less responsive to N than 'Kufii Sindhuri', 'Kufii Chandramukhi', 'Kufri Alankar' and Kufri Bahar (Grewal and Saini, 1971-73 and Grewal *et al.*, 1974).

Gupta and Ghosh (1973) reported that the rates of stem elongation and leaf production and the number of axillary branches were increased with an increase in the levels of nitrogen. The leaf surface was increased till the tuber initiation stage but decreased during the tuber development stage. The increase in the total leaf surface was because of the production of more branches and leaves and expansion of the leaves under high nitrogen fertilizer. Similarly, increasing N fertilizers application increased plant growth rates and N uptake and absorption.

Swaminathan (1972) found that the efficiency of urea was lower in light texture alluvial soils as compared to black cotton soils. Low efficiency of urea has been attributed to its adverse effect on the germination of tubers.

The Central Potato Research Institute (CPRI), India released ‘Kufri Sindhuri’ in 1967 and 9 other varieties including ‘Kufri Chandramukhi’, ‘Kufri Jyoti’ in 1968. Out of them, ‘Kufri Sindhuri’, a long-duration variety, was highly responsive to N when compared with ‘Kufiri Chandramukhi’, a short-duration variety. (De, 1960; Birhman and Verma, 1983; Singh and Sharma, 1982). It was also reported that ‘Kufri Sindhuri’ could even respond to 300 kg N ha^{-1} in the alluvial soil of Jalandhar and its yields were much higher than that of ‘Kufri Chandramukhi’.

2.2 Effect on vermicompost

Akbasova *et al.* (2015) conducted an experiment and reported that the increase of root crops yield 1.2-1.5 times in with 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 (NPK) 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) conducted an experiment to evaluate the use of organic fertilizers (Vermicompost and Chicken manure) on the plant height and number and weight of micro tuber Marfona cultivator potato (diameter of 25-35mm) 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 height was increased. Also highest number and weight of tubers with a diameter of 25-35 mm belonged to 12 ton Chicken manure treatment with 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 27.55 cm) and weight

(189.31, 215.31 and 244.64 g) 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 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 shoot length, number of leaves, dry matter weight of shoots and roots, fruit number and fruit weight were influenced significantly 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 shoot of 52 folds and root of 115 folds, number of fruit(s) $plant^{-1}$ of 6 folds and mean fruit weight of 29 folds while the highest rate of NPK fertilizer of 200% increased dry weight of shoot of 35 folds and root of 80 folds, number of fruit(s) $plant^{-1}$ 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.

Panwar and Wani (2014) conducted a field experiment in the sweet potato filed with Nitrogen, Potash, and Phosphorus was applied in form of organic manure though farm yard manure, vermicompost, and neemcake. Vermicompost recorded highest survival percent, length of vine, number of branches $vine^{-1}$, shoot fresh weight, shoot dry weight, tuber yield $plot^{-1}$, and number of tuber per plot under poplar trees.

Singh and Chauhan (2014) conducted an experiment and the results revealed that plant per meter row length, height of main shoot, dry matter (g) and number of leaves plant^{-1} higher in treatment T_4 (1/3 N-FYM+1/3 N-Vermicompost + 1/3 N-Neem cake plus agronomic practices). On an average treatment T_4 (1/3 N-FYM+1/3 N-Vermicompost + 1/3 N-Neem cake plus agronomic practices for weed and pest control (without chemical) significantly maximum tuber yield.

Mojtaba *et al.* (2013) conducted an experiment on nitrogen fertilizer with three levels (50, 100 and 150 kg ha^{-1} as urea) and vermicompost with 4 levels (0, 4.5, 9, and 12 ton ha^{-1}). Results illustrated that the highest amount of plant height, leaf and stem dry weight, leaf area index (LAI), fresh and dry weight of tuber, total tuber weight, total number of tuber, 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 ton ha^{-1} promoted all above traits except plant height in compared to control treatment. Furthermore, the Combined effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK content of tuber compared with nitrogen and/or vermicompost alone treatments. To gain highest yield and avoidance of environments pollution use of 150 kg ha^{-1} nitrogen fertilizer and vermicompost application of 12 t ha^{-1} are suggested.

Maria *et al.* (2013) conducted an 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 t ha^{-1}, respectively) were applied. Through the following doses of granulated vermicompost were applied to the soil 40, 80, 120, 160 and 240 kg ha^{-1} N. 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.

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 shoot length, root length, shoot dry weight, root dry weight, shoot wet weight, root wet weight, shoot: root ratio and the alkaloid withaferin A and withanolide D were significantly increased in the plants cultivated in the soil amended with poultry feather vermicompost.

Singh *et al.*(2013) conducted a field experiment 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.) with an ultimate aim of optimizing water and nutrient requirement of tomato in mild-tropical climate during dry season. The vermicompost together with organic mulching increased plant height (106.5 cm), leaf area (40.6 cm^2), leaf weight (1301 mg $leaf^{-1}$), 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 (5.2º 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.

Zandonadi and Busato (2012) was reported that the current global increase in human population represents an important environmental challenge with accompanying demand for consumption of food and goods which in turn results in the generation of tons of wastes. Food production to meet the need of this teeming populace on one hand and reduction of ecological foot print on the other, represent two sides of the same coin that are hard to confront simultaneously. It has therefore become necessary to employ alternative ways that improve productivity without causing environment degradation. The conversion of organic waste into fertilizers through vermicomposting (or earthworm composting) is one of such alternatives. The use of 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 present in vermicompost and its products may increase both nutrient content and availability.

Kumar *et al*. (2012) conducted a field experiment with farm yard manure (FYM), poultry manure (PM), vermicompost (VC) and solubilizing bacteria (PSB) and *Azotobactor* + 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. 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 improved tuber yield, nutrient uptake, and gave higher return as compared to other treatment combinations.

Goutam *et al.* (2011) was 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 trials 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 T_1 was kept as control and five others were treated by different category of fertilizers (T_2-Chemical fertilizers, T_3-Farm Yard Manure (FYM), T_4-Vermicompost, T_5-vermicompost supplemented with NPK and T_6- FYM supplemented with chemical fertilizers and vermicompost supplemented with chemical fertilizer respectively).The treatment plots (T_6) showed 73% better yield of fruits than control, Besides, vermicompost supplemented with N.P.K treated plots (T_5) 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.

Shweta and Sharma (2011) conducted an experiment with Application of organic manures along with chemical fertilizers had a significant effect on the tuber and haulm yield. Highest tuber (30.46 t ha^{-1}) and haulm yield (9.04 t ha^{-1}) was recorded with application of 100 % NPK + 25 t vermicompost ha^{-1} 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^{-1} or 12.5 t vermicompost ha^{-1} applied along with 75% of recommended dose of NPK thereby, indicating a saving of 25% in NPK.

Ansari (2008) studied 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) conducted an experiment to study the effect of vermicompost and NPKS fertilizers on growth and yield of potato. There were 12 treatments *viz*. control, vermicompost (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% NPKS, VC 10 t ha^{-1}+50% NPKS, VC 2.5 t ha^{-1}+100% NPKS, VC 5 t ha^{-1}+100% NPKS, VC 10 t ha^{-1}+100% NPKS, 50% NPKS and 100% NPKS. 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 VC 10 t ha^{-1}+100% NPKS 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 of 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. It is suggested that 100% inorganic fertilizers with 5-10 t ha^{-1} of vermicompost is suitable for better production of potato but 10 t ha^{-1} of vermicompost may not economically profitable.

Sood and Sharma (2001) had a field experiment at Shimla for assessing the utility of growth promoting bacteria, *Azotobacter* and vermicompost for potato production. The study indicated that 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.

From the above mentioned literatures, it can be concluded that higher doses of nitrogen give better yield as compared to the lower doses of nitrogen. It is also observed that there is considerable variation and Combined of nitrogen and vermicompost respond differently to different doses of nitrogen and vermicompost.

2.3 Combined effect on nitrogen and vermicompost

Yourtchi *et al.* (2013) conducted an experiment to study the effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato. 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 ton ha^{-1}). Results illustrated that the highest amount of plant height, leaf and stem dry weight, Leaf Area Index(LAI), fresh and dry weight of tuber , total tuber weight, total number of tuber, 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 ton ha^{-1} promoted all above traits except plant height in compared to control treatment. Furthermore, the Combined effects between different nitrogen rates and vermicompost application significantly improved growth parameters, yield and NPK 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 ton ha^{-1} are suggested.

More *et al.* (2013) conducted an experiment to study the effect of integrated nitrogen management with vermiwash in corn on growth and yield. The nitrogen treatments tested were 100% N through chemical fertilizer, 75% N through chemical fertilizer + 25% through bio-compost, 75% N through chemical fertilizer + 25% through vermicompost, 50% N through chemical fertilizer + 25% through biocompost + 25% through vermicompost along with two vermicompost treatments *viz.*, no sprays of vermiwash and three sprays of vermiwash. Combined analysis of variance for them depicted significant results for all the yield contributing characters. The highest grain yield (5261 kg ha^{-1}) and stover yield (7405 kg ha^{-1}) were obtained from the 50% nitrogen through chemical fertilizer + 25% through biocompost + 25% through vermicompost. The use of vermiwash imparted a rise of 11.21% grain and 10.28% stover yield over control.

Najm *et al.* (2010) conducted an experiment to study the effect of utilization of organic and inorganic nitrogen source on the potato shoots dry matter, leaf area index and plant height, during middle stage of growth. In this research the effects of the use of cattle manure (5, 10, 15 and 20 ton ha^{-1}), Nitrogen fertilizer (50, 100 and 150 kg N ha^{-1}) and their Combined on potato growth were evaluated. Results showed that, dry weight of Shoots, LAI and plant height increased linearly and very significantly in response to the application of manure and Nitrogen fertilizer. While the Combined between manure and Nitrogen fertilizer just on the LAI and plant height was significant, somehow the maximum amount of plant height (73 cm) was obtained by using 150 kg Nitrogen + 15 tons of manure per hectare, and maximum LAI (5.36) was obtained by using 150 kg Nitrogen + 20 tons of manure per hectare. Also in this experiment maximum tuber yield (36.8 tons ha^{-1}) was obtained by the utilization of 150 kg Nitrogen per hectare + 20 tons manure.

CHAPTER III

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 experiments and methods are described below-

3.1 Experimental period

The experiment was conducted during the period from November 12, 2013 to February 20, 2014 in Rabi season.

3.2 Site description

3.2.1 Geographical location

The experimental area was situated at $23^0 77'$N latitude and $90^0 33'$E longitude at an altitude of 8.6 meter above the sea level.

3.2.2 Agro-Ecological Region

The experimental 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 experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2.3 Climate of the experimental site

Experimental site was located in the sub-tropical monsoon climatic zone, set aparted by winter during the months from November, 2013 to February, 2014. Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for potato growing in Bangladesh. The weather data during the study period at the experimental site are shown in Appendix II.

3.3 Details of the experiment

3.3.1 Experimental treatments

The experiment consisted of two factors such as nitrogen and vermicompost level. The treatments were as follows:

Factor A: Nitrogen level: 4

1. N_0= 0 kg N ha^{-1}
2. N_1= 100 kg N ha^{-1}
3. N_2=150 kg N ha^{-1}
4. N_3=200 kg N ha^{-1}

Factor B: Vermicompost level: 4

1. Vm_0= 0 t ha^{-1}
2. Vm_1= 5 t ha^{-1}
3. Vm_2= 10 t ha^{-1}
4. Vm_3= 15 t ha^{-1}

Treatment combination: Sixteen treatment combinations

N_0Vm_0	N_1Vm_0	N_2Vm_0	N_3Vm_0
N_0Vm_1	N_1Vm_1	N_2Vm_1	N_3Vm_1
N_0Vm_2	N_1Vm_2	N_2Vm_2	N_3Vm_2
N_0Vm_3	N_1Vm_3	N_2Vm_3	N_3Vm_3

3.3.2 Experimental design

The experiment was laid out in a split-plot design with 3 replications having levels of nitrogen in the main plots and levels of vermicompost in the sub-plots. There are 16 treatment combinations and 48 unit plots. The unit plot size was 5 m^2 (2.5 m × 2.0 m). The main plot and unit plots were separated by 1.0 m and 0.50 m spacing respectively.

3.4 Planting material

BARI TPS-I was used as planting material. BARI TPS-I was released and developed by Tuber Crops Research Centre (TCRC), BARI in 1997. Average yield of this cultivar is about 35-40 t ha^{-1}. The seed tuber was round shaped and free from mixture of other seeds, weed seeds and extraneous materials.

3.5 Crop management

3.5.1 Collection of seed

Seed potato (certified seed) of BARI TPS-I was collected from, Tuber Crops Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. Individual weight of seed potato was 20 g.

3.5.2 Preparation of seed

Collected seed tubers were kept in room temperature to facilitate sprouting. Finally sprouted potato tubers were used as a planting material.

3.5.3 Land preparation

The experimental land was opened with a power tiller on 05 November, 2013. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on 11 November, 2014 and was ready for planting seeds.

3.5.4 Fertilizer application

The experimental field was fertilized with following dose of triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid.

Fertilizers	Dose (kg ha^{-1})
TSP	150
MoP	250
Gypsum	120
Zinc Sulphate	10
Boric Acid	10

Source: Mondal *et al.* (2011)

The entire amounts of vermicompost (as per treatments), triple superphosphate, muriate of potash, gypsum, zinc sulphate, boric acid and one third of urea (as per treatments) were applied as basal dose at 3 days before potato planting. Rest of the urea was applied in two equal installments i.e., first was done at 30 days after planting (DAP) and second was at 50 DAP.

3.5.5 Planting of seed tuber

The well sprouted healthy and uniform sized potato tubers were planted according to treatment and a whole potato was used for one hill. Seed potatoes were planted in such a way that potato does not go much under soil or does not remain in shallow. On an average, potatoes were planted at 4-5 cm depth in soil on November 12, 2013.

3.5.6 Intercultural operations

3.5.6.1 Weeding

Weeding was necessary to keep the plant free from weeds. The newly emerged weeds were uprooted carefully in the entire field after complete emergence of sprouts and afterwards when necessary.

3.5.6.2 Watering

Frequency of watering was done upon moisture status of soil retained as requirement of plants. Excess water was not given, because it always harmful for potato plant.

3.5.6.3 Earthing up

Earthing up process was done by spade at two times, during crop growing period. First was done at 45 DAP and second was at 60 DAP.

3.5.6.4 Plant protection measures

Dithane M-45 was applied at 30 DAP as a preventive measure for controlling fungal infection. Ridomil (0.25%) was sprayed at 45 DAP to protect the crop from the attack of late blight.

3.5.6.5 Haulm cutting

Haulm cutting was done at February 12, 2014 at 90 DAP, when 40-50% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening. The cut haulm was collected, bagged and tagged separately for further data collection.

3.5.6.6 Harvesting of potatoes

Harvesting of potato was done at February 20, 2014 at 7 days after haulm cutting. The potatoes of each treatment were separately harvested, bagged and tagged and brought to the laboratory. Harvesting was done manually by hand.

3.5.7 Recording of data

Experimental data were recorded from 15 DAP and continued until harvest. The following data were collected during the experimentation.

A. Crop growth characters
    i. Days to emergence
    ii. Plant height at 30, 45, 60, 75 and harvest (cm)

iii. Number of leaves plant^{-1} at 30, 45, 60, 75 and harvest

iv. SPAD value of leaves at 20, 40 and 60 DAP

v. Stem diameter at 30, 45, 60, 75 and harvest (cm)

B. Yield and yield components

vi. Number of tubers hill^{-1}

vii. Number of tubers m^{-2}

viii. Weight of tuber m^{-2} (kg)

ix. Average weight of tuber (g)

x. Yield of tuber (t ha^{-1})

C. Quality characters

xi. Grading of tubers (% by weight)

xii. Tuber dry matter content (%)

xiii. Specific gravity

xiv. TSS (Total soluble solids) (^{0} Brix)

3.5.8 Experimental measurements

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

A. Crop growth characters

i. Days to emergence

After planting the potato tuber keenly observed the emergence twice in a day (morning and afternoon) until 100% emergence.

ii. Plant height (cm)

Plant height refers to the length of the plant from ground level to the tip of the tallest stem. It was measured at an interval of 15 days starting from 15 DAP till harvest. The height of selected plant was measured in cm with the help of a meter scale and mean was calculated.

iii. Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at an interval of 15 days starting from 15 DAP till harvest. Leaves number plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of leaves of all sampled plants then the average data were recorded.

iv. SPAD value

SPAD value of leaves was measured at 20, 40 and 60 DAP. Mature leaf (fourth leaves from top) were measured all time. Three mature plants of each sampled plants were measured by using portable Chlorophyll Meter (SPAD-502, Minolta, Japan) and then calculated an average SPAD value for each pot 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).

v. Stem diameter (cm)

Stem diameter was measured at an interval of 15 days starting from 15 DAP till harvest. The stem diameter of each samples plant was measured in cm by using Slide Calipers and mean was calculated.

B. Yield and yield components

vi. Number of tubers hill^{-1}

Number of tubers hill^{-1} was counted at harvest. Tuber numbers hill^{-1} was recorded by counting all tubers from sample plant.

vii. Number of tubers m^{-2}

Number of tubers m^{-2} was counted at harvest. Tuber numbers m^{-2} was recorded by counting all tubers from sample plant.

viii. Weight of tubers m^{-2}

Weight of tuber m^{-2} was measure at harvest. Tuber weight m^{-2} was recorded by measuring all tubers from sample plant.

ix. Average weight of tuber (g)

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

$$\text{Average weight of tuber} = \frac{\text{Yield of tuber/m}^{-2}}{\text{Number of tubers/m}^{-2}}$$

x. Yield of tuber (t ha^{-1})

Tuber yield was recorded on the basis of total harvested tuber $plot^{-1}$ and was expressed in terms of yield (t ha^{-1}).

C. Quality characters

xi. Grading of tuber (% by weight)

Tubers harvested from each treatment were graded by number on the basis of diameter into the >55 mm, 45-55 mm, 28-45 mm and <28 mm and converted to percentages (Hussain, 1995). A special type of frame (potato riddle) was used to grading of tuber.

xii. Tuber dry matter content (%)

The samples of tuber were collected from each treatment. After peel off the tubers the samples were dried in oven at 72^0C for 72 hours. From which the weights of tuber flesh dry matter content % were recorded. From which the dry matter percentage of tuber was calculated with the following formula (Elfinesh *et al.,* 2011)-

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

xiii. Specific Gravity

It was measured by using the following formula (Gould, 1995)-

$$\text{Specific gravity} = \frac{\text{Weight of tube in air}}{\text{Weight of tuber in water at } 4^{0}\text{ C}}$$

xiv. TSS (^{o}Brix)

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

3.5.9 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by Least Significance Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the growth, yield and quality of BARI TPS- I as influenced by nitrogen and vermicompost. The results obtained from the study have been presented, discussed and compared in this chapter through table(s) and figures. The analysis of variance of data in respect of all the parameters has been shown in Appendix V-XII. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings.

4.1 Crop growth characters

4.1.1 Days to first emergence (Visual observation)

4.1.1.1 Effect of nitrogen doses

There was no significant difference observed in days to first emergence due to different nitrogen doses (Figure1). Results revealed that the minimum days to first emergence (12.98 days) was required in N_3 treatment and the maximum (13.49 days) was recorded in N_1 treatment.

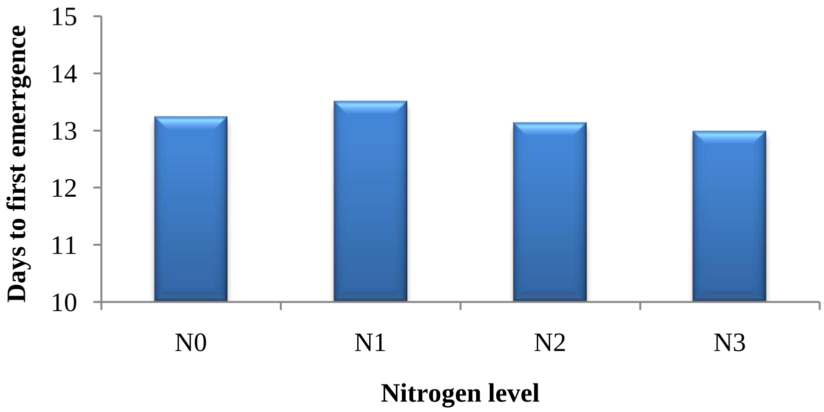

Figure 1. Effect of nitrogen doses on days to first emergence of BARI TPS-I

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.1.1.2 Effect of vermicompost levels

Vermicompost levels had no significant effect on the days to first emergence (Figure 2). The minimum days to first emergence (12.92 days) were required in Vm_2 treatment and the maximum (13.52 days) was recorded in Vm_1 treatment.

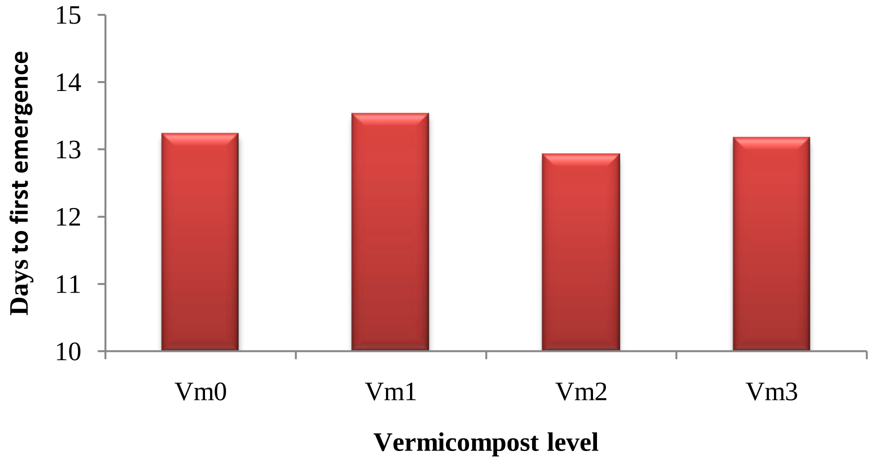

Figure 2. Effect of vermicompost levels on days to first emergence of BARI TPS-I

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.1.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels had no significant effect on the days taken to first emergence of BARI TPS-I (Table 1). The minimum duration for first emergence (11.47 days) was recorded from the combination of N_3 and Vermicompost levels Vm_3 treatment, whereas the maximum duration (14.66 days) was recorded from the combination of N_1 and Vm_3.

4.1.2 Days to final emergence (Visual observation)

4.1.2.1 Effect of nitrogen doses

Days to final emergence was significantly influenced by the different nitrogen doses (Figure 3). Results revealed that the treatment N_1 took the minimum days (17.97 days) for final emergence which was statistically similar with N_0 and N_2

treatment and the maximum days (19.27 days) was taken by N_3 treatment which was statistically similar with N_0 and N_2.

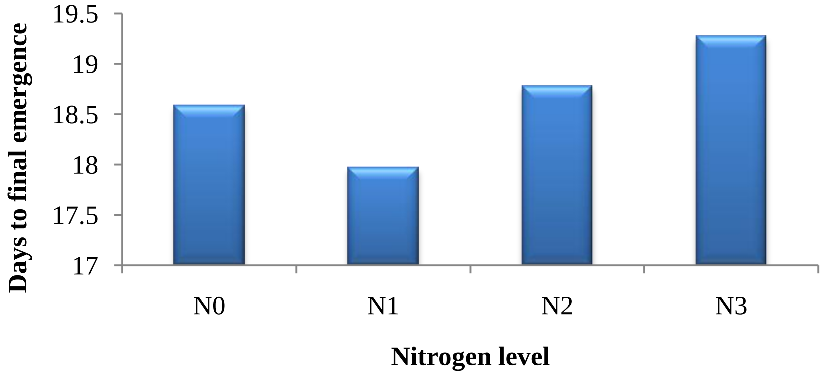

Figure 3. Effect of nitrogen doses on days to final emergence of BARI TPS-I (LSD $_{(0.05)}$ = 1.06)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.1.2.2 Effect of vermicompost levels

Vermicompost levels had no significant effect on the days to final emergence (Figure 4). The minimum days to final emergence (17.60 days) were required in Vm_2 treatment and the maximum (19.42 days) was recorded in Vm_3 treatment.

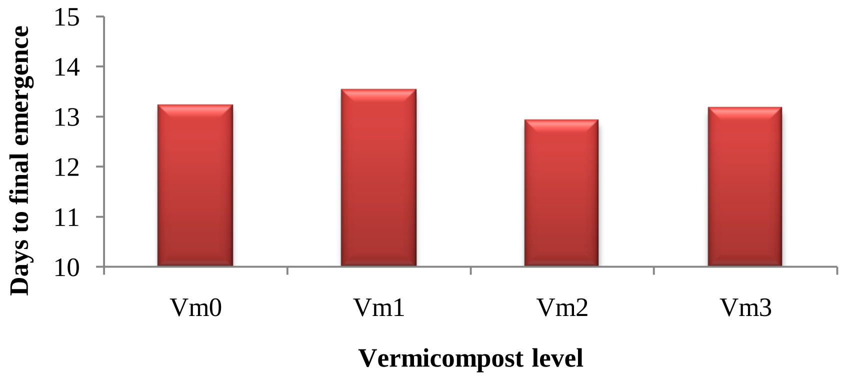

Figure 4. Effect of vermicompost levels on days to final emergence of BARI TPS-I

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.2.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels had no significant effect on the days to final emergence (Table 1). The minimum duration for final emergence (16.25 days) was recorded from the combination of N_1Vm_2. The maximum duration (21.40 days) was recorded from the combination of N_3Vm_2.

Table 1. Combined effect of nitrogen doses and vermicompost levels on days to first emergence and days to final emergence of BARI TPS-I

Treatments	Days to first emergence	Days to final emergence
N_0Vm_0	14.40	19.32
N_0Vm_1	13.53	17.53
N_0Vm_2	12.48	20.10
N_0Vm_3	12.51	17.41
N_1Vm_0	13.53	16.55
N_1Vm_1	13.51	18.81
N_1Vm_2	12.26	16.25
N_1Vm_3	14.66	20.25
N_2Vm_0	12.52	17.00
N_2Vm_1	13.44	20.47
N_2Vm_2	12.52	16.41
N_2Vm_3	14.00	21.24
N_3Vm_0	12.46	17.51
N_3Vm_1	13.59	19.37
N_3Vm_2	14.42	21.40
N_3Vm_3	11.47	18.80
LSD $_{(0.05)}$	ns	ns
CV (%)	23.00	17.57

ns = non significant

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1},

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.3 Plant height

4.1.3.1 Effect of nitrogen doses

The plant height of BARI TPS-I was significantly influenced by different nitrogen doses at 75 DAP and at harvest but it was insignificant at 30, 45 and 60 DAP (Fig. 5). The result revealed that at 30 and 45 DAP; the tallest plant

(24.34 and 45.99 cm, respectively) was obtained from treatment N_3 while the shortest plant (21.87 and 39.93 cm, respectively) was obtained from the N_2 and N_0 treatment respectively. At 60 DAP the tallest plant (68.24) was obtained from treatment N_2 while the shortest plant (53.23) was obtained from the N_0 treatment. At 75 DAP and at harvest the tallest plant (72.58 and 70.98 cm, respectively) was obtained from treatment N_2 which was statistically similar with N_3 treatment while the shortest plant (57.92 and 56.20 cm, respectively) was obtained from N_0 treatment. Results showed that, in all treatment, plant height were increased significantly by increasing N fertilizer. The result of the present investigation was similar with the studies conducted by Najm *et al.* (2013). The different of plant height of a crop depends on the plant vigor, cultural practices, growing environment and the fertilizer management. In the present experiment since all the treatments were grown in the same environment, the variation in the plant height among the treatments might be due to the different nitrogen doses.

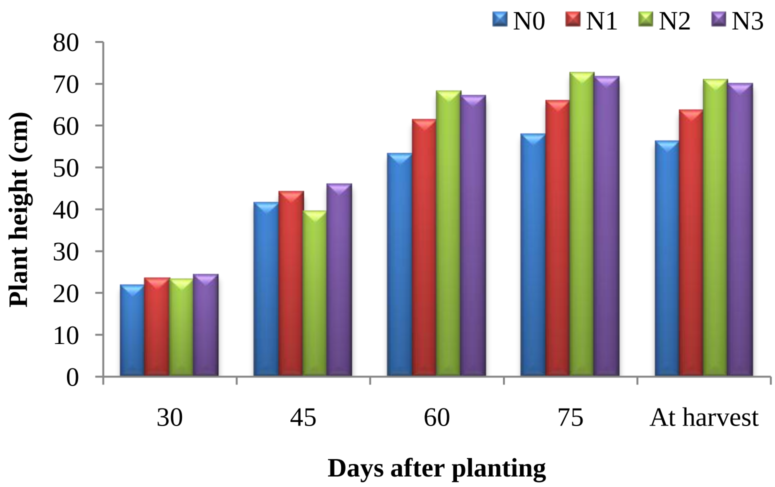

Figure 5. Effect of nitrogen doses on plant height (cm) of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 1.61 and 3.62 at 75 DAP and at harvest respectively)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.1.3.2 Effect of vermicompost levels

The plant height of BARI TPS-I was significantly influenced by different vermicompost levels at 75 DAP and at harvest but it was insignificant at 30, 45 and 60 DAP (Figure 6). The result revealed that at 30 and 45 DAP, the tallest plant (24.38 and 44.90 cm, respectively) was obtained from treatment Vm_0 while the shortest plant (22.57 and 41.46 cm, respectively) was obtained from the Vm_2 and Vm_3 treatment respectively. At 60 DAP the tallest plant (65.34) was obtained from treatment Vm_3 while the shortest plant (58.94) was obtained from the Vm_2 treatment. At 75 DAP and at harvest the tallest plant (69.70 and 68.52 cm, respectively) was obtained from treatment Vm_3 which was statistically similar with Vm_0 and Vm_1 treatment while the shortest plant (63.11 and 61.22 cm, respectively) was obtained from Vm_2 treatment. The result showed that with increasing vermicompost fertilizer, plant height was increased at 60, 75 DAP and at harvest. The result of the present investigation was similar with the studies conducted by Shirzadi (2015).

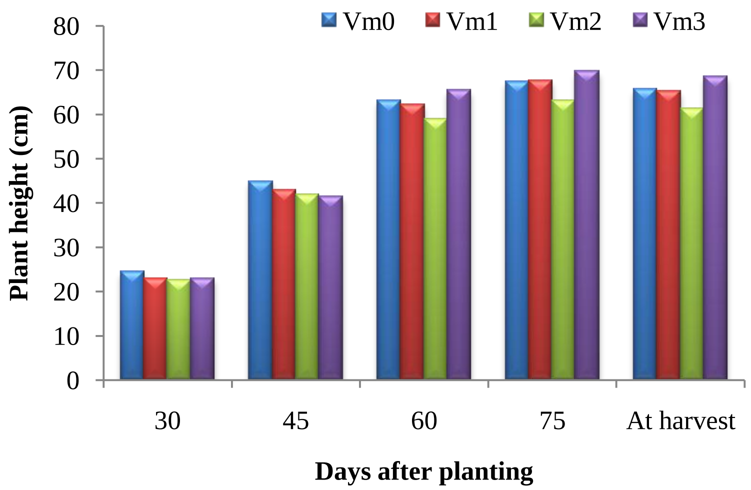

Figure 6. Effect of vermicompost levels on plant height (cm) of BARI TPS-I at different growth stages ($LSD_{(0.05)}$ = 3.45 and 3.25 at 75 DAP and at harvest respectively)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.3.3 Combined effect of nitrogen doses and vermicompost levels

Significant combined effect of nitrogen doses and vermicompost levels on plant height was observed at 60, 75 DAP and at harvest but it was insignificant at 30 and 45 DAP (Table 2). At 30 DAP, the tallest plant (25.93 cm) was obtained from the combination of N_2Vm_0 and the shortest plant (19.58 cm) was obtained from the N_2Vm_2 treatment combination. At 45 DAP, the tallest plant (54.11 cm) was obtained from the combination of N_3Vm_1 and the shortest plant (35.87 cm) was obtained from the N_1Vm_1 treatment combination. At 60, 75 and at harvest, the highest plant height (75.44, 81.09 and 79.39 cm, respectively) was observed from the N_2Vm_1 treatment combination and it was statistically similar with all other treatments except N_0Vm_1 treatment combination at 60 DAP, with N_2Vm_3 (74.39 cm), N_3Vm_1 (78.39 cm) at 75 DAP, and N_3Vm_1 (75.23 cm) at harvest whereas, the smallest plant (43.57, 48.84 and 45.58 cm, respectively) was obtained from N_0Vm_1 treatment combination. The combined effects between different nitrogen rates and vermicompost application significantly increased plant height was observed by Yourtchi *et al.* (2013).

Table 2. Combined effect of nitrogen doses and vermicompost levels on plant height of BARI TPS-I at different days after planting

Treatments	Plant height (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	At harvest
N_0Vm_0	21.72	46.00	57.64 ab	60.86 gh	59.99 gh
N_0Vm_1	22.50	36.20	43.57 b	48.84 i	45.58 i
N_0Vm_2	20.32	39.75	52.11 ab	57.61 h	55.19 h
N_0Vm_3	22.96	44.58	59.61 ab	64.38 d-h	64.04 d-g
N_1Vm_0	24.17	42.33	61.07 ab	66.27 d-g	63.00 e-g
N_1Vm_1	21.29	35.87	57.67 ab	62.44 f-h	60.96 f-h
N_1Vm_2	25.15	50.98	61.00 ab	65.14 d-g	62.68 e-g
N_1Vm_3	23.28	46.79	64.99 ab	69.37 c-e	67.73 c-e
N_2Vm_0	25.93	39.85	64.28 ab	68.64 c-f	67.29 c-f
N_2Vm_1	24.33	45.26	75.44 a	81.09 a	79.39 a
N_2Vm_2	19.58	36.00	62.83 ab	66.21 d-g	64.98 d-g
N_2Vm_3	23.28	36.37	70.42 ab	74.39 a-c	72.25 bc
N_3Vm_0	25.70	51.43	69.56 ab	73.74 bc	72.47 bc
N_3Vm_1	23.79	54.11	72.22 a	78.39 ab	75.23 ab
N_3Vm_2	25.25	40.32	59.83 ab	63.48 e-h	62.04 e-g
N_3Vm_3	22.63	38.10	66.33 ab	70.68 cd	70.05 b-d
$LSD_{(0.05)}$	ns	ns	28.38	6.90	6.51
CV (%)	19.46	25.32	26.98	6.12	5.92

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

ns = non significant

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.4 Number of leaves plant^{-1}

4.1.4.1 Effect of nitrogen doses

Different nitrogen doses exhibited significant variation in respect of number of leaves plant^{-1} at 75 DAP and at harvest but it was insignificant at 30, 45 and 60 DAP (Fig. 7). Number of leaves plant^{-1} increased with advancing growing period up to 75 DAP and thereafter decreased due to senescence of leaves (Fig. 7). At 30 DAP, the maximum leaves number plant^{-1} (27.83) was observed from the N_3 and the minimum number (22.75) was observed from N_2. The result revealed that at 45, 60, 75 DAP and at harvest the maximum leaves number plant^{-1} (121.01, 146.41, 151.32 and 143.81, respectively) was obtained from treatment N_3 while the minimum number (98.50, 109.50, 141.10 and 106.51, respectively) was obtained from the N_0 treatment.

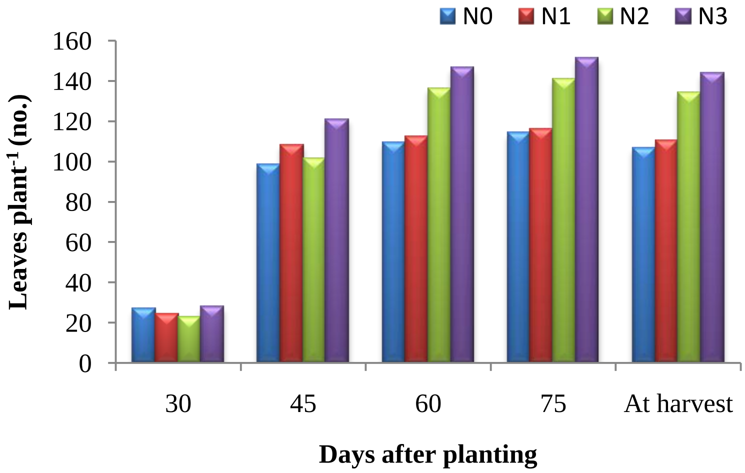

Figure 7. Effect of nitrogen doses on leaves plant^{-1} (No.) of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 1.89 and 5.07 at 75 DAP and at harvest respectively)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.1.4.2 Effect of vermicompost levels

The number of leaves plant^{-1} was significantly influenced by different vermicompost levels at 75 DAP and at harvest but it was insignificant at 30, 45 and 60 DAP (Fig. 8). At 30 DAP, the maximum leaves number plant^{-1} (27.17) was observed from the Vm_1 and the minimum number (22.92) was observed from Vm_0. At 45, 60, 75 DAP and at harvest, the maximum leaves number plant^{-1} (117.80, 135.88, 140.12 and 132.81, respectively) was observed from the Vm_3 treatment which was statistically similar (136.2) with Vm_1 at 75 DAP and the minimum leaves number plant^{-1} (99.08, 117.25, 122.3 and 117.03, respectively) was counted from Vm_1 treatment at 45 DAP and Vm_2 treatment at 60, 75 DAP and at harvest. This result was in agreement with the findings reported by Singh and Chauhan (2014). Whom reported that the vermicompost levels had significant effect on number of leaves plant^{-1} of potato tuber.

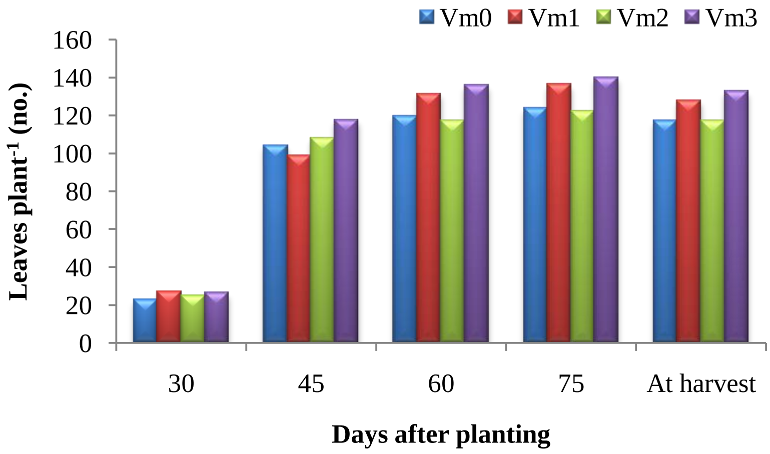

Figure 8. Effect of vermicompost levels on leaves plant^{-1} (No.) of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 4.34 and 3.64 at 75 DAP and at harvest respectively)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.4.3 Combined effect of nitrogen doses and vermicompost levels

There was significant variation among the combination of nitrogen doses and vermicompost levels on the total numbers of leaves plant^{-1} at all growth stage except 30 DAP (Table 3). Number of leaves plant^{-1} increased with advancing growing period up to 75 DAP irrespective of nitrogen doses and vermicompost levels and thereafter decreased (Table 3). At 30 DAP, the maximum number of leaves plant^{-1} (30.33) was recorded from the combination of N_3Vm_1 treatment and the minimum (20.67) was recorded from the N_2Vm_1 treatment combination. At 45 DAP, the maximum number of leaves plant^{-1} (145.33) was counted from the N_3Vm_3 treatment combination and it was statistically similar with N_0Vm_2, N_0Vm_3, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_0, N_2Vm_2, N_2Vm_3, N_3Vm_0, N_3Vm_1 and N_3Vm_2 treatment combination whereas, the minimum (84.87) was counted from the N_0Vm_1 treatment combination which was statistically similar with N_0Vm_0, N_0Vm_2, N_0Vm_3, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_0, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0, N_3Vm_1 and N_3Vm_2. At 60, 75 DAP and at harvest, the maximum leaves number (181.87, 186.55 and 175.28, respectively) was obtained from the N_3 with Vm_1 combination treatment and the minimum number of leaves plant^{-1} (88.33, 93.03 and 90.01, respectively) was recorded from the combination of N_1 with Vm_2.

Table 3. Combined effect of nitrogen doses and vermicompost levels on leaves plant^{-1} of BARI TPS-I at different days after planting

Treatments	Leaves plant^{-1} (No.) at				
	30 DAP	45 DAP	60 DAP	75 DAP	At harvest
N_0Vm_0	24.67	85.67 b	98.67 b	103.11 h	96.14 hi
N_0Vm_1	30.00	84.67 b	101.33 b	106.07 h	97.82 gh
N_0Vm_2	24.33	112.33 ab	114.33 b	120.04 g	111.81 f
N_0Vm_3	29.00	111.33 ab	123.67 ab	127.11 e-g	120.07 e
N_1Vm_0	22.00	114.00 ab	133.33 ab	135.33 de	125.85 e
N_1Vm_1	27.67	104.77 ab	105.33 b	110.02 h	104.47 g
N_1Vm_2	23.33	92.00 ab	88.33 b	93.03 i	90.01 i
N_1Vm_3	23.33	122.00 ab	121.77 ab	125.22 fg	120.81 e
N_2Vm_0	21.33	107.77 ab	121.00 ab	126.41 fg	120.62 e
N_2Vm_1	20.67	86.00 b	137.77 ab	142.01 cd	134.21 d
N_2Vm_2	24.67	120.00 ab	140.77 ab	145.05 c	139.66 cd
N_2Vm_3	24.33	92.67 ab	145.77 ab	150.37 bc	143.09 bc
N_3Vm_0	23.67	109.33 ab	126.33 ab	130.11 ef	126.14 e
N_3Vm_1	30.33	121.00 ab	181.77 a	186.55 a	175.28 a
N_3Vm_2	28.67	108.33 ab	125.77 ab	131.03 ef	126.53 e
N_3Vm_3	28.67	145.33 a	152.00 ab	157.52 b	147.29 b
$LSD_{(0.05)}$	ns	57.15	67.16	8.68	7.27
CV (%)	33.14	31.60	31.61	3.95	3.49

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

ns = non significant

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.5 SPAD value

4.1.5.1 Effect of nitrogen doses

SPAD value of potato leaves were significantly affected by nitrogen doses at 50 and 70 DAP but it was insignificant at 30 DAP (Figure 9). At 30 DAP, the maximum SPAD value (52.20) was recorded from N_0 and the minimum (49.91) was recorded from N_2 treatment. At 50 DAP, the highest SPAD value (51.59) was recorded from N_2 treatment which was statistically similar with N_1 and N_3

and the lowest (46.10) was recorded from N_0 treatment. At 70 DAP the maximum SPAD value (52.51) was recorded from N_1 which was statistically similar with N_2 and N_3, whereas the minimum (46.46) was recorded from treatment N_0. Nitrogen is the core component of chlorophyll molecule and thus, its content in leaf is directly correlated with chlorophyll content. Effects of nitrogen on the leaf chlorophyll were significantly influenced by nitrogen rate was observed by (Guler, 2009).

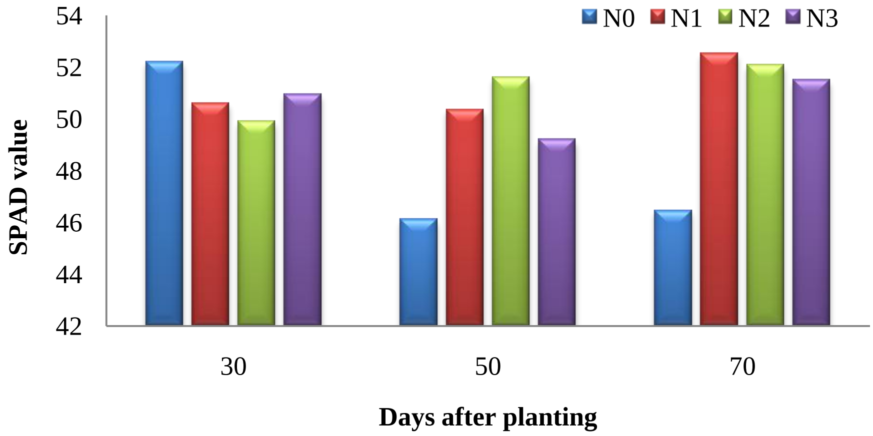

Figure 9. Effect of nitrogen doses on SPAD value of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 2.90 and 2.57 at 50 and 70 DAP respectively)

Note: N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.1.5.2 Effect of vermicompost levels

SPAD value of potato leaves showed statistically significant variation among the different vermicompost levels at 30 and 70 DAP but it was insignificant at 50 DAP (Fig. 10). At 30 DAP, the highest SPAD value (51.80) was recorded from Vm_3 treatment which was statistically similar with Vm_0 and Vm_1 treatment and the lowest SPAD value (49.63) was found from the Vm_2 treatment. At 50 DAP, the highest SPAD value (50.52) was recorded from Vm_0 treatment and the lowest SPAD value (47.74) was found from the Vm_1 treatment. At 70 DAP, the highest SPAD value (52.18) was recorded from Vm_2 treatment which was statistically similar with Vm_0 and Vm_3 treatment and the lowest SPAD value (47.45) was found from the Vm_1 treatment.

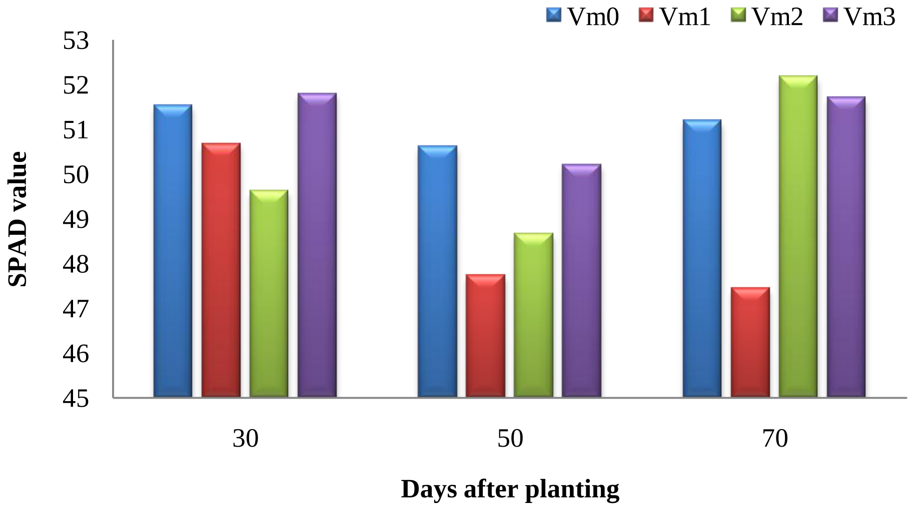

Figure 10. Effect of vermicompost levels on SPAD value of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 2.08 and 4.07 at 30 and 70 DAP respectively)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.5.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of different nitrogen doses and vermicompost levels in terms of SPAD value also exposed significant variation at 30, 50 and 70 DAP (Table 4). At 30 DAP, the maximum SPAD value (54.18) was recorded from the combination of N_0 with Vm_3 which was statistically similar with all other treatment combination except N_2Vm_2 and N_3Vm_1 whereas, the minimum (45.29) was recorded N_2Vm_2 which was statistically similar with N_3Vm_1 treatment combination. At 50 DAP, the highest SPAD value (54.08) was recorded from N_2Vm_0 which was statistically similar with N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0, N_3Vm_1, N_3Vm_3, N_3Vm_2 and N_0Vm_3 whereas, the lowest (43.69) was recorded from the N_0Vm_1 treatment combination. At 70 DAP, the maximum SPAD value (56.08) was recorded from N_2Vm_2 treatment combination which was statistically similar with all other treatment combination except N_0Vm_1 and N_0Vm_2 and the minimum (41.17) was recorded from the N_0Vm_1 treatment combination which was statistically similar with N_0Vm_2, N_0Vm_3, N_1Vm_1 and N_3Vm_1 treatment combination.

Table 4. Combined effect of nitrogen doses and vermicompost levels on SPAD value of BARI TPS-I at different days after planting

Treatments	SPAD value at different days after planting		
	30	**50**	**70**
$\mathbf{N_0Vm_0}$	53.83 a	46.49 b-d	49.40 ab
$\mathbf{N_0Vm_1}$	50.39 ab	43.69 d	41.17 c
$\mathbf{N_0Vm_2}$	50.42 ab	44.23 cd	47.23 bc
$\mathbf{N_0Vm_3}$	54.18 a	49.97 a-c	48.05 a-c
$\mathbf{N_1Vm_0}$	50.14 ab	53.28 a	54.80 ab
$\mathbf{N_1Vm_1}$	51.31 ab	48.55 a-d	48.58 a-c
$\mathbf{N_1Vm_2}$	50.68 ab	50.95 ab	51.83 ab
$\mathbf{N_1Vm_3}$	50.28 ab	48.67 a-d	54.81 ab
$\mathbf{N_2Vm_0}$	50.16 ab	54.08 a	50.02 ab
$\mathbf{N_2Vm_1}$	52.17 ab	48.99 a-d	52.08 ab
$\mathbf{N_2Vm_2}$	45.29 c	50.86 ab	56.08 a
$\mathbf{N_2Vm_3}$	52.01 ab	52.44 ab	50.10 ab
$\mathbf{N_3Vm_0}$	52.05 ab	48.65 a-d	50.54 ab
$\mathbf{N_3Vm_1}$	48.85 bc	49.72 a-d	47.99 a-c
$\mathbf{N_3Vm_2}$	52.14 ab	48.59 a-d	53.58 ab
$\mathbf{N_3Vm_3}$	50.72 ab	49.78 a-c	53.87 ab
LSD $_{(0.05)}$	4.16	6.07	8.12
CV (%)	4.84	7.30	9.52

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.6 Stem diameter

4.1.6.1 Effect of nitrogen doses

Significant variation was recorded for stem diameter due to different nitrogen doses of BARI TPS-I at 75 DAP and at harvest DAP but it was insignificant at 30, 45 and 60 DAP (Fig. 11). Stem diameter increased with advancing growing period up to 75 DAP irrespective of different nitrogen doses and thereafter decreased (Fig. 11). In vegetative stage, potato stems were fleshy and succulent and at later (harvesting) stage it becomes hard and slender due to senescence of plant. At 30 DAP the widest stem diameter (0.72 cm) was recorded from both N_0 and N_3 treatment whereas; the narrowest (0.65 cm) was recorded from N_1 treatment. At 45 DAP the widest stem diameter (0.88 cm) was recorded from N_0 treatment whereas; the narrowest (0.77 cm) was recorded from N_1 treatment. At 60 DAP the widest stem diameter (0.92 cm) was recorded from N_0 treatment whereas; the narrowest (0.77 cm) was recorded from N_1 and N_2 treatment. At 75 DAP the widest stem diameter (0.98 cm) was recorded from N_0 treatment whereas, the narrowest (0.78 cm) was recorded from N_1 treatment which was statistically similar with N_2 (0.79 cm) treatment. At harvest the widest stem diameter (0.89 cm) was recorded from N_0 treatment which was statistically similar with N_3 (0.87 cm) treatment whereas, the narrowest (0.74 cm) was recorded from N_2 treatment which was statistically similar with N_1 (0.75 cm) treatment.

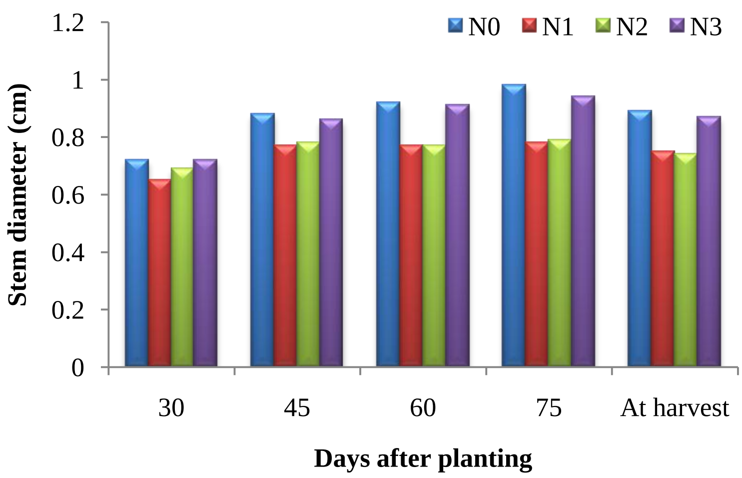

Figure 11. Effect of nitrogen doses on stem diameter (cm) of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 0.03 and 0.05 at 75 DAP and at harvest respectively)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.1.6.2 Effect of vermicompost levels

Stem diameter showed no significant variation with different vermicompost levels at all growing stage of BARI TPS-I potato (Fig. 12). Stem diameter increased with increasing different growing stages up to 75 DAP irrespective of vermicompost levels and thereafter decreased (Figure 12). In vegetative stage potato stems were fleshy and succulent and at later (harvesting) stage it becomes hard and slender due to senescence of plant. At 30 DAP the widest stem diameter (0.72 cm) was recorded from the Vm_1 and the narrowest (0.67 cm) was recorded from the Vm_2 treatment. At 45 DAP the widest stem diameter (0.84 cm) was recorded from both Vm_2 and Vm_3 whereas the narrowest (0.81 cm) was recorded from the Vm_0 and Vm_1 treatment. At 60 DAP the widest stem diameter (0.87 cm) was recorded from the Vm_2 and the narrowest (0.82 cm) was recorded from the Vm_3 treatment. It was observed that, at 75 DAP and at harvest the widest stem diameter (0.88, and 0.83 cm, respectively) was recorded from both Vm_2 and Vm_3 treatment whereas, the narrowest (0.86 and 0.80 cm, respectively) was recorded from the Vm_1 treatment.

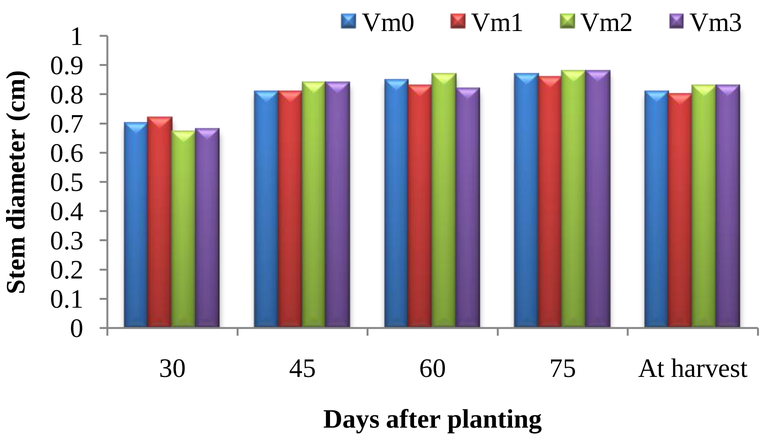

Figure 12. Effect of vermicompost levels on stem diameter (cm) of BARI TPS-I at different growth stages (LSD $_{(0.05)}$ = 0.88 and 0.83 at 75 DAP and at harvest, respectively)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.1.6.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels was significant in respect of stem diameter at 30, 45, 60, 75 DAP and at harvest (Table 5). Stem diameter increased with increasing advancing growing period up to 75 DAP irrespective of nitrogen doses and vermicompost levels and thereafter decreased due to senescence of plant (Table 5). At 30 DAP, the widest stem diameter (0.86 cm) was recorded from the combination of N_0Vm_3 treatment which was statistically similar with N_1Vm_0, N_2Vm_0, N_2Vm_1, N_3Vm_1, N_3Vm_2 and the narrowest (0.57 cm) was recorded from the combination of N_2Vm_3 which was statistically similar with N_0Vm_1, N_0Vm_2, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_2, N_3Vm_0, N_3Vm_3 and N_0Vm_0 treatment combination. At 45 DAP the widest stem diameter (0.92 cm) was recorded from the combination of N_0Vm_0 treatment which was statistically similar with all others treatment combination except N_1Vm_1 and the narrowest (0.57 cm) was recorded from the combination of N_1Vm_1 which was statistically similar with all others treatment combination except N_0Vm_0 and N_3Vm_1 treatment combination. At 60, 75 DAP and at harvest, the widest stem diameter (1.02, 1.22 and 1.11, respectively) was obtained from the N_0 with Vm_3 combination treatment and the narrowest stem diameter (0.68, 0.70 and 0.67, respectively) was recorded from the combination of N_2 with Vm_3.

Table 5. Combined effect of nitrogen doses and vermicompost levels on stem diameter of BARI TPS-I at different DAP

Treatments	Stem diameter (cm) at				
	30 DAP	45 DAP	60 DAP	75 DAP	At harvest
N_0Vm_0	0.69 b-d	0.92 a	0.94 a	0.97 bc	0.86 bc
N_0Vm_1	0.65 b-d	0.86 ab	0.80 a-c	0.81 d-f	0.76 cd
N_0Vm_2	0.67 b-d	0.87 ab	0.91 ab	0.92 b-d	0.84 bc
N_0Vm_3	0.86 a	0.88 ab	1.02 a	1.22 a	1.11 a
N_1Vm_0	0.71 a-d	0.76 ab	0.80 a-c	0.83 c-f	0.76 cd
N_1Vm_1	0.65 b-d	0.66 b	0.71 bc	0.74 ef	0.74 cd
N_1Vm_2	0.66 b-d	0.85 ab	0.85 a-c	0.82 d-f	0.80 b-d
N_1Vm_3	0.61 cd	0.83 ab	0.71 bc	0.73 f	0.68 d
N_2Vm_0	0.75 a-c	0.78 ab	0.79 a-c	0.82 d-f	0.76 cd
N_2Vm_1	0.81 ab	0.81 ab	0.81 a-c	0.83 c-f	0.76 cd
N_2Vm_2	0.65 b-d	0.75 ab	0.80 a-c	0.83 c-f	0.77 cd
N_2Vm_3	0.57 d	0.79 ab	0.68 c	0.70 f	0.67 d
N_3Vm_0	0.67 b-d	0.79 ab	0.85 a-c	0.88 c-e	0.81 b-d
N_3Vm_1	0.78 ab	0.91 a	0.98 a	1.04 b	0.94 b
N_3Vm_2	0.73 a-c	0.89 ab	0.93 ab	0.95 b-d	0.89 bc
N_3Vm_3	0.69 b-d	0.86 ab	0.87 a-c	0.90 b-d	0.85 bc
$LSD_{(0.05)}$	0.16	0.24	0.23	0.14	0.15
CV (%)	13.73	17.09	15.78	9.51	10.96

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.2 Yield and yield components

4.2.1 Number of tubers $hill^{-1}$

4.2.1.1 Effect of nitrogen doses

Number of tubers $hill^{-1}$ significantly influenced by the nitrogen doses (Figure 13). Figure 13 exhibited that number of tubers $hill^{-1}$ increased with increasing nitrogen levels though N_0 to N_3. The maximum number of tubers $hill^{-1}$ (9.50) was recorded from the N_3 treatment which was statistically similar with N_1 and N_2 whereas, the minimum (6.58) was found from the N_0 treatment which was statistically similar with N_1 and N_2.

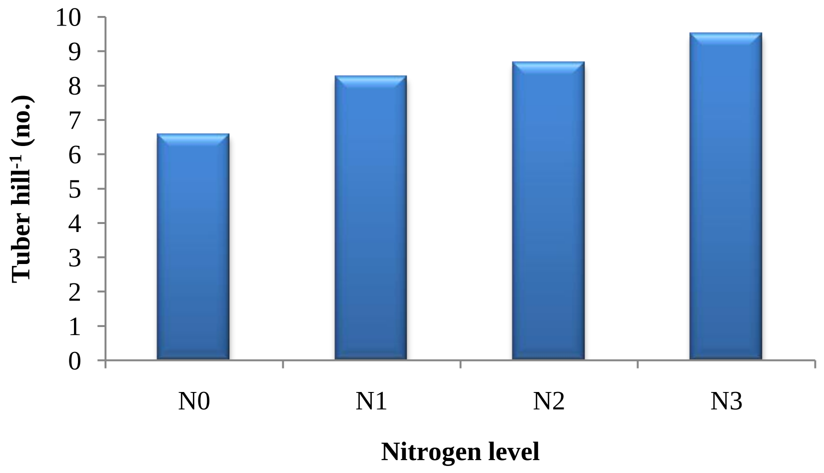

Figure 13. Effect of nitrogen doses on number of tubers hill^{-1} of BARI TPS-I (LSD $_{(0.05)}$ = 2.46)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.2.1.2 Effect of vermicompost levels

Number of tubers hill^{-1} had no significantly influenced by different vermicompost levels (Fig. 14). The maximum number of tubers hill^{-1} (9.0) was produced from the Vm_2 treatment whereas; the minimum (7.58) was counted from the Vm_1 treatment.

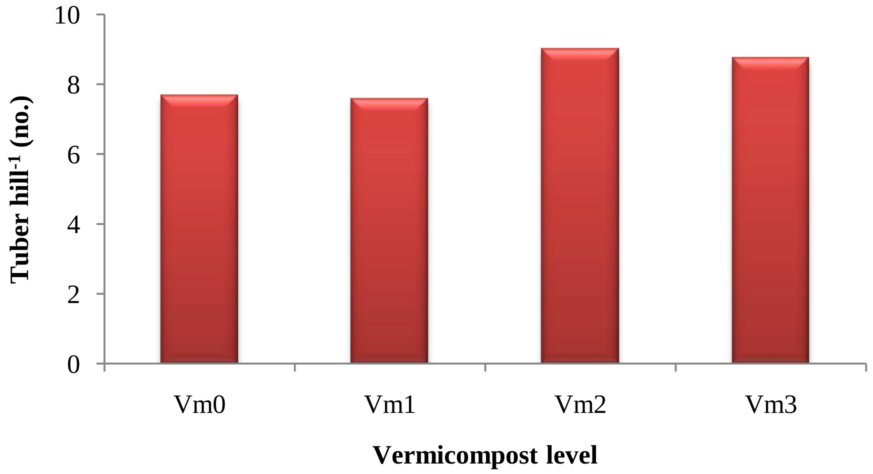

Figure 14. Effect of vermicompost levels on number of tubers hill^{-1} of BARI TPS-I

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.2.1.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels showed significant variation in respect of number of tubers hill^{-1} (Table 6). The maximum number of tubers hill^{-1} (11.02) was recorded from the combination of N_3Vm_2 which was statistically similar with N_0Vm_3, N_1Vm_0, N_1Vm_2, N_1Vm_3, N_2Vm_0, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0, N_3Vm_1 and N_3Vm_3 whereas, the minimum (5.67) was recorded from the combination of N_0Vm_0 which was statistically similar with N_0Vm_1, N_0Vm_2, N_0Vm_3, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_0, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0 and N_3Vm_1 treatment combination.

4.2.2 Number of tubers m^{-2}

4.2.2.1 Effect of nitrogen doses

Number of tubers m^{-2} significantly influenced by the nitrogen doses (Figure 15). Figure 15 exhibited that number of tubers m^{-2} increased with increasing nitrogen levels though N_0 to N_3. The maximum number of tubers m^{-2} (79.0) was recorded from the N_3 treatment which was statistically similar with N_1 and N_2 whereas, the minimum (56.92) was found from the N_0 treatment which was statistically similar with N_1 and N_2.

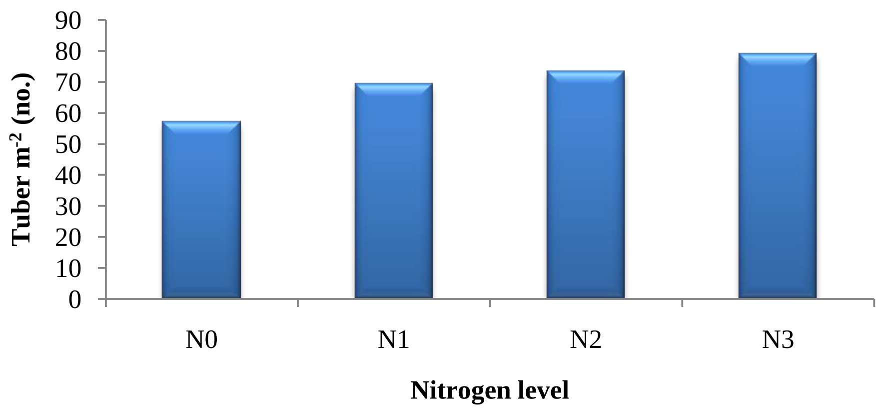

Figure 15. Effect of nitrogen doses on number of tubers m^{-2} of BARI TPS-I (LSD $_{(0.05)}$ = 20.23)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.2.2.2 Effect of vermicompost levels

Number of tubers m^{-2} had no significantly influenced by different vermicompost levels (Fig. 16). The maximum number of tubers m^{-2} (75.08) was produced from the Vm_2 treatment whereas; the minimum (64.33) was counted from the Vm_1 treatment.

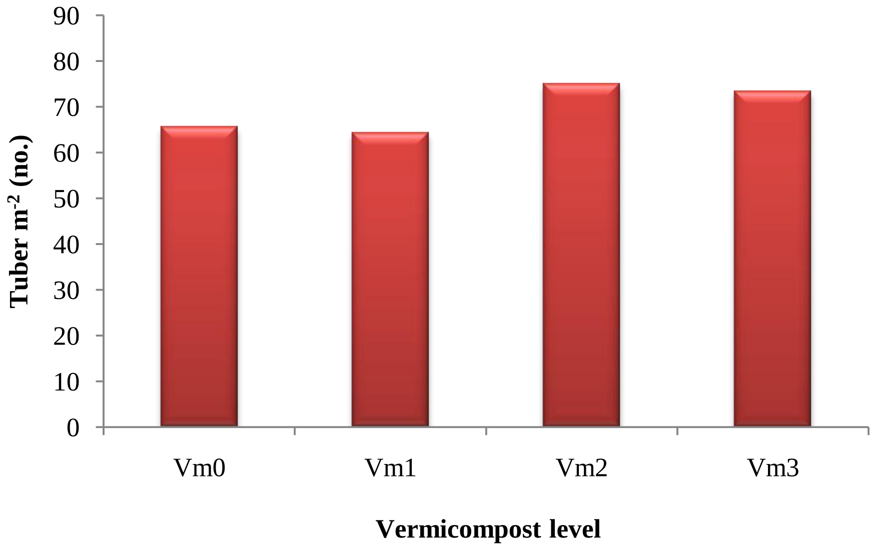

Figure 16. Effect of vermicompost levels on number of tubers m^{-2} of BARI TPS-I

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.2.2.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels showed significant variation in respect of number of tubers m^{-2} (Table 6). The maximum number of tubers m^{-2} (89.67) was recorded from the combination of N_3Vm_2 which was statistically similar with N_0Vm_1, N_0Vm_3, N_1Vm_0, N_1Vm_2, N_1Vm_3, N_2Vm_0, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0, N_3Vm_1 and N_3Vm_3 whereas, the minimum (49.33) was recorded from the combination of N_0Vm_0 which was statistically similar with N_0Vm_1, N_0Vm_2, N_0Vm_3, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_0, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0 and N_3Vm_1 treatment combination. The combined effects between different nitrogen rates and vermicompost application significantly improved number of tubers was observed by Yourtchi *et al.* (2013).

4.2.3 Weight of tuber m^{-2}

4.2.3.1 Effect of nitrogen doses

Weight of tuber m^{-2} significantly influenced by the nitrogen doses (Fig. 17). The maximum weight of tubers m^{-2} (2.67 kg) was recorded from the N_2 treatment whereas, the minimum (1.85 kg) was found from the N_0 treatment.

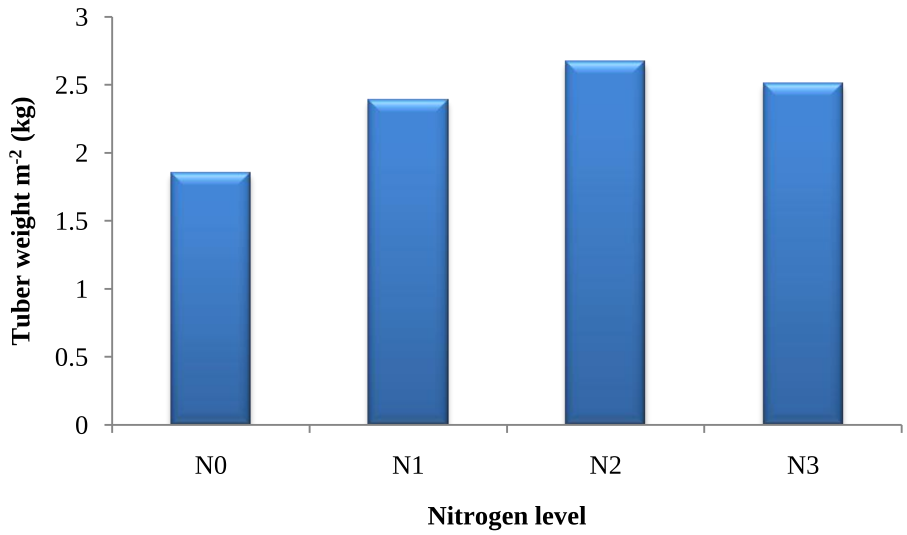

Figure 17. Effect of nitrogen doses on weight of tuber m^{-2} of BARI TPS-I (LSD $_{(0.05)}$ = 0.08)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.2.3.2 Effect of vermicompost levels

Weight of tuber m^{-2} had significantly influenced by different vermicompost levels (Fig. 18). The maximum weight of tubers m^{-2} (2.60 kg) was produced from the Vm_3 treatment which was statistically similar with Vm_2 (2.54 kg) treatment whereas; the minimum (1.98 kg) was counted from the Vm_0 treatment.

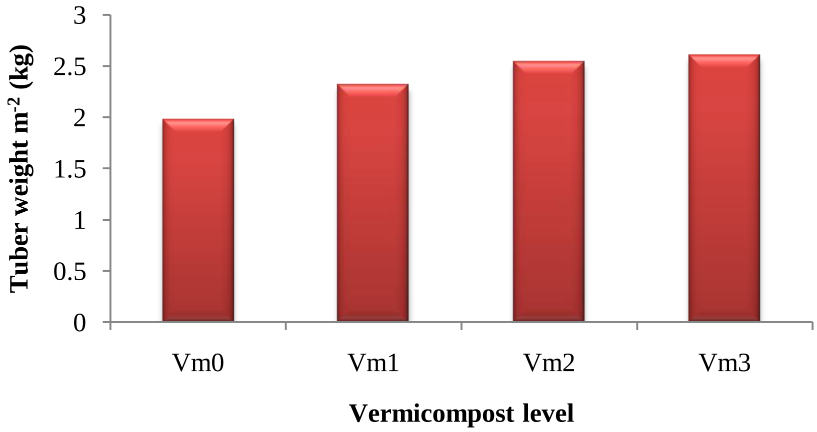

Figure 18. Effect of vermicompost levels on weight of tubers m^{-2} of BARI TPS-I (LSD $_{(0.05)}$ = 0.10)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.2.3.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels showed significant variation in respect of weight of tubers m^{-2} (Table 6). The maximum weight of tubers m^{-2} (2.91 kg) was recorded from the combination of N_3Vm_2 which was statistically similar with N_2Vm_2, N_2Vm_3, and N_3Vm_3 whereas, the minimum (1.37 kg) was recorded from the combination of N_0Vm_0. The combined effects between different nitrogen rates and vermicompost application significantly improved weight of tubers was observed by Yourtchi *et al.* (2013).

4.2.4 Average tuber weight (g)

4.2.4.1 Effect of nitrogen doses

The average tuber weight varied significantly due to different nitrogen doses (Fig. 19). The maximum average tuber weight (36.60 g) was recorded from the N_2 treatment which was statistically similar with N_1 (34.83 g) whereas, the minimum (31.56 g) was obtained from the N_3 treatment which was statistically similar with N_0 (32.24 g) treatment.

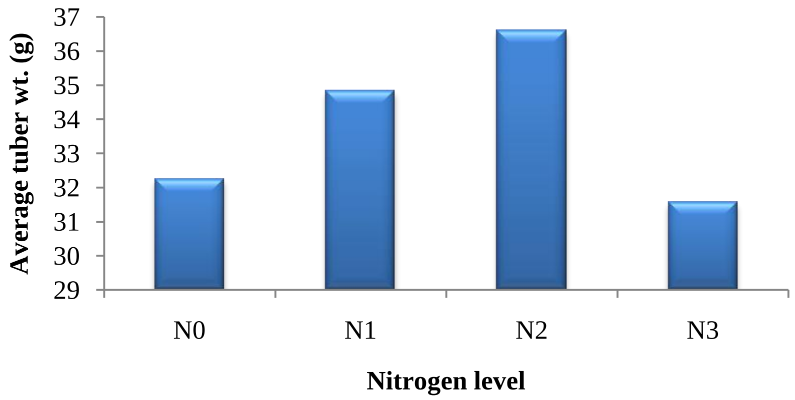

Figure 19. Effect of nitrogen doses on average tuber weight of BARI TPS-I (LSD $_{(0.05)}$ = 2.03)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.2.4.2 Effect of vermicompost levels

The average tuber weight significantly affected by the different vermicompost levels (Fig. 20). The highest average tuber weight (36.08 g) was recorded from the Vm_1 treatment and it was statistically similar (35.44 g) with treatment Vm_3 and the lowest (29.72 g) was recorded from the Vm_0 treatment.

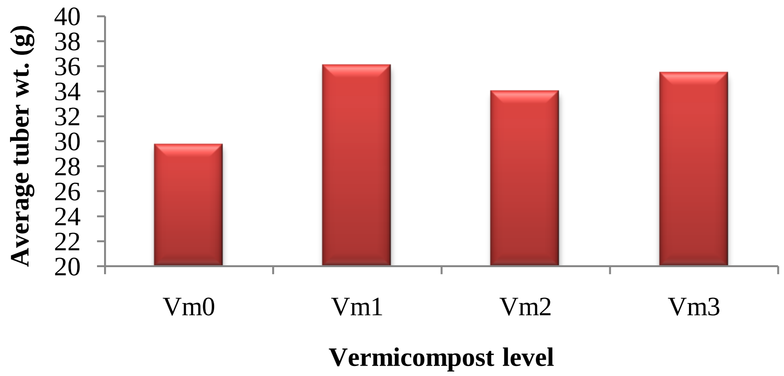

Figure 20. Effect of vermicompost levels on average tuber weight of BARI TPS-I (LSD $_{(0.05)}$ = 1.31)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.2.4.3 Combined effect of nitrogen doses and vermicompost levels

Combination of nitrogen doses and vermicompost levels had significant effect on average tuber weight (Table 6). The maximum average tuber weight (39.42

g) was recorded from the combination of N_1Vm_1 which was statistically similar with N_2Vm_1 and N_2Vm_3 whereas, the minimum (27.24 g) was recorded from the combination of N_0Vm_0 and it was statistically similar with N_3Vm_0 (27.58 g) treatment combinations.

4.2.5 Yield of tuber (t ha^{-1})

4.2.5.1 Effect of nitrogen doses

The tuber yield varied significantly due to different nitrogen doses (Figure 21). The maximum tuber yield (26.70 t ha^{-1}) was recorded from the N_2 treatment whereas; the minimum (18.53 t ha^{-1}) was obtained from the N_0 treatment. Nitrogen fertilization caused a significant increase in yield of potato tubers (Kolodziejczyk, 2014). The yield variation of different nitrogen treatment was significantly different from each other reported by Getie *et al.* (2015).

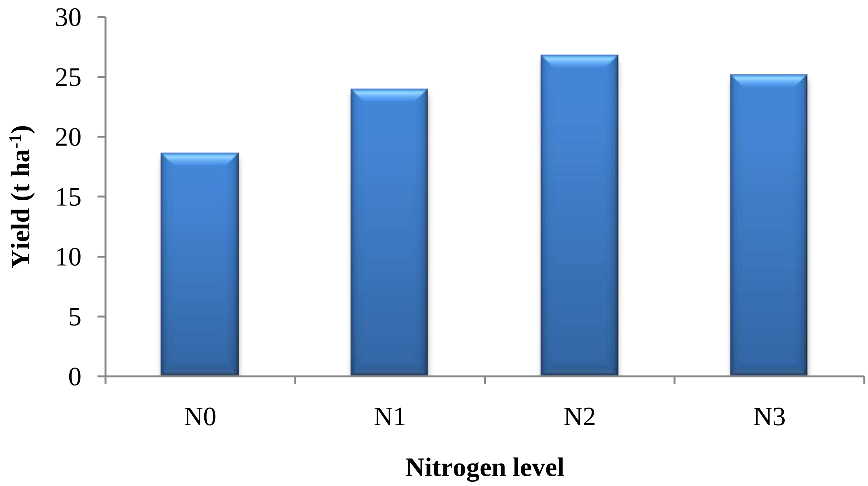

Figure 21. Effect of nitrogen doses on tuber yield of BARI TPS-I (LSD $_{(0.05)}$ = 0.77)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.2.5.2 Effect of vermicompost levels

The tuber yield varied significantly due to different vermicompost levels (Fig. 22). The maximum tuber yield (26.03 t ha^{-1}) was recorded from the Vm_3 treatment which was statistically similar with Vm_2 (25.40 t ha^{-1}) whereas, the minimum (19.75 t ha^{-1}) was obtained from the Vm_0 treatment. This variation might be due to change the yield contributing character under different vermicompost level. This result was in agreement with the findings reported by Alam *et al.* (2007); Shweta and Sharma (2011). They reported that the vermicompost levels had significant effect on tuber yield of potato.

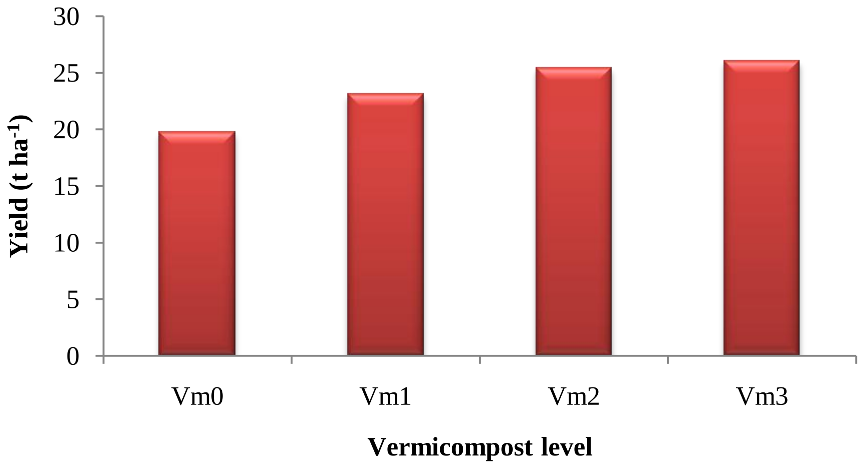

Figure 22. Effect of vermicompost levels on tuber yield of BARI TPS-I (LSD $_{(0.05)}$ = 1.02)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.2.5.3 Combined effect of nitrogen doses and vermicompost levels

Combination of nitrogen doses and vermicompost levels had significant effect on tuber yield (Table 6). The maximum tuber yield (29.13 t ha^{-1}) was recorded from the N_3Vm_2 treatment combination which was statistically similar with N_2Vm_3, N_2Vm_2 and N_3Vm_3 whereas, the minimum (13.72 t ha^{-1}) was obtained from the N_0Vm_0 treatment. The combined effects between different nitrogen rates and vermicompost application significantly improved tuber yield was observed by Yourtchi *et al.* (2013).

Table 6. Combined effect of nitrogen doses and vermicompost levels on number of tubers $hill^{-1}$, number of tubers m^{-2}, weight of tuber m^{-2}, average tuber weight and tuber yield of BARI TPS-I

Treatments	No. of tubers $hill^{-1}$	No. of tubers m^{-2}	Wt. of tuber m^{-2} (kg)	Average tuber Wt. (g)	Yield ($t\ ha^{-1}$)
N_0Vm_0	5.67 c	49.33 c	1.37 j	27.24 e	13.72 j
N_0Vm_1	7.00 bc	61.00 a-c	2.02 gh	33.07 cd	20.21 g-i
N_0Vm_2	6.33 bc	55.33 bc	1.96 hi	35.42 bc	19.63 hi
N_0Vm_3	7.33 a-c	62.00 a-c	2.06 gh	33.23 cd	20.63 f-h
N_1Vm_0	8.00 a-c	68.67 a-c	2.20 fg	32.03 d	22.04 fg
N_1Vm_1	6.67 bc	57.33 bc	2.26 ef	39.42 a	22.62 ef
N_1Vm_2	9.33 a-c	75.67 a-c	2.41 de	31.85 d	24.11 de
N_1Vm_3	9.00 a-c	75.00 a-c	2.70 bc	36.00 b	27.03 bc
N_2Vm_0	9.33 a-c	78.33 a-c	2.51 cd	32.04 d	25.12 cd
N_2Vm_1	7.33 a-c	63.00 a-c	2.47 d	39.21 a	24.71 d
N_2Vm_2	9.33 a-c	79.67 a-c	2.88 ab	36.15 b	28.81 ab
N_2Vm_3	8.67 a-c	72.33 a-c	2.82 ab	38.99 a	28.24 ab
N_3Vm_0	7.67 a-c	66.00 a-c	1.82 i	27.58 e	18.22 i
N_3Vm_1	9.33 a-c	76.00 a-c	2.48 d	32.63 d	24.81 d
N_3Vm_2	11.02 a	89.67 a	2.91 a	32.45 d	29.13 a
N_3Vm_3	10.01 ab	84.33 ab	2.83 ab	33.56 b-d	28.31 ab
LSD (0.05)	3.82	30.70	0.20	2.62	2.03
CV (%)	27.50	26.17	5.07	4.61	5.11

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.3 Quality characters

4.3.1 Grading of tuber (% by weight)

4.3.1.1 Effect of nitrogen doses

Different nitrogen doses had significant effect on grading of tuber (% by weight) at 28-45 mm grade but it was insignificant at <28 mm, 45-55 mm and >55 mm grades (Fig. 23). N_1 produced the highest percentage (7.97) of small tubers (<28 mm) whereas, the lowest (5.51 %) were produced by N_0. In case of 28-45 mm, treatment N_1 produced the highest tuber weight (60.16 %) which was statistically similar with N_0 (53.01 %) whereas, the lowest (50.50 %) was produced by N_2 treatment which was statistically similar with N_3 (50.96 %). In case of 45-55 mm, the highest grade of tuber weight (31.20 %) was produced by N_3 while the treatment N_1 produced the lowest (20.31 %). In case of large sized tubers (>55 mm), treatment N_2 produced the highest grade of tuber weight (16.33 %) and N_3 produced the lowest grade of tuber weight (11.49 %).

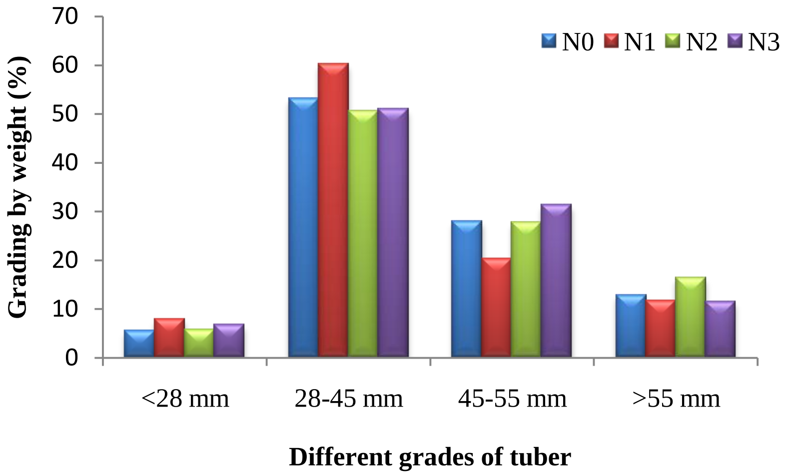

Figure 23. Effect of nitrogen doses on Grading of tuber (% by weight) of BARI TPS-I (LSD $_{(0.05)}$ = 8.87 at 28-45 mm grade)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.3.1.2 Effect of vermicompost levels

Grading of tuber (% by weight) had no significantly influenced by different vermicompost levels except large sized tubers (>55 mm grades) (Figure 24). In case of under sized tubers (<28 mm), the maximum grade of tuber weight (7.31 %) was found from the Vm_1 treatment whereas, the lowest (5.50 %) was produced by Vm_0 treatment. In case of 28-45 mm, the highest percentage of tuber weight (58.49) was produced by Vm_3 treatment whereas, the lowest (51.54 %) was produced by Vm_1 treatment. In case of (45-55 mm) grade, Vm_0 produced the maximum number of tuber (31.06 %) and the lowest (25.59 %) was produced by Vm_1 treatment. In case of large sized tubers (>55 mm), treatment Vm_1 produced the highest grade of tuber weight (16.56 %) which was statistically similar with Vm_0 and Vm_2 whereas, the lowest (8.52 %) was produced by Vm_3 treatment which was statistically similar with Vm_0 and Vm_2

treatment. This variation might be due to change in tuber size under different vermicompost level.

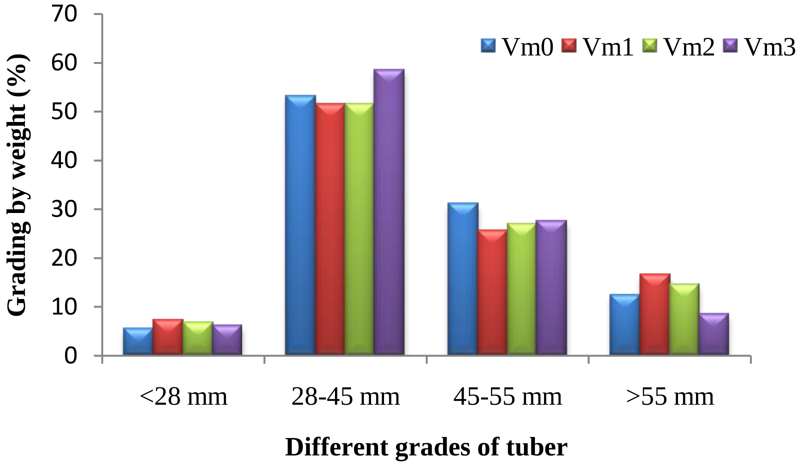

Figure 24. Effect of nitrogen doses on Grading of tuber (% by weight) of BARI TPS-I (LSD $_{(0.05)}$ = 7.47 at >55 mm grade)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.3.1.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels significantly influenced the grading of tuber (% by weight) (Table 7). In case of under sized tubers (<28 mm), the highest percentage of tuber weight (12.55) was produced by combinations of N_1Vm_1 which was statistically similar with N_1Vm_0, N_1Vm_2, N_3Vm_2 and N_1Vm_2 treatment combinations whereas, the lowest (4.40 %) from the combination of N_2Vm_0 treatment which was statistically similar with N_0Vm_0, N_0Vm_1, N_0Vm_2, N_0Vm_3, N_1Vm_0, N_1Vm_2, N_1Vm_3, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_0, N_3Vm_1, N_3Vm_3 and N_3Vm_2 treatment combinations. In case of 28-45 mm, the highest percentage of tuber weight (65.49) was produced by combinations of N_2Vm_3 which was statistically similar with N_0Vm_0, N_0Vm_1, N_0Vm_3, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_1, N_2Vm_2, N_3Vm_0, N_3Vm_1, N_3Vm_2 and N_3Vm_3 treatment combination while N_2Vm_0 showed the lowest percentage (38.11) of tuber weight which was statistically similar with N_0Vm_1, N_0Vm_2, N_0Vm_3, N_1Vm_1, N_2Vm_1, N_2Vm_2, N_3Vm_0, N_3Vm_1, N_3Vm_2 and N_3Vm_3 treatment combination. In case of 45-55 mm, the highest (41.85 %) of tuber weight was produced by combinations of N_2Vm_0 which was statistically similar with N_0Vm_1, N_0Vm_2, N_3Vm_0, N_3Vm_1, N_3Vm_2 and N_3Vm_3 while the combinations of N_2Vm_1 showed the lowest percentage of tuber weight (16.89 %) which was statistically similar with N_0Vm_0, N_0Vm_1, N_0Vm_3, N_1Vm_0, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_2, N_2Vm_3, N_3Vm_0 and N_3Vm_2 treatment combination. In case of large sized tubers (>55 mm), the highest percentage of tuber weight (28.94) was found from the combinations of N_2Vm_1 which was statistically similar with N_0Vm_2, N_0Vm_3, N_1Vm_1, N_2Vm_0, N_2Vm_2 and N_3Vm_0 whereas, the lowest (4.03 %) was found from the combinations of N_2Vm_3 which was statistically similar with all other treatment except N_2Vm_1 treatment combination.

Table 7. Combined effect of nitrogen and vermicompost on grading of tuber (% by weight) of BARI TPS-I at different days after planting

Treatments	**Grading of tuber (% by weight)**			
	<28 mm	**28-45 mm**	**45-55 mm**	**>55 mm**
N_0Vm_0	4.87 b	64.68 a	21.87 bc	8.92 b
N_0Vm_1	5.22 b	52.68 a-c	32.74 a-c	9.36 b
N_0Vm_2	6.56 b	41.43 bc	35.03 ab	17.25 ab
N_0Vm_3	5.38 b	53.26 a-c	25.76 bc	15.65 ab
N_1Vm_0	7.06 ab	60.66 ab	22.54 bc	10.07 b
N_1Vm_1	12.55 a	44.98 a-c	26.02 bc	16.46 ab
N_1Vm_2	7.48 ab	62.54 a	17.48 c	12.51 b
N_1Vm_3	4.80 b	62.60 a	26.20 bc	7.48 b
N_2Vm_0	4.40 b	38.11 c	41.85 a	15.40 ab
N_2Vm_1	6.41 b	48.30 a-c	16.89 c	28.94 a
N_2Vm_2	5.67 b	51.11 a-c	26.26 bc	16.96 ab
N_2Vm_3	6.33 b	65.49 a	24.82 bc	4.03 b
N_3Vm_0	5.69 b	49.76 a-c	28.99 a-c	15.56 ab
N_3Vm_1	5.05 b	50.20 a-c	33.28 ab	11.47 b
N_3Vm_2	7.60 ab	51.27 a-c	29.14 a-c	12.00 b
N_3Vm_3	8.30 ab	52.60 a-c	33.37 ab	6.937 b
LSD $_{(0.05)}$	5.55	21.01	14.15	14.95
CV (%)	50.95	23.23	29.68	67.91

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.3.2 Specific gravity

4.3.2.1 Effect of nitrogen doses

In present study nitrogen doses had insignificant effect on specific gravity (Fig. 25). Numerically the highest specific gravity (1.05) was obtained from the N_1 and N_2 whereas, the lowest (1.03) specific gravity was found from the N_3 treatment.

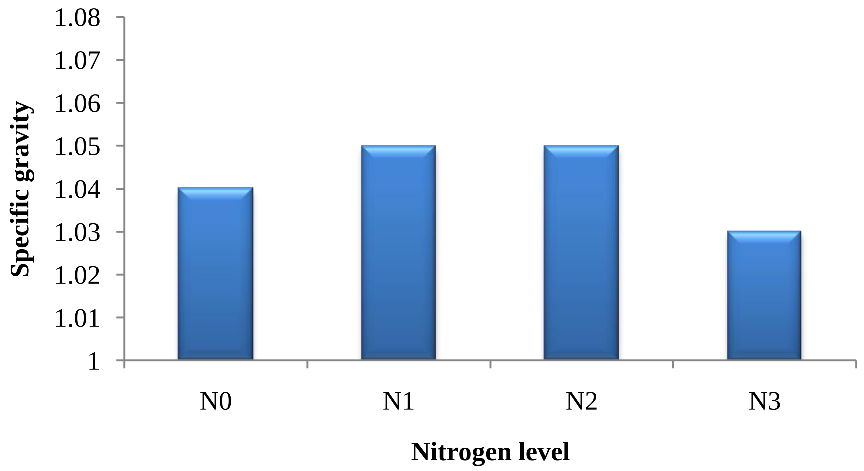

Figure 25. Effect of nitrogen on specific gravity of BARI TPS-I

Note: N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.3.2.2 Effect of vermicompost levels

Different vermicompost levels showed insignificant effect on the specific gravity (Fig. 26). Figure 30 exhibited that specific gravity increased with increasing vermicompost levels. Highest specific gravity (1.05) was found from the Vm_2 and Vm_3 treatments while the lowest (1.03) was obtained from the Vm_1 treatment.

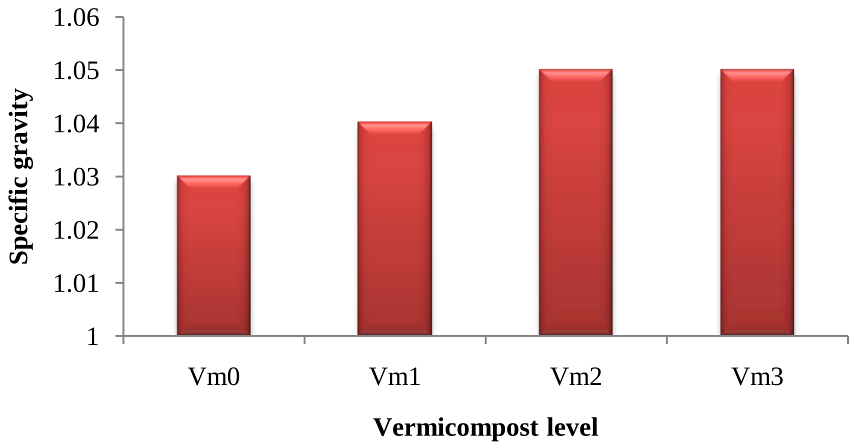

Figure 26. Effect of vermicompost on specific gravity of BARI TPS-I

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.3.2.3 Combined effect of nitrogen and vermicompost

Specific gravity had no significant effect on combination of different nitrogen doses and vermicompost levels (Table 8). N_1Vm_2 and N_2Vm_2 treatment combinations showed the maximum specific gravity (1.06) while the minimum (1.02) was recorded from the combination of N_3Vm_0.

4.3.3 Tuber dry matter content (%)

4.3.3.1 Effect of nitrogen

Tuber dry matter content showed significant variations among the different nitrogen doses (Fig. 27). The maximum dry matter content of tuber (19.38 %) was recorded from the treatment N_1 which was statistically similar with N_2 and N_3. The minimum tuber dry matter content (17.13 %) was recorded from N_0. Osaki *et al.* (1992) reported that dry matter content of tuber was increased significantly with the application of nitrogen. The result of the present investigation was similar with the studies conducted by Anand and Krishnappa (1989).

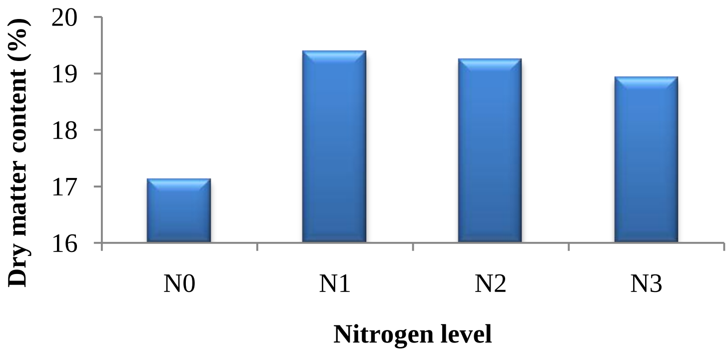

Figure 27. Effect of nitrogen doses on tuber dry matter content of BARI TPS-I (LSD $_{(0.05)}$ = 0.49)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.3.3.2 Effect of vermicompost levels

Dry matter content of tuber varied significantly with different vermicompost levels (Fig. 28). The maximum dry matter content (19.55 %) was obtained from the Vm_2 treatment which was statistically similar with Vm_1 and Vm_3 while, the minimum (16.41 %) was found from the Vm_0 treatment. This result was in agreement with the findings reported by Singh and Chauhan (2014); Shweta and Sharma (2011).They reported that the vermicompost levels had significant effect on dry matter content of potato tuber.

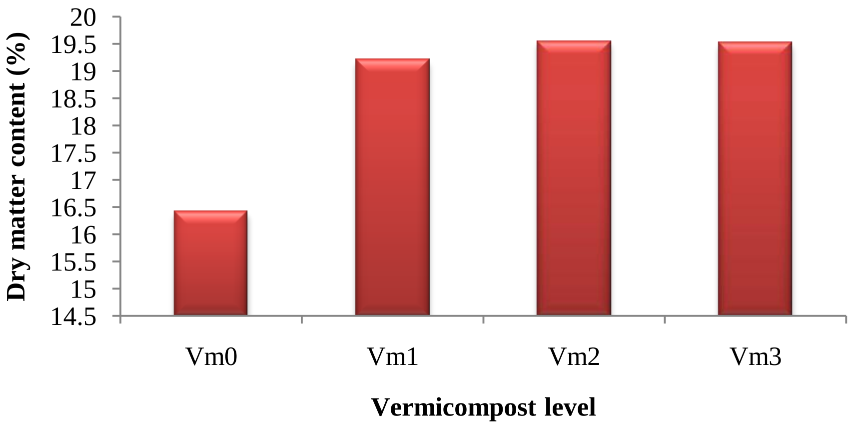

Figure 28. Effect of vermicompost on tuber dry matter content of BARI TPS-I (LSD $_{(0.05)}$ = 0.65)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.3.3.3 Combined effect of nitrogen doses and vermicompost levels

Combined effect of nitrogen doses and vermicompost levels significantly influenced the tuber dry matter content (Table 8). The maximum tuber dry matter content (20.50 %) was obtained from the combination of N_1 with Vm_2 which was statistically similar with N_1Vm_1, N_1Vm_3, N_2Vm_1, N_2Vm_2, N_2Vm_3, N_3Vm_1, N_3Vm_2 and N_3Vm_3 treatment combination whereas, the minimum (15.90 %) was obtained from the combination of N_3Vm_0 which was statistically similar with N_0Vm_0, N_0Vm_1, N_1Vm_0 and N_2Vm_0 treatment combination. The combined effects between different nitrogen rates and vermicompost application significantly improved tuber dry matter content was observed by Yourtchi *et al.* (2013).

4.3.4 Total soluble solids (^{o}Brix)

4.3.4.1 Effect of nitrogen doses

Nitrogen doses differed significantly between themselves regarding TSS (Fig. 29). The maximum TSS (6.77) was recorded from the N_2 treatment which was statistically similar (6.70) with N_1 treatment whereas; the minimum (6.02) was obtained from the N_0 which was statistically similar (6.18) with N_3 treatment. Study referred that the N_2 treatment expressed best result in terms of TSS.

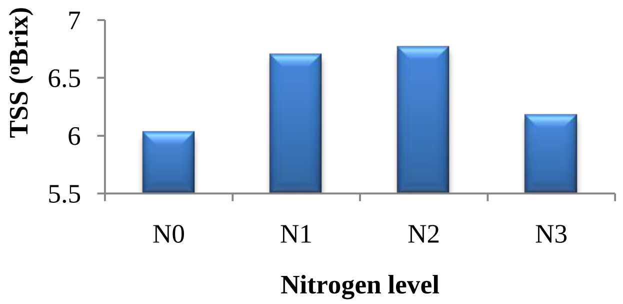

Figure 29. Effect of nitrogen doses on TSS of BARI TPS-I (LSD $_{(0.05)}$ = 0.16)

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1} and N_3- 200 kg N ha^{-1}

4.3.4.2 Effect of vermicompost levels

Different vermicompost levels had significant effect on TSS of potato tuber (Fig. 30). The maximum TSS (6.80) was found from the Vm_3 treatment which was statistically similar with Vm_1 and Vm_2 treatment whereas; the minimum (5.69) was found from the Vm_0 treatment.

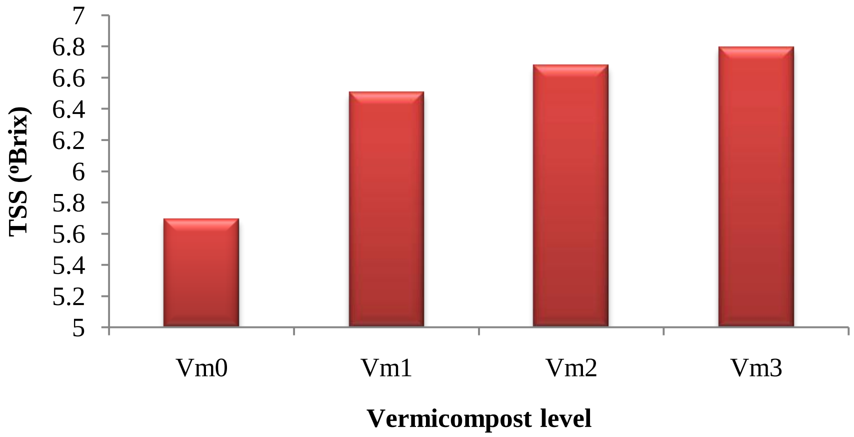

Figure 30. Effect of vermicompost levels on TSS of BARI TPS-I (LSD $_{(0.05)}$ = 0.37)

Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

4.3.4.3 Combined effect of nitrogen doses and vermicompost levels

It was found that TSS was affected significantly due to the combination of nitrogen doses and vermicompost levels (Table 8). The highest TSS(^{0}Brix) 7.16 was recorded from the combination of N_2 and Vm_1 which was statistically similar 6.56, 6.75, 7.00, 6.88, 7.06, 7.14, 6.92 and 6.45, respectively with the combination of N_0Vm_2, N_0Vm_3, N_1Vm_1, N_1Vm_2, N_1Vm_3, N_2Vm_2, N_2Vm_3 and N_3Vm_3 whereas, the minimum 5.16 was found from the combination of N_0Vm_0 which was statistically similar 5.62, 5.86 and 5.85, respectively with N_0Vm_1, N_1Vm_0 and N_2Vm_0 treatment combination.

Table 8. Combined effect of nitrogen doses and vermicompost levels on specific gravity, dry matter content and TSS of BARI TPS-I

Treatments	Specific gravity	Dry matter content (%)	TSS (^{o}Brix)
N_0Vm_0	1.03	16.13 c	5.16 f
N_0Vm_1	1.04	16.90 bc	5.62 ef
N_0Vm_2	1.05	17.60 b	6.56 a-d
N_0Vm_3	1.05	17.90 b	6.75 a-c
N_1Vm_0	1.05	16.70 bc	5.86 d-f
N_1Vm_1	1.05	20.10 a	7.00 a
N_1Vm_2	1.06	20.50 a	6.88 ab
N_1Vm_3	1.05	20.20 a	7.06 a
N_2Vm_0	1.05	16.90 bc	5.85 d-f
N_2Vm_1	1.05	20.00 a	7.16 a
N_2Vm_2	1.06	20.20 a	7.14 a
N_2Vm_3	1.05	19.90 a	6.92 ab
N_3Vm_0	1.02	15.90 c	5.90 de
N_3Vm_1	1.04	19.80 a	6.23 b-e
N_3Vm_2	1.04	19.90 a	6.12 c-e
N_3Vm_3	1.05	20.10 a	6.45 a-d
LSD $_{(0.05)}$	ns	1.29	0.73
CV (%)	2.70	4.10	6.77

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by LSD at 0.05 level of probability.

ns = non significant

N_0- 0 kg N ha^{-1}, N_1- 100 kg N ha^{-1}, N_2- 150 kg N ha^{-1}, N_3- 200 kg N ha^{-1}, Vm_0 – 0 t ha^{-1}, Vm_1 – 5 t ha^{-1}, Vm_2 – 10 t ha^{-1} and Vm_3 – 15 t ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was done at the research field, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2013 to February, 2014 to find out the growth, yield and quality of BARI TPS-I as influenced by nitrogen and vermicompost. The experiment was laid out in a split plot design with three replications. The experiment comprised with two factors viz. (i) nitrogen dose and (ii) vermicompost level. Four N doses (N_0= 0 kg N ha^{-1}, N_1= 100 kg N ha^{-1}, N_2= 150 kg N ha^{-1}, N_3= 200 kg N ha^{-1}) and four vermicompost level (Vm_0= 0 t ha^{-1}, Vm_1= 5 t ha^{-1}, Vm_2= 10 t ha^{-1}, Vm_3= 15 t ha^{-1}). Nitrogen dose was placed along the main plot and vermicompost level was placed along the sub plot. The size of the individual plot was 2.5 m x 2.0 m and total numbers of plots were 48.

The data on crop growth parameters like days to emergence, plant height, leaves $plant^{-1}$, SPAD value of leaves and stem diameter were recorded at different growth stages. Yield and other crop characters like number of tubers $hill^{-1}$, number of tubers m^{-2}, weight of tuber m^{-2}, average weight of tuber and yield of tuber were recorded after harvest. Quality parameter like grading of tubers (% by weight), tuber dry matter content, specific gravity and total soluble solids (TSS) tuber were recorded after harvest. Data were analyzed using MSTAT-C package. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

Results showed that different nitrogen doses had no significant effect on days to first emergence but significant effect on day to final emergence. In days to first emergence N_3 treatment need minimum days to emergence and N_1 treatment needs maximum day to emergence. On the other hand treatment N_1 need minimum days and N_3 treatment need maximum days for final emergence. In vermicompost levels was no significant effect on days to first emergence and days to final emergence. In days to first emergence vermicompost 10 t ha^{-1}

required minimum days and 5 t ha^{-1} need maximum days. In combination of nitrogen doses and vermicompost levels, N_1Vm_2 generated the minimum days whereas N_3Vm_2 required maximum days in both days to first emergence and days to final emergence.

The plant height of BARI TPS-I was significantly influenced by different nitrogen doses and vermicompost levels at 75 DAP and at harvest but it was insignificant at 30, 45 and 60 DAP. Significant combined effect of nitrogen doses and vermicompost levels on plant height was observed at 60, 75 DAP and at harvest but it was insignificant at 30 and 45 DAP. At 60, 75 and at harvest, the highest plant height (75.44, 81.09 and 79.39 cm, respectively) was observed from the N_2Vm_1 treatment whereas, the smallest plant (43.57, 48.84 and 45.58 cm, respectively) was obtained from N_0Vm_1 treatment combination.

Number of leaves $plant^{-1}$ increased with advancing growing period up to 75 DAP and thereafter decreased due to senescence of leaves. Different nitrogen doses and vermicompost levels exhibited significant variation in respect of number of leaves $plant^{-1}$ at 75 DAP and at harvest but it was insignificant at 30, 45 and 60 DAP. At 60, 75 DAP and at harvest, the maximum leaves number (181.87, 186.55 and 175.28, respectively) was obtained from the N_3 with Vm_1 combination treatment and the minimum number of leaves $plant^{-1}$ (88.33, 93.03 and 90.01, respectively) was recorded from the combination of N_1 with Vm_2.

In terms of SPAD value combined effect of different nitrogen doses and vermicompost levels also exposed significant variation at all growing stage. At 70 DAP, the maximum SPAD value (56.08) was recorded from N_2Vm_2 treatment combination and the minimum (41.17) was recorded from the N_0Vm_1 treatment combination.

Among the different nitrogen doses, the maximum number of tubers $hill^{-1}$ (9.50) was recorded from the N_3 treatment which was statistically similar with N_1 and N_2 whereas, the minimum (6.58) was found from the N_0 treatment which was statistically similar with N_1 and N_2. In case of vermicompost levels, the maximum number of tubers hill^{-1} (9.0) was produced from the Vm_2 treatment whereas; the minimum (7.58) was counted from the Vm_1 treatment. In combination of nitrogen doses and vermicompost levels, the maximum number of tubers hill^{-1} (11.02) was recorded from the combination of N_3Vm_2 whereas, the minimum (5.67) was recorded from the combination of N_0Vm_0.

Considering the nitrogen doses, the maximum average tuber weight (36.60 g) was recorded from the N_2 treatment which was statistically similar with N_1 (34.83 g) and the minimum (31.56 g) was obtained from the N_3 treatment. Whereas observing the vermicompost levels, the highest average tuber weight (36.08 g) was recorded from the Vm_1 treatment and it was statistically similar (35.44 g) with treatment Vm_3 and the lowest (29.72 g) was recorded from the Vm_0 treatment. In combination of nitrogen doses and vermicompost levels, the maximum average tuber weight (39.42 g) was recorded from the combination of N_1Vm_1 which was statistically similar with N_2Vm_1 and N_2Vm_3 whereas, the minimum (27.24 g) was recorded from the combination of N_0Vm_0.

Among the different nitrogen doses, the maximum tuber yield (26.70 t ha^{-1}) was recorded from the N_2 treatment and the minimum (18.53 t ha^{-1}) was obtained from the N_0 treatment. Whereas observing the vermicompost levels, the maximum tuber yield (26.03 t ha^{-1}) was recorded from the Vm_3 treatment which was statistically similar with Vm_2 (25.40 t ha^{-1}) whereas, the minimum (19.75 t ha^{-1}) was obtained from the Vm_0 treatment. In combination of nitrogen doses and vermicompost levels, the maximum tuber yield (29.13 t ha^{-1}) was recorded from the N_3Vm_2 treatment combination which was statistically similar with N_2Vm_3, N_2Vm_2 and N_3Vm_3 whereas, the minimum (13.72 t ha^{-1}) was obtained from the N_0Vm_0 treatment.

In present study nitrogen doses had insignificant effect on specific gravity. Numerically the highest specific gravity (1.05) was obtained from the N_1 and N_2 whereas, the lowest (1.03) specific gravity was found from the N_3 treatment. In case of vermicompost levels, highest specific gravity (1.05) was found from the Vm_2 and Vm_3 treatments while the lowest (1.03) was obtained from the Vm_1 treatment. In combination of nitrogen doses and vermicompost levels, N_1Vm_2 and N_2Vm_2 treatment combinations showed the maximum specific gravity (1.06) while the minimum (1.02) was recorded from the combination of N_3Vm_0.

Among the N doses, the maximum dry matter content of tuber (19.38 %) was recorded from the treatment N_1 which was statistically similar with N_2 and N_3. The minimum tuber dry matter content (17.13 %) was recorded from N_0. Whereas observing vermicompost level had significance effect on the dry matter content of tuber. The maximum dry matter content (19.55 %) was obtained from the Vm_2 treatment which was statistically similar with Vm_1 and Vm_3 while, the minimum (16.41 %) was found from the Vm_0 treatment. In combination of nitrogen doses and vermicompost levels, the maximum tuber dry matter content (20.50 %) was obtained from the combination of N_1 with Vm_2 whereas, the minimum (15.90 %) was obtained from the combination of N_3Vm_0.

Considering the nitrogen doses, N_2 treatment expressed best result in terms of TSS. Whereas observing the vermicompost levels the maximum (6.80^0) total soluble solid (TSS) of tuber was recorded from Vm_3 treatment which was statistically similar with Vm_1 and Vm_2 treatment whereas; the minimum (5.69^0) was found from the Vm_0 treatment. In combination, the highest TSS (7.16^0) was recorded from the combination of N_2 and Vm_1 whereas, the minimum (5.16^0) was found from the combination of N_0Vm_0.

Considering the results of the present experiment, it may conclude that different nitrogen doses and vermicompost levels had potential effect on tuber yield and yield attributes characters and finally on specific gravity, dry matter content and TSS. The findings revealed that though treatment N_3 (200 kg N ha^{-1}) with Vm_2 (vermicompost 10 t ha^{-1}) performed the best results in terms of growth, most of the yield and quality parameters. However, to reach a specific conclusion and recommendation the same experiment need to be repeated and more research work should be done over different Agro-ecological zones with other quality parameters.

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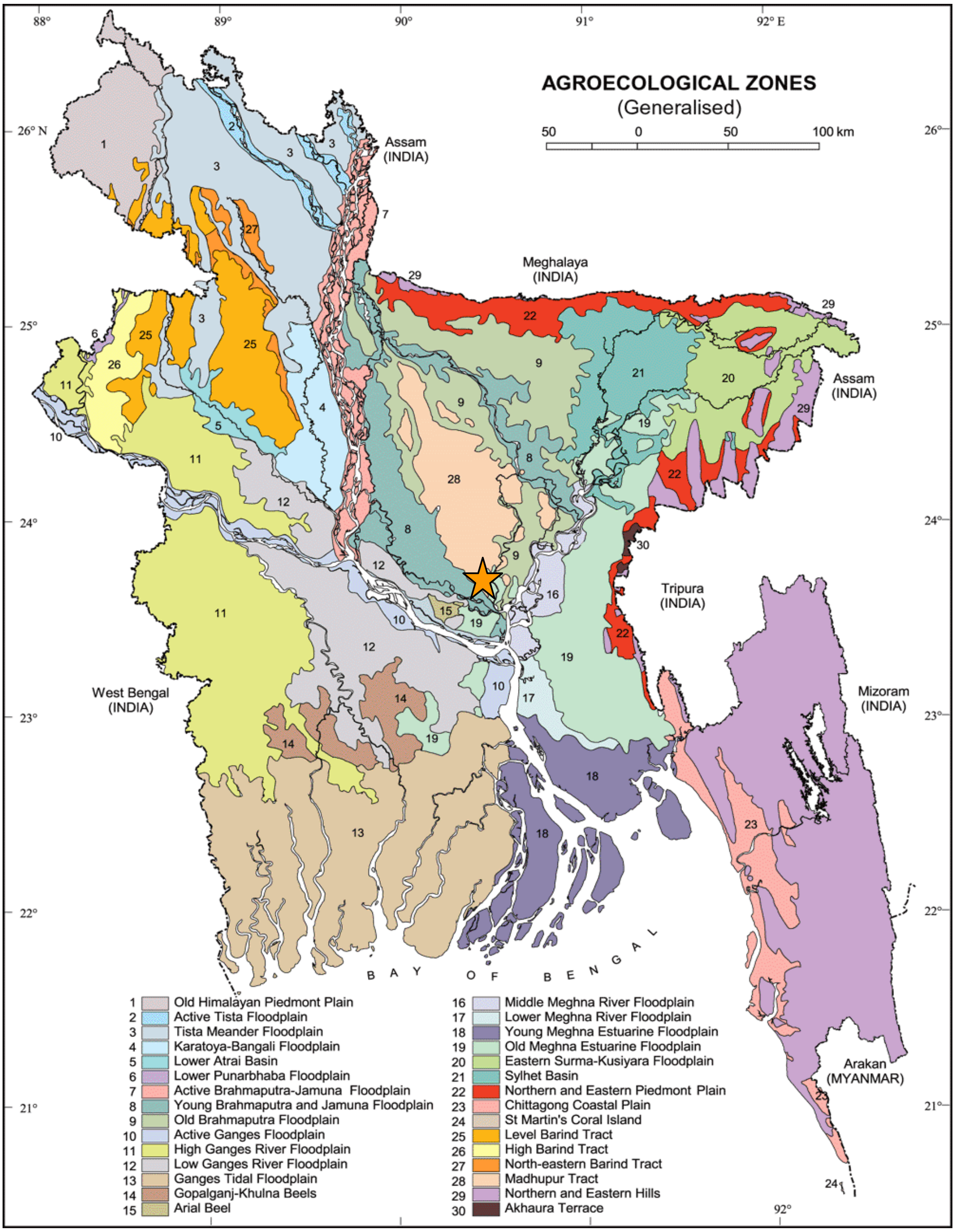
APPENDICES

Appendix I. Map showing the experimental sites under study



☆ **The experimental site under study**

Appendix II. Monthly average of air temperature, relative humidity and total rainfall of the experimental site during the period from November, 2013 to February, 2014

Months	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November	28.73	19.14	68.21	68
December	23.93	14.54	78.58	5
January	24.55	12.09	65.39	14
February	27.86	16.5	47.16	34

Source: Weather station, Sher-e-Bangla Agricultural University, Dhaka-1207

Appendix IIIa. Physical properties of the soil

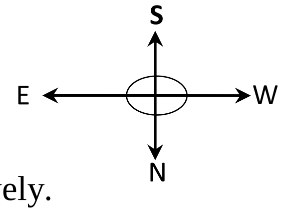
Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Appendix IIIb. Chemical properties of the soil

Soil characters	Value	
	Before sowing	After harvest
Organic matter (%)	0.86	1.19
Total nitrogen (%)	0.05	0.06
Phosphorus	6.49 µg g^{-1} soil	5.26 µg g^{-1} soil
Sulphur	27.62 µg g^{-1} soil	10.06 µg g^{-1} soil
Calcium	10.06meq $100g^{-1}$ soil	14.08meq $100g^{-1}$ soil
Potassium	0.18meq $100g^{-1}$ soil	0.21meq $100g^{-1}$ soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix IV. Layout for experimental field



Total number of unit plots: 16 × 3 = 48
Unit plot size: 2.5 m×2.0 m = 5.0 m^2
The blocks and unit plots were separated by 1 m and 0.5 m, respectively.

Replication 1	N_0Vm_1	N_0Vm_0	N_0Vm_2	N_0Vm_3
	N_3Vm_0	N_3Vm_1	N_3Vm_2	N_3Vm_3
	N_1Vm_0	N_1Vm_1	N_1Vm_2	N_1Vm_3
	N_2Vm_3	N_2Vm_2	N_2Vm_1	N_2Vm_0
Replication 2	N_0Vm_0	N_0Vm_3	N_0Vm_2	N_0Vm_1
	N_2Vm_2	N_2Vm_0	N_2Vm_3	N_2Vm_1
	N_1Vm_3	N_1Vm_2	N_1Vm_1	N_2Vm_0
	N_3Vm_1	N_3Vm_0	N_3Vm_2	N_3Vm_3
Replication 3	N_1Vm_2	N_1Vm_3	N_1Vm_0	N_1Vm_1
	N_2Vm_0	N_2Vm_1	N_2Vm_2	N_2Vm_3
	N_0Vm_1	N_0Vm_0	N_0Vm_3	N_0Vm_2
	N_3Vm_3	N_3Vm_2	N_3Vm_0	N_3Vm_1

Appendix V. Mean square values for plant emergence of BARI TPS-I

Source of variation	df	Mean square value	
		Plant emergence	
		Day to first emergence	Day to final emergence
Replication	2	0.29	1.02
Nitrogen dose (A)	3	0.55 NS	3.48*
Error	6	1.25	1.12
Vermicompost level (B)	3	0.73 NS	7.51 NS
Nitrogen dose (A) X Vermicompost level (B)	9	3.76 NS	11.41 NS
Error	24	9.23	10.74

*Significant at 5% level of significance

NS Non significant

Appendix VI. Mean square values for plant height (cm) of BARI TPS-I at different DAP

Sources of variation	df	Mean square value				
		Plant height (cm)				
		30 DAP	45 DAP	60 DAP	75 DAP	At harvest
Replication	2	57.17	268.59	1246.69	3.35	2.31
Nitrogen dose (A)	3	12.57 NS	98.86 NS	562.79 NS	543.65*	557.99*
Error	6	30.47	150.60	294.58	2.59	13.15
Vermicompost level (B)	3	7.42 NS	29.12 NS	84.57 NS	92.21*	108.26*
Nitrogen dose (A) X Vermicompost level (B)	9	10.82 NS	134.13 NS	94.72*	104.84*	108.44*
Error	24	20.47	117.12	283.55	16.79	14.90

*Significant at 5% level of significance

NS Non significant

Appendix VII. Mean square values for leaves plant^{-1} (no.) of BARI TPS-I at different DAP

Sources of variation	df	Mean square value				
		Number of leaves plant^{-1} at				
		30 DAP	45 DAP	60 DAP	75 DAP	At harvest
Replication	2	12.89	5012.31	12489.08	2.98	0.69
Nitrogen dose (A)	3	68.94 ^{NS}	1194.24 ^{NS}	3941.94 ^{NS}	4100.35*	3984.07*
Error	6	98.76	3049.79	3842.69	3.578	25.77
Vermicompost level (B)	3	40.72 ^{NS}	756.13 ^{NS}	959.50 ^{NS}	945.81*	753.50*
Nitrogen dose (A) X Vermicompost level (B)	9	13.56 ^{NS}	680.73*	1017.33*	975.27*	781.98*
Error	24	70.93	1150.06	1588.13	26.53	18.62

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Mean square values for stem diameter (cm) BARI TPS-I at different DAP

Source of variation	df	Mean square value				
		Stem diameter (cm) at				
		30 DAP	45 DAP	60 DAP	75 DAP	At harvest
Replication	2	0.012	0.006	0.017	0.002	0.004
Nitrogen dose (A)	3	0.011 ^{NS}	0.037 ^{NS}	0.083 ^{NS}	0.128*	0.077*
Error	6	0.009	0.051	0.038	0.001	0.002
Vermicompost level (B)	3	0.005 ^{NS}	0.003 ^{NS}	0.007 ^{NS}	0.002 ^{NS}	0.004 ^{NS}
Nitrogen dose (A) X Vermicompost level (B)	9	0.023*	0.010*	0.017*	0.041*	0.029*
Error	24	0.009	0.020	0.018	0.007	0.008

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Mean square values for SPAD value of BARI TPS-I at different DAP

Sources of variation	df	Mean square value		
		SPAD value		
		30 DAP	50 DAP	70 DAP
Replication	2	2.01	28.69	30.63
Nitrogen dose (A)	3	11.11 ^{NS}	66.56*	94.79*
Error	6	11.22	8.45	6.61
Vermicompost level (B)	3	11.49*	21.77 ^{NS}	55.91*
Nitrogen dose (A) X Vermicompost level (B)	9	13.45*	11.06*	19.22*
Error	24	6.08	12.94	23.24

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Mean square values for number of tubers hill^{-1}, number of tubers m^{-2}, weight of tuber m^{-2} (kg), average tuber weight (g) and yield (t ha^{-1}) of BARI TPS-I

Sources of variation	df	Mean square value				
		Number of tubers hill^{-1}	Number of tubers m^{-2}	Weight of tuber m^{-2} (kg)	Average tuber weight (g)	Yield (t ha^{-1})
Replication	2	18.75	1289.15	0.04	24.99	3.73
Nitrogen dose (A)	3	18.06*	1053.41*	1.51*	65.37*	150.89*
Error	6	6.06	410.20	0.01	4.14	0.59
Vermicompost level (B)	3	6.39 ^{NS}	354.02 ^{NS}	0.97*	98.29*	96.84*
Nitrogen dose (A) X Vermicompost level (B)	9	2.70*	152.73*	0.12*	10.99*	12.27*
Error	24	5.15	331.79	0.01	2.43	1.45

*Significant at 5% level of significance

^{NS} Non significant

Appendix XI. Mean square values for grading of tuber (% by weight) of BARI TPS-I

Sources of variation	df	Mean square value			
		Grading of tuber (% by weight)			
		<28 mm	28-45 mm	45-55 mm	>55 mm
Replication	2	4.10	216.89	60.05	64.95
Nitrogen dose (A)	3	15.23 NS	241.64*	84.35 NS	61.15 NS
Error	6	7.14	78.76	44.93	57.18
Vermicompost level (B)	3	7.34 NS	129.85 NS	41.91 NS	143.06*
Nitrogen dose (A) X Vermicompost level (B)	9	12.03*	197.77*	123.80*	101.57*
Error	24	10.83	155.46	70.49	78.68

*Significant at 5% level of significance

NS Non significant

Appendix XII. Mean square values for specific gravity, dry matter content (%) and TSS (^{o}Brix) content of potato tuber

Sources of variation	df	Mean square value		
		Specific gravity	Dry matter content (%)	TSS (^{o}Brix)
Replication	2	0.001	1.078	0.055
Nitrogen dose (A)	3	0.001 NS	13.039*	1.665*
Error	6	0.001	0.236	0.026
Vermicompost level (B)	3	0.001 NS	27.606*	2.967*
Nitrogen dose (A) X Vermicompost level (B)	9	0.001 NS	1.180*	0.343*
Error	24	0.001	0.586	0.189

*Significant at 5% level of significance

NS Non significant