MORPHO-PHYSIOLOGICAL CHARACTERIZATION OF TWENTY TWO POTATO GERMPLASM

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CERTIFICATE

This is to certify that the thesis entitled **"MORPHO-PHYSIOLOGICAL CHARACTERIZATION OF TWENTY TWO POTATO GERMPLASM,** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in HORTICULTURE*** *embodies the results of a piece of research work carried out by* ***LINTA AKHTAR, Registration no. 10-03833*** *under my supervision and guidance. No part of the 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: June, 2016
Place: Dhaka, Bangladesh

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To

My Honorable Supervisor

Prof. Dr. Abul Faiz Md. Jamal Uddin

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ABSTRACT

A field research was accomplished at Horticultural farm, Sher-e-Bangla Agricultural University, during the period from October 2014 to April 2015 to study morpho-physiological characterization of twenty two potato germplasm. The experiment was conducted using RCBD with three replications. Potato germplasm from different sources were used in this experiment expressed as G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53. Growth and yield attributing parameters were studied in the experiment. Later twenty two potato germplasm have been categorized on the basis of morphological variation using visual observation following UPOV authorized guidelines. The highest percentage of large sized tuber (50%) found in G_{13} and yield ha^{-1} was maximum (29.9 t/ha) in G_3. Among twenty two potato germplasm 4 germplasm (G_8, G_{15}, G_{17}, G_{22}) were found short oval tuber; 6 germplasm (G_2, G_6, G_7, G_{10}, G_{19}, G_{21}) were oval; 5 germplasm (G_1, G_9, G_{13}, G_{14}, G_{20}) were long oval; 3 (G_{11}, G_{12}, G_{16}) were long; 2 germplasm (G_4, G_5) were very long and 2 germplasm (G_3, G_{18}) were recorded round shaped tubers. Among twenty two germplasm 13 potato germplasm (G_1, G_2, G_6, G_7, G_9, G_{10}, G_{11}, G_{13}, G_{14}, G_{16}, G_{19}, G_{20}, G_{21}) were found oval to long shaped tubers and their length were close to 90 mm so they can be used in French frying industry while oval germplasm G_2, G_6, G_7, G_8, G_{10}, G_{15}, G_{17} G_{19}, G_{21} and G_{22} might be suitable for chips making industry and rest of germplasm G_3, G_4, G_5, G_{18} can be considered as suitable germplasm in canning and dehydrated product making industry. The findings of the experiment can be considered as a basis for further research on identifying potential potato germplasm for industrial use.

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ABBREVIATIONS

AEZ- Agro Ecological Zone

BARI- Bangladesh Agricultural Research Institute

BBS- Bangladesh Bureau of Statistics

Cm-Centimeter

Cv .- Coefficient of Variance

DAP- Days After Planting

et al.- And others

FAO- Food and Agricultural Organization of the United Nations

g-Gram

G -Germplasm

Ha- Hectare

HYV- High Yielding Verity

Kg- Kilogram

LSD- Least Significant Difference

Mm-Millimeter

MoP-Muriate of Potash

RCBD- Randomized Complete Block Design

T-Tons

UPOV- International Union for the Protection of new Varieties of plants

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum)* is one of the leading vegetable and next to cereals in Bangladesh. It is an important food crop and belongs to annual dicotyledonous herbaceous tetraploid (2n=28) belongs to Solanaceae family. Potato is ranked fourth in production after rice, wheat and maize. Potato is a prominent non-cereal tuber crop enriched with carbohydrate, protein, vitamins and minerals. Irish potato is one of the most immensely grown tuber crops in the world and contributes highly to human nutrition and food security .It is considered as a vegetable crop and contributes as much 55% of total vegetables production in Bangladesh (BBS, 1995). Recent data indicate that potatoes have 75 percent more food energy per unit area than wheat and 58 percent more than rice. Also, potatoes have 54 percent more protein per unit area than wheat and 78 percent higher than rice. Potato is now the third most important food item of Bangladesh by tonnage production Ahmed *et al*., (2013). Potato tubers are not only rich in carbohydrate but also are a mineral resource for consumption, as well as the food needs of half a billion people in the world. It is a vegetable crop with a relatively high growth rate. This results in it having a relatively short growing period.

Potato is indigenous in Andean area of South America. It is introduced in the Indian sub-continent in seventh century. In Bangladesh 4.5 lac ha of land was taken under potato production and total production was 9.2 metric tons in 2014-2015 which is the 7^{th} largest in the world (BBS, 2016). Chittagong, Hobigonj, Mymensing, Kishorgonj, Bogra, Noagaon, Thakurgaon, Panchogor, Nilphamari, Munshigonj, Rangpur, Comilla, Bhola are considered major potato producing districts. High yielding potato

varieties are first introduced in Comilla and Munshigonj districts. In Bangladesh potato has been introduced in two grouped – a) Deshi or local varieties and b) Modern varieties or HYVs. Local varieties are low yielding, poor quality for industrial use and pithy storage capacity while modern introduced varieties are comparatively have good keeping quality.

Potato growers become accustomed with heterogenous drawbacks like bulkiness in tuber, high seed tuber price, poor tuber quality, lack of knowledge in advance technology and most significant problem is the poor storage facility in cold storage. Our research increases to sort out desired varieties and grade them in suitable classes. To be useful for plant breeders genetic resources must be characterized by morphological and agronomic traits. For this reason, there is need to collect, characterize and evaluate remnant local germplasm before they get disappeared. It will assist to identify the proper group for desirable purposes like industrial raw material, table potato demand, further research on disease and pest resistant varieties. Globally thousands of potato varieties are found near about 5000 in numbers with divergence in size, shape, color, texture and flavor qualities. This is why it is important to characterize them according to the potato morphological descriptors to obtain an adequate description of a certain variety. Mehraj *et al*. (2014) determined morphological variables of a set of germplasm to provide information for breeder reported while characterizing strawberry cultivars. Morphological characterization will help in identification of varieties and for selection of desirable characters for cultivars (Gupta and Dutta, 2005). Datta *et al*. (2015) observed thirty five potato germplasm those were grouped into nine clusters for growth characters and ten clusters for quality traits respectively. Ghislain *et al*. (2004) used microsatellites to

characterize potato cultivars. Characterization also studied in sweet potato (Moulin *et al*., 2012), in cassava (Fukuda *et al*., 2010), in strawberry (Mehraj *et al*., 2014), in *Lagenaria siceraria.* (Yetişir *et al*., 2008).

In commercial production morphological evaluation is also important for tuber crops like potato. However, the perspectives of potato cultivation is poor in Bangladesh due to traditional habits of consumers and lack of information availability of modern technology for creating potato industry such as chips, canned and potato flour. Huge amount of tuber production creates challenge for potato growers. As potato requires cultivating at one season only vast target of production is assured by the government. These vast quantities of tuber are sold at local market at low cost. Farmers hardly got benefit of their hard work. So, it is high time to characterize our potato germplasm to develop a category of early varieties, summer type varieties and industrial potato varieties to overcome this challenge. Characterization obtained in this study could provide a basis for future research that could be selected separately for each in terms of investigation of potato breeding.

Objectives:

- To study growth related and yield attributing parameters.
- To study morpho-physiological characteristics.

CHAPTER II

REVIEW OF LITERATURE

Potato plays significant role in national Agriculture. Bangladesh produce huge amount of potato during winter. After meeting national demand excess potato remains to store for using in off season. Our aim is to identify the variety that could challenge these national drawbacks. Characterization of twenty two potato germplasm is important to identify the desired germplasm for using as industrial raw materials and for conducting advance research. Therefore, information regarding potato characterization has been reviewed and presented year wise in this chapter under following sub headings.

2.1. Growth, yield and morphology related literature:

Mahmun *et al*. (2016) conducted an experiment with top-shoot cuttings which were planted with the whole tuber (as a control) at different dates using three spacings at the Horticultural Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University to evaluate the performance of top-shoots as planting material and to determine the optimum time of planting and the optimum spacing for top-shoot cuttings as planting material for breeder seed production. Significant variations were found among the treatment combinations for plant height at 45 and 60 days after planting (DAP), foliage coverage at 45 and 60 DAP, number of branches per plant, number of tubers per plant, individual tuber weight, tuber yields per plant and per hectare yield. The highest mean yield (46.57 t/ha) was produced by whole tubers planted on 10 November with 50 × 10 cm spacing which was similar to whole tubers planted on 1 November with 50 × 10 cm spacing. On the other hand, plants from top-

shoot cuttings yielded 34.82 t/ha in T_3S_2 followed by T_1S_1 (33.34 t/ha), T_3S_3 (30.70 t/ha).

A field experiment was carried out with the Irish potato (*Solanum tuberosum* L.) variety BP1 to determine the effect of inorganic fertilizer on the growth rate, yield and quality of potatoes grown in bags. The experiment was laid out in a randomized complete block design (RCBD) with five treatments replicated four times, giving a total of 20 plots. In each plot, 5 plants were planted to give a total plant population of 100.The treatments comprised of different inorganic Compound C fertilizer (6% nitrogen; 17% phosphorus; 15% potassium) application rates: Treatment 1- 1800 kg ha-1, Treatment 2- 1400 kg ha^{-1}, Treatment 3- 1000 kg ha^{-1}, Treatment 4- 600 kg ha^{-1} and Treatment 5 (control) with no fertilizer. All treatments were top dressed with ammonium nitrate (34.5% N) applied at a rate of 200 kg per hectare except the control. A significant difference ($P<0.05$) is noted on the average yields obtained per plant among different treatments. Treatment 2 had the highest yield (0.777 kg/plant) while the control treatment had the least yield (0.163 kg/plant). There are significant differences ($P<0.05$) in all the tuber sizes produced in different treatments. Treatment 1 had the highest number of very large tubers, while treatment 2 produced the highest number of large and small tubers (Rumhungwe *et al*., 2016).

Pulok *et al*. (2016) observed effect of potassium (K) and mulch materials on grading of different types of tuber were investigated at the Agronomy research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2013 to March 2014. The experiment comprised of four different doses of K viz., 0 kg K ha^{-1}, 100 kg K ha^{-1}, 125 kg K ha^{-1}, 150 kg K ha^{-1} and four different types of mulch materials viz., soil mulch, rice straw, water hyacinth and saw dust. The experiment was laid out in a split plot design with 3 replications. Statistical analysis done by

using MSTAT-C program and mean differences among the treatments were compared by Least Significant Difference (LSD) at 5% level of significance. Maximum large sized tubers were produced by 150 kg K ha^{-1} with rice straw mulch. Application of 125 kg K ha^{-1} with rice straw produced maximum seed potato and tuber for French fry.

A field experiment was conducted from November to March during the 2012/2013 planting season at Africa University Farm, Mutare, Zimbabwe to evaluate plant spacing and different potato varieties on growth, yield and quality of potato. The experiment was designed as a Randomized Block Design with 4×3 factorial arrangements of treatments. First factor was plant spacing (in- row spacing); 20,25 30 and 35 cm and second factor was varieties 'BP1', 'KY20', 'Mnandi'. Very close spacing produced highest number of small tuber leading to reduced market yield. Highest stem count was observed at high plant densities and lowest at low plant densities. An in–row spacing of 25 cm can be used by seed producers since the highest number of medium sized tuber was obtained in the study. (Mangani *et al*., 2015).

Plant height increased rapidly at the early stages of growth; however, rate of progression in height was slow at the later stages except 'Jam Alu'. the highest plant height (69.43 cm) was observed from the 'BARI TPS-1' with As0 treatment combination which was statistically similar (68.77 cm and 67.80 cm, respectively) the lowest plant (26.63 cm) was obtained from the 'Lady Rosetta'. Number of leaves At harvest, the maximum leaves number $plant^{-1}$ (167.3) was obtained from the 'Jam Alu', the minimum (26.67) was recorded from the combination of 'Courage' . Days to emergence Days to emergence was significantly influenced by the different potato varieties the variety 'Jam Alu' took the maximum duration (17.78 days) for

emergence whereas, the minimum (10.22 days) was taken by 'Quincy'(Haque *et al*. 2015).

An investigation was carried out to study the genetic diversity using Mahalanobis's D^2– technique among thirty five potatoes (*Solanum tuberosum* L.) The D^2 values were calculated and thirty five potato germplasms were grouped into nine clusters for growth characters and ten clusters for quality traits respectively. All the germplasms included in the present investigation, were indigenous, but their grouping in different clusters, suggested that germplasms did not follow the geographic distribution. The cluster I contained the maximum number of germplasms with respect to both yield attributing and quality traits. The inter cluster distance in most of the cases were higher than the intra-cluster distance indicating wider genetic diversity among the germplasms of different groups. Average tuber weight of potato plant contributed maximum (31.76%), followed by number of tuber per plant (27.56%). So, these traits will offer a good scope for improvement of yield and quality through rational selection of parental germplasms for future potato breeding. The findings indicated that use of parents selected from the same cross or from a cross involving a common parent should be avoided in hybridization. The results broadly showed there was no parallelism between geographical and genetic divergence (Datta *et al*., 2015).

Liao *et al*. (2015) conducted an experiment To reduce the error and faster classification by mechanizing in classifying the potato shape and size through machine vision using the extraction of characters procedure to identify the size, and using the shape detection procedure to identify the shape.

Shayanowako *et al.,*(2014) studied that was carried out to determine the effect of stem density on growth, yield and quality of potato (*Solanum tuberosum* L.) variety

‘amethyst’ in Zimbabwe. Three stem density treatments were used and these were initially derived from the number of sprouts or eyes per tuber: 2 stems/hill, 4 stems/hill and +6 stems/hill. Emergence, haulm growth, yield and quality characteristics of tubers were the main parameters measured. There was a significant difference in emergence among the 3 treatments ($P<0.05$). A mean of 30 plants/plot were recorded from the treatment with 6 stems/hill compared to 27.50 plants/plot from the treatment with 2 stems/hill at 12 day after planting. A high marketable yield was obtained at 2 stems/hill compared to 6 stems/hill. An average of 21.08 small tubers per hill that is, those considered unsellable were obtained from treatments derived from 6 stems per hill compared to 3.75 small tubers /plant from plants with 2 stems per hill.

Ganga *et al*. (2014) conducted a study on ten varieties of potato tubers namely- Kufri Chipsona-2, Atlantic, Kufri Surya, Kufri Khayti, Kufri Jyoti, Kufri Pushkar, Kufri-Bahar, Kufri- Ashoka , J/99-24 with Kufri Pukhraj revealed that tubers mean length varied significantly ($p\leq0.01$) between the cultivars ranging from 5.9 cm in J/99-242 to 7.6 cm in Kufri Ashoka. Mean breadth of tubers ranged between 4.4 cm to 5.6 cm with shortest in Kufri Pushkar and longest in Kufri Ashoka. Kufri Ashoka showed significantly ($p\leq0.01$) large mass (113 g), highest volume (106.9cc) and longest diameter (5.8 cm) while Kufri Pushkar had significantly smallest mass, lowest volume whereas Kufri Surya recorded significantly shortest diameter. Majority of the cultivars were oval shaped with brown coloured skin and cream flesh, number of eyes were less in most of the cultivars with shallow eye depth, without scars and green tint. Highest numbers of natural depressions were found in Kufri Chipsona-2. Kufri Khayti produced highest slices (84.00%) as well as chips (22.83%) and thus ranked first.

Four CIP potato clones with 1 check variety 'Asterix' were grown during 2010-11 and 2011-12 at Horticulture Research Farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh to observe the effect of water stress on canopy structure, yield and growth rate of potato. The study validated that all the germplasms showed reduction in plant height, number of above ground shoots per plant, tuber number per plant and yield by different degrees of drought. Significant yield reduction was found among the germplasms due to drought treatments. Tuber number per plant ranged from 5.76 to 10.80 in 2010-11 & 7.23 to 10.42 in 2011-12 respectively found by (Mahmud *et al*., 2014).

Qasim *et al*. (2013) conducted an experiment which was carried out at Himalayan Agricultural Research Station (HARS) during summer season 2005. Where maximum tuber growth 88.7%, number of stems per plant 3.5 and minimum number of stem per plant 1.9, plant expansion 45.5 cm, average number of tuber per plant 10.1 and yield per hectare 12.4 t/ha were significantly different and higher when potatoes were planted on wide bed covered with soil from one side .Tallest plants 53.4 cm were observed when potatoes were sown on the ridges.

Taheri *et al.* (2013) conducted a research on the effect of planting date and plant density on the yield and efficiency of energy production in potato tubers has been investigated. The experiment was conducted in split-plot design with four replications. Main plots consisted of 4 treatments, planting dates, 15 April (T_1), 30 April (T_2), 15 May (T_3) and 30 May (T_4), respectively.Results showed that among treatments, maximum and minimum of potato yield was related to T_2 and T_1, respectively the study revealed planting dates, May 15 and 25 cm density of the product was obtained the highest yield (29.92 t/ha).

Hasan *et al*. (2013) conducted an experiment it is observed that the tallest (85.71 cm) plant was observed in the germplasm 'LB-6' and the shortest (44.23 cm) in the Diamont and Diamant had more under sized (below 28 mm) tubers (95.0 tubers) and 'LB-7' had the least (39 tubers). Tuber weight also showed similar results.The clone 'LB-7' produced more marketable (28-55 mm size) .The highest yield (49.69 t ha^{-1}) and dry matter content (21.32%) were produced by 'LB-7' followed by 'LB-3'.

The classification of potato tubers through the separation of the product in plots with more homogeneous size characteristics, unite the market language of the different instances of the production chain. The results referring to this tubers classification, considering the greater diameter, fits completely in the classes II (29%) and III (71%), not having been verified tubers greater than 85mm and smaller than 33mm, represented by the classes I and IV, respectively. Among the classes the greater percentage was verified in the class III. (Lopes *et al*., 2013).

Kaspar *et al*. (2013) studied carotenoid concentrations in white and purple potatoes were similar, while yellow potatoes had a 45-fold greater carotenoids concentration compared to white and purple potatoes. Consumers ranked the aroma and appearance of white and yellow potatoes higher than purple ($P < 0.05$). However, no significant differences were observed in overall acceptance between the potato cultivars. These results suggest that consumers may be willing to consume pigmented potatoes, which are beneficial to health due to their higher antioxidant content.

Khan *et al*. (2012) conducted another research on 11 potato cultivars to assess their genetic variability of different morphological parameters including emergence percentage (%), date of flowering , plant height (cm), number of leaves per plant ,average leaf area , number of flowers per plant , number of stems per plant and number of fruits per plant. All of these characters showed a high level of variation

among the varieties. Locally developed advanced line ‘SH-19’ showed maximum emergence percentage (92.33%). However, ‘Aziza’, ‘Leonardo’ and ‘Avalanche’ carried 2.67 and 1 stem per plant, respectively.

A field study was carried out with the potato (*Solanum tuberosum* L.) variety ‘BP1’ to determine the influence of plant population density and seed tuber size on the crop’s physiological growth components and yield performance under optimal field conditions. Two factors considered were seed tuber size and population density. The first factor involved four seed sizes. The second factor was population density (E) and it was at three levels. Parameters measured included shoot emergence (germination), haulm growth and yield. There were significant differences in mean percentage germination at 9, 10, 11 and 12 days after planting across the four seed sizes. It has observed that plant population density for good yield was 90 by 30 cm and that large and very large seed sets gave the best yield. (Masarirambi *et al*., 2012).

Ranjbar *et al*. (2012) observed phenotypic diversity in potato, *Solanum tuberosum* was assessed using morphological traits. To verify, how this diversity is distributed among the main potato varieties in the growing areas in Iran. A total of eleven potato varieties, ‘Ramose’, ‘Sante’, ‘Shepody’, ‘Marfona’, ‘Maradona’, ‘Milova’, ‘Santana’, ‘Boren’, ‘Cosima’, ‘Granola’ and ‘Agria’, were evaluated under vivo and situ experimental conditions. This study also studied number of tuber and average tuber weight.

Ten exotic potato varieties were used in an experiment during Nov. 2010 to Jan 2011 where the highest tuber number (57.52) per plant was found in Daisy germplasm and the lowest number of tubers (8.82) per plant was recorded in red varieties .Total tuber weight per plant was highest (344.6 g) in Diamont and lowest was (65.05 g). All blue

varieties were showed the most potential yield in this experiment. (Karim *et al*., 2011).

Ahmad *et al*. (2011) conducted an experiment on five hybrid rose cultivars namely 'Amalia', 'Anjlique', 'Kardinal', 'Whisky Mac' and 'Rosy Cheeks'. Maximum plant height was found in Rosy Cheeks (83.0 cm) and minimum in 'Kardinal' (46.7 cm). Maximum numbers of leaves/plant were found in Rosy Cheeks (10.8) and minimum in Kardinal (8.8). Maximum leaf area was found in Whisky Mac (104.86 cm^2) and minimum in Anjlique (65.20 cm^2). Maximum leaf chlorophyll content was found in Whisky Mac (58.12mg g^{-1}) and minimum in Rosy cheeks (49.80 mg g^{-1}). Maximum bud diameter was found both in Amalia and Whisky Mac (3.1 cm) and minimum in Rosy Cheeks (2.6 cm). Maximum flower diameter was found in Amalia (5.8 cm) and minimum in Anjlique (4.8 cm).

Bansal and Trehan (2011) conducted an experiment on the application of potash fertilizers. In India a review of many field experiments conducted on response of potato to potassium application revealed a yield increase between 1.0 t ha^{-1} and 5.2 t ha^{-1} at different sites. Results of many experiments indicate that potassium nutrition influences tuber size, dry matter content, susceptibility to black spot bruise, after-cooking darkening, reducing sugar content, fry colour and storage quality. Considering the fact that tuber quality parameter are related to variety, to tuber maturity, growth and site conditions, water uptake and others, making of general recommendations on the optimal K fertilizer use is a complicated issue.

Khan *et al*. (2011) studied a field trial which was conducted to optimize the sowing date and crop growth period of potato at the Agricultural Research Institute, Dera Ismail Khan, NWFP during 2004-05. The tubers were planted on four dates with one-

week interval starting from September 24 in 2004. Tubers planted at each sowing date were harvested on six different dates starting from week-10 and ending at week-15. Total number of stems increased with the delay in planting. Total numbers of tubers per unit area and percentage of large sized tubers (> 55 mm) were the highest at the earliest planting of September 24. Smaller tubers (< 35 mm) increased with delay in planting. Total number of tubers, percent larger and medium sized tubers, tuber yield and plant dry bio-mass increased with the delay in harvesting. However, dry matter in tuber was found higher at earlier harvestings.

Datta *et al.* (2011) undertaken a study on five mustard cultivars namely V_1- WBBN-1, V_2 –NC-1, V_3-YST-151, V_4-Ragini, V_5-B_9. Among these varieties, maximum chlorophyll content was found in V_4 (1.550) and minimum in V_1 (1.311).

An experiment was conducted in farmer's field in the village of Arazi Postompur under sadarthana of Thakurgaon district to study the effect of different irrigation regimes on the yield and yield contributing characters of high yielding potato varieties namely 'Binella', 'Cardinal', 'Chamak' and 'Heera'. Five irrigation treatments: no irrigation, irrigation at IW/CPE ratios of 0.25, 0.50, 0.75 and 1.00 were tried in the silty loam soil of the Himalayan Piedmont Plain having pH value 5.3, average bulk density 1.43 gm/cc and field capacity 26.85% (dry basis). The experiment was laid out in split plot design and replicated thrice. Among all the varieties Chamak was found to be superior in respect of tuber yield followed by Heera, Binella and Cardinal under the different irrigation regimes. Plant height, number stem per hill, nuber of tuber per hill also have been studied in this experiment (Amanullah *et al*., 2010).

During the growing season 2006 and 2007 eight potato varieties from Netherlands: 'Kondor' (as standard check), 'Agria', 'Agata', 'sinora', 'Virgo', 'Aladin', 'Armada'

and ‘Romano’), were tested in the fields of the Agricultural Research Institute of Peja. The experiment was conducted at two most important agro-climatic regions for potato production in Kosova, Vitomirica (Dukagjini plain) and Pestova (Kosova plain). The obtained results have shown that there are highly significant differences as for the tuber yield and dry matter content, among tested potato varieties. The highest tuber yield was realized with variety Aladin (32.89 kg) while the lowest with variety Riviera (26.19 kg). The highest content of dry matter was realized with variety Agria (19.92%) and the lowest one with variety Armada (12.26%). The results of other parameters like colour of skin, colour of flesh, disintegration of the flesh after cooking (Musa *et al*., 2009).

An experiment was carried out to study the morphological characteristics and yield potentialities of 23 potato varieties The varieties Ladyrosetta, Diamant, Provento, Granola and Dheera showed greater number of seed tuber emergence (>90%) while Terragold, Ladyolympic, Processor, Laura, Remarka and Almera showed poor performance (<40%) within 20 days after planting. Plant height ranged between 37 (Processor) to 76 cm (Quiney). Highest number of sprout per hill was produced in Diamant (8.53) followed by Innovator or Asterix while lowest in Ladyolympic (2.73). Largest canopy foliage expansion was noticed in Diamant (93%) followed by Quiney, Dheera and Innovator, and minimum (47%) in Ladyolympic. (Awal *et al.,* 2007).

Host genetic resistance against pathogens and insects can be directly associated with leaf morpho-anathomical characteristics. The aim of the experiment was to study leaf morph-anatomical characteristics of five potato (*Solanum* spp.) clones differing in ploidy level and genetic background observed in that experiment.(Bisognin *et al*. ,2006).

A set of seventeen potato germplasm was evaluated for seven characters in sub-tropical plains (Modipuram and Jalandhar) and temperate hills ('Kufri') to estimate genetic parameters and character associations. Sufficient variation was present for all characters except for number of leaves and tuber dry matter. Heritability values were moderate to high for all characters except for number of leaves at all the locations and for plant height and number of shoots at 'Kufri'. Plant height was positively associated with number of leaves, and tuber yield with average tuber weight at all the locations. Tuber yield was not associated with any of the foliage characters. (Joseph *et al*., 2005)

Lachman and Hamouz, (2005) have studied red and purple potatoes are in addition contained acylated anthocyanins and pigmented potatoes display two to three times higher antioxidant potential in comparison with white-flesh potato.

Holtan *et al.* (2003) found in an experiment on tomato leaves variatrion and observed thatleaves are one of the most conspicuous and important organs of all seed plants. A fundamental source of morphological diversity in leaves is the degree to which the leaf is dissected by lobes and leaflets and the experiment used publicly available segmental introgression lines to describe the quantitative trait loci (QTL) controlling the difference in leaf dissection seen between two tomato species, *Lycopersicon esculentum* and *Lycopersicon pennellii*. The study have defined eight morphological characteristics that comprise the mature tomato leaf and describe loci that affect each of these characters.

Sultana *et al.* (2001) studied with The treatments comprised of four sizes of seedling tubers viz. 5.0, 7.5, 12.5 and 17.5 g derived from the TPS progeny HPS II/67 and four depths of planting viz. surface level, 2.5, 5.0 and 7.5 cm with their all possible

combinations. Seedling tuber size significantly influenced the growth and yield of potato. Yield was found to increase with the increase in seedling tuber size and the maximum yield (39.34 t/ha) was obtained from the large seeds (17.5g). Depth of planting had no significant effect on the growth and yield of potato.

Ayyub *et al.* (2001) conducted a study with the application of Potash fertilizers with organic matter like FYM and found FYM improves potassium uptake by potato plants. Results revealed that parameters like day to emergence, total emergence percentage and number of stems per plant was greatly affected by sulphate of Potash. Number of tubers per plant and number of compound leaves per plant was significantly affected by ½ MP and ½ of FYM. plant height was found highest with FYM.

Ahmed *et al*. (2000) carried an experiment by on the yield of potato in relation to variety (Cardinal and Desiree) and spacing (50, 75 and 100 cm) was conducted during the autumn in Peshawar conditions. Variety Desiree was significantly early (20 days) in 50% emergence as compared to 22 days of Cardinal. Plant Vigor in terms of height and spread was significantly more only after 60 days through 80 days while only plant spread was significantly more after 40 days. Highest number of stems were in Cardinal (3.88) as compared to 2.41 in Desiree. The total tuber yield was significantly higher in Cardinal (12.76 tons/ha) as compared to 9.80 tons/ha of Desiree. Maximum total yield of 14.31 and 13.52 tons/ha was produced in 50 cm spacing while it was minimum 9.95 and 6.37 tons/ha at 100 cm in Cardinal and Desiree accordingly.

Genet (1992) found an increasing proportion of the New Zealand potato crop is processed, the quality of the raw material has assumed increasing importance. The main quality characteristics of interest to both French fry and crisp producers are tuber size and shape, flesh colour, dormancy and storability, dry matter content and reducing sugar content. the dictates of processors' packaging and slicing equipment require round, medium size (100-200 g) tubers. Large crisps are more prone to damage, and are more difficult to fit in small packs. As tubers cannot be orientated at the slicing stage, long tubers are difficult to cut. Moreover he observed Present attitudes favour white-fleshed french fries and yellow crisps.

Maity and Chatterjee (1977) reported that leaflet size , number of tubers per plant and plant height were closely related with tuber yield .

Taha (1961) studied the relationship between yields and shoot number and found that yield generally increased with an increase in shoot population and that small seed was inferior to large seed at the same number of shoots per acre. He attributed this to the greater vigor, earlier emergence and earlier tuber initiation in large seed, the effect of this on yield was apparently more than sufficient to offset any possible effects of the more shoot distribution in small seed.

2.2. Methodology related literature:

Kesaulya *et al*. (2015) studied information on morphological characteristics of potato (Solanum tuberosum L.) variety Hartapel, origin South Buru. The research was conducted in the Fakal village of South Buru of Moluccas located 1124 m above sea level. The results showed that potato variety Hartapel was found to be a local variety which has long been adapted to local growing environment. Morphological characters of this variety are influenced by environmental factors. The morphological

characterization of Hartapel potato variety from South Buru can provide a source of information that can be useful for preserving germplasm diversity of potato varieties.Morphology of stems, leaves, flowers and tubers are specific, including the shape and color which are all forming identification keys of Hartapel potato variety. Morphological characterization of Hartapel potato variety can provide a source of information that can be used for conserving germplasm diversity of potato varieties.

An experiment was conducted at Sher-e-Bangla Agricultural University for morphological characterization of three strawberry germplasm viz. V_1, V_2, V_3. It was narrated that morphological variables of a set of germplasm were determined to provide information for breeders. Grouping was done to classify strawberry germplasm based on morphology. The experiment found that $V_1$was suitable for commercial production. The grower who both seedling and yield with quality can select V_3. (Mehraj *et al*.,2014).

Thirty small flowered cultivars of chrysanthemum were selected and their different morphological characters and chlorophyll content of leaves both at vegetative and flowering stages were determined and categorized on the basis of their flower types for preparation of Chrysanthemum. It will help in identification of varieties and for selection of desirable characters for cultivar (Gupta and Dutta, 2005).

Moulin *et al*. (2012) collected germplasm to assess genetic variability within sweet potatoes and cook very important action to avoid genetic variability losses. The goals of his work were to collect sweet potato from farms in the north of Rio de Janeiro state; to gather information regarding to the farmers profile, and to characterize the sweet potato landraces collected using morphological descriptors. Fifty three farms were visited in six collection expedition and 46 accessions were collected. The

morphological characterization was efficient to detect genetic variability among accessions, revealing that traditional farmers from Campos dos Goytacazes and São João da Barra are responsible for sweet potato germplasms conservation with expressive genetic diversity in their properties.Great variability was detected for root shape of sweet potato with seven classes. The predominant color of the root skin of the accessions characterized was classified as pink, along with the colorings cream, orangey-brown and dark purple.

Fukuda *et al.* (2010) has conducted an experiment on Cassava germplasm. Major objectives of the project were to document and characterize, both genotypically and phenotypically, cassava germplasm that breeders use in the region. This includes improved varieties as well as locally adapted farmer varieties. To analyze data together and draw comparisons, it is important that data collection, storage, and analysis are standardized. This descriptor list aims at helping to standardize characterization data.

Yetişir *et al. (*2008) conducted an experiment on the landraces of *Lagenaria siceraria* in Turkey show great diversity for morphologic traits, particularly in fruit size and shape. Its diversity has been gradually declining over the last 25 years. With the aim of assessing variations in plant, fruit and seed morphology among the L. siceraria landraces, 15 field trips for collection of germplasm to southern parts of Turkey (Mediterranean region) were carried out in the period of 2003–2004. The study also aimed at developing a representative core collection of the material to guide future studies and uses concerning its existing genetic diversity in Turkey. A total of 182 accessions (fruits and/or seeds) were collected. The morpho-agronomic characterization was carried out following the international standards for crop descriptors set by Bioversity International.

Characterization of nearly 1,000 cultivated potato accessions with simple sequence repeats (SSRs; also referred to as microsatellites) has allowed the identification of a reference set of SSR markers for accurate and efficient genotyping (Ghislain *et al*. 2004).

Dam *et al*. (1999) observed an study where two segregating resource populations were constructed, one of 216 clones using the tetraploid clones Cara and LT7 as parents and one of 176 clones using the tetraploid clones NT8 and LT7 as parents. The populations were used, in replicates, to estimate genetic parameters for total glycoalkaloid (TGA) content in the tubers, and for other agronomic and morphological traits such as tuber weight, maturity and plant height.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October to February 2015 to study morpho-physiological characterization of twenty two potato germplasm. This section emphasizes information on materials and methodology used in accomplishing the experiment. The materials and methods that were used and followed for conducting the experiment presented under the following headings-

3.1 Experimental site

The study was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the characterization of twenty two potato germplasm. Location of the site is $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8 meter from sea level in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

3.2 Climatic condition

Experimental site was located in the subtropical monsoon climatic zone, set aparted by heavy rainfall during the months from April to September (Kharif season) and scant of rainfall during the rest of the year (Rabi season). Plenty of sunshine and moderately low temperature prevails during October to March (Rabi season), which is suitable for potato growing in Bangladesh.

3.3 Planting Materials

Twenty two potato germplasm have been collected from different sources within Bangladesh and from Burma, Japan and USA. Germplasm used in this experiment were –

Table 1. List of twenty two potato germplasm

Germplasm	Sources
Lal Pakri 1, (G_1)	Local
Lal Pakri 1,(G_2)	Local
Dohazari, (G_3)	Local
Shilbilati, (G_4)	Local
Jam Alu, (G_5)	Local
Fuata Pakri,(G_6)	Local
Bogra Guti, (G_7)	Local
Ausha, (G_8)	Local
Blue White, (G_9)	Japan (Exotic)
Blue Yellow, (G_{10})	Japan (Exotic)
Burma 1, (G_{11})	Burma (Exotic)
Burma 2, (G_{12})	Burma (Exotic)
Diamont,(G_{13})	BARI
Cardinal (G_{14})	BARI
Granula (G_{15})	BARI
Asterix (G_{16})	BARI
Courage (G_{17})	BARI
Lady Rosetta, (G_{18})	BARI
Segita (G_{19})	BARI
Sarpo Mira, (G_{20})	USA (Exotic)
BARI Aloo 46, (G_{21})	BARI
BARI Aloo 53, (G_{22})	BARI

* BARI-Bangladesh Agricultural Research Institute

3.4 Design and Layout of the Experiment

The experiment was laid out in randomized completely block design (RCBD) with three replications. A layout of research work is given below:

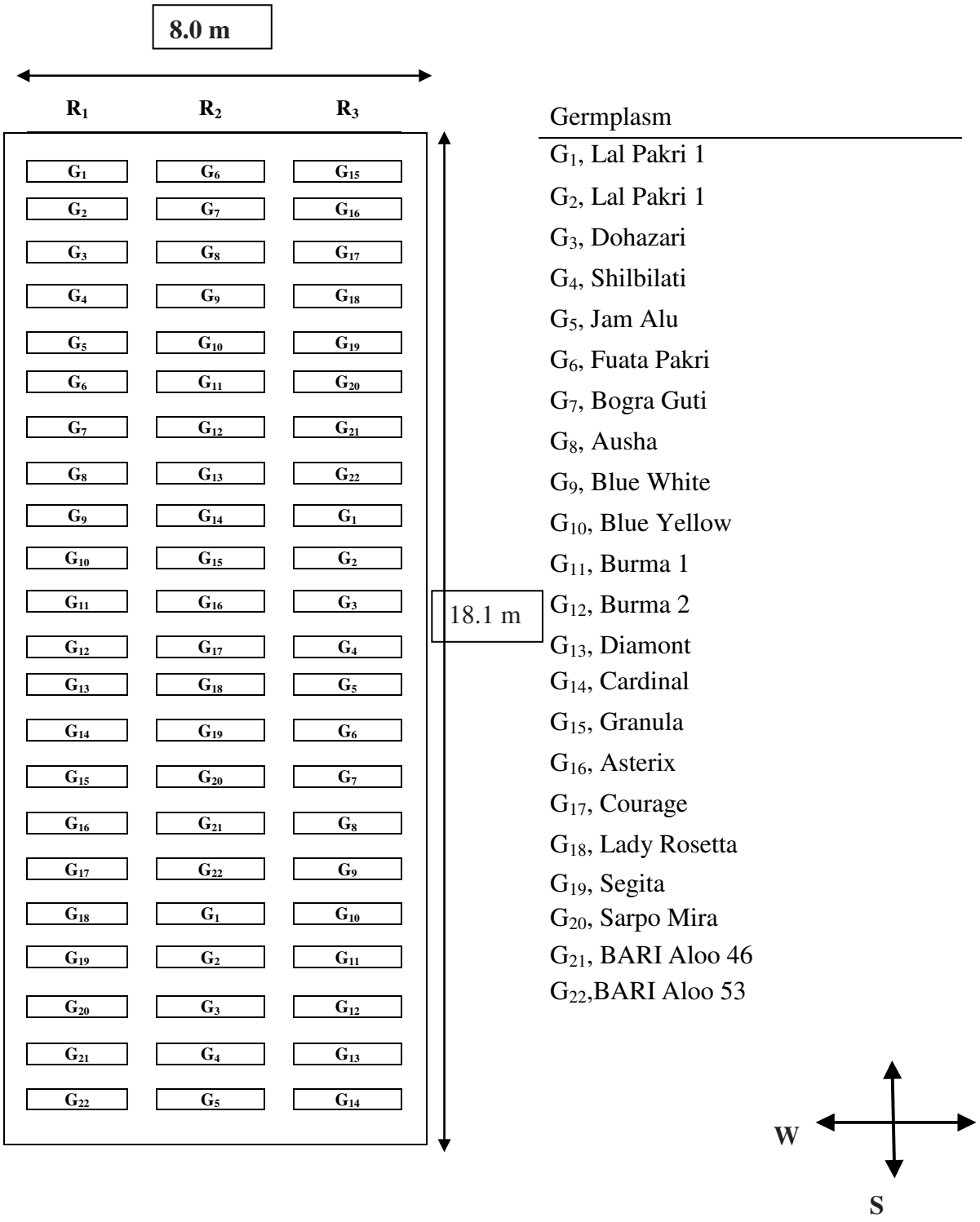

Plate 1. Layout of research work

Experimental area was consisted with total 66 plots. Each plot size was 2.4 m × 1.5 m. Plot to plot distance was 50 cm. Tubers were sown at 60 cm×25 cm spacing.(BARI)

3.5 Land preparation

The land was first open by ploughing with the help of power tiller and then it kept open to sun for seven days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering. The weeds and stubbles were removed after each laddering. Simultaneously the clods were broken and the soil was made into good tilt.

3.6 Application of manure and fertilizers

In this experiment urea, TSP and MoP were applied at the rate of 220- 250 kg/ha, 120-150 kg/ha, and 220-250 kg/ha, respectively (BARI 2005).

Table 2. Manures and fertilizers with BARI recommended dose along with plot wise application dose

Manure/ fertilizers	Recommended Dose	Application dose
Cow dung	8-10 t/ha	3.6 kg/m^2
Urea	220-250 kg/ha	82.8 g/ m^2
TSP	120-150 kg/ha	46.8 g/m^2
MoP	220-250 kg/ha	82.8 g /m^2

During experiment whole amount of cow dung, half of urea, whole amount of TSP, MP, gypsum have been applied at the time of tuber seed sowing. Rest of urea has been applied 30-35 DAP and 50-60 DAP with three installments.

3.7 Intercultural operation

When the seedlings started to emerge in the beds it was always kept under careful observation. After emergence of seedlings, various intercultural operations, like weeding, top dressing, irrigation was accomplished for growth and development of potato.

3.7.1 Irrigation and drainage

Overhead irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening. Further irrigation was done when needed .Stagnant water was effectively drained out at the time of heavy rains.

3.7.2 Weeding

Weeding was done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully after completing the emergence of potato whenever it was necessary. Breaking the crust of soil was done when needed.

3.7.3 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 3 equal installments. The fertilizers were applied on both sides of plant rows and mixed with the soil by hand. Earthing up was done with the help of nirani immediately after top dressing of nitrogen fertilizer.

3.7.4 Earthing up

This operation was done throughout the growing period. The first was done during planting tubers and the remaining two were done at 30 DAP and 50 DAP just after top dressing of fertilizers.

3.7.5 Plant protection measures

Furadan 3G @ 20 kg/ha was applied at final land preparation to prevent soil insects. Ripcord and Diathan M-45 mixture were applied at 30 DAP. Acrobat MZ (0.2%) was sprayed at 45 DAP to protect crop from the attack of late blight.

3.8 Harvesting

Tubers have been harvested periodically. Harvesting was started from 80 DAP which was continued up to 100 DAP with 10 days interval.

3.9 Parameters of the field experiment

1) **Growth related parameters**
    a) Emergence percentage
    b) Plant height
    c) Chlorophyll percentage
    d) Days to maturity
    e) Number of stem $hill^{-1}$
    f) Number of leaves $hill^{-1}$
    g) Number of tuber $hill^{-1}$
2) **Yield attributing parameters**
    a) Tuber length (cm)
    b) Tuber diameter (mm)
    c) Percentage of tuber $hill^{-1}$ (%)
    d) Individual tuber weight (g)
    e) Yield $hill^{-1}$ (kg $hill^{-1}$)
    f) Yield ha^{-1} (t ha^{-1})

3) Phenotypic parameters

a) Sprout characteristics (Appendix VIII)

i. Sprout Shape

ii. Sprout size

iii. Anthocyanin coloration at the base

iv. Intensity of anthocyanin coloration at the base

b) Leaf characteristics (Appendix X)

i. Leaf openness

ii. Intensity of green color

iii. Presence of secondary leaflets

iv. Frequency of secondary leaflets

v. Frequency of leaf coalescence

vi. Terminal leaflet shape

vii. Terminal leaflet tip shape

viii. Terminal leaflet base shape

ix. Lateral leaflet shape

x. Lateral leaflet tip shape

xi. Lateral leaflet base shape

xii. Size of secondary leaflets

xiii. Number of primary leaflet pairs

c) **Plant characteristics (Appendix XI)**

i. Foliage structure

ii. Canopy structure

iii. Growth habit

d) Tuber characteristics (Appendix XII)

i. Tuber shape

ii. Tuber skin color

iii. Tuber flesh color

iv. Depth of eyes

3.10 Data collection

Three plants were randomly selected from each unit of plot for the collection of data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid the border effect. However the yield of all plants was considered per plot yield. Data have been collected on the basis of three attributes like – growth related parameters and yield attributing parameters and Morphological or phenotypic parameters. In phenotypic observation under four aspects such as sprout characteristics, leaf characteristics, plant characteristics, tuber characteristics were observed to characterized 22 potato germplasm by following DUS test descriptors. The international Union for the Protection of New varieties of Plants (UPOV) provides the procedure for conducting DUS test. Data have been collected on basis of following procedure.

3.10.1 Growth related parameters

3.10.1.1 Emergence percentage

Emergence percentage of twenty two potato germplasm was counted within10 DAP.

3.10.1.2 Plant height

The height of the plant was measured by placing a meter scale from ground level to the tip of the outer longest leaf of an individual plant. Thus, mean of five selected

plants of a plot was recorded and expressed in centimeter (cm). It was measured from 40 DAP. (Plate 3. d.)

3.10.1.3 Chlorophyll percentage

SPAD-502 Chlorophyll Meter was used for measuring chlorophyll content (%).

3.10.1.4 Days to maturity

Maturity of potato tubers were counted after observing their visual maturity. Mature plants have changed its color from green to brown color.

3.10.1.5 Number of stem hill^{-1}

Number of stem per hill was recorded by counting all branches of four plants after 40 DAP and mean was calculated. Bunch length of each plant was measured in centimeter (cm) by using meter scale and mean was calculated.

3.10.1.6 Number of leaves hill^{-1}

The number of leaves per hill was counted individually after 20 days of transplanting and continued up to 48 days after transplanting at an interval of seven days.

3.10.1.7 Number of tubers hill^{-1}

Number of tubers per hill was counted individually after final harvesting.

3.10.2 Yield attributing parameters

3.10.2.1 Tuber length

The length of tuber was measured with a slide calipers from the neck of the fruit to bottom of five selected marketable tuber from each plant, and their average was calculated in centimeter. (Plate 3. a.)

3.10.2.2 Tuber diameter

Tuber length and diameter were measured using Digital Caliper -515 (DC-515) in millimeter (mm). Mean was calculated each treatment. (Plate 3. a)

3.10.2.3 Percentage of tuber hill^{-1}

Individual tubers have been harvested followed by grading of tubers according to their size large, medium and small tubers. Mean was calculated.

3.10.2.4 Individual tuber weight

Tuber weight was measured by Electronic Precision Balance in gram (Plate 2d). Total tuber weight of each pot was obtained by addition of weight of the total tuber number and average tuber weight was obtained from division of the total tuber weight by total number of tuber. (Plate 3. b.)

3.10.2.5 Yield hill^{-1}

Potato yield per hill was calculated by multiplying total number of fruits with single tuber weight per hill and expressed in Kilogram (kg).

3.10.2.6 Yield ha^{-1}

The yield obtained unit plot was converted into per hectare yield and expressed in tons.

3.10.3 Phenotypic parameters

3.10.3.1 Sprout characteristics

Potato sprouts were varied significantly among different germplasm. Sprouts were varied in size, shape, anthocyanin coloration at base and intensity of anthocyanin

coloration at base. Visual observation was done to characterized tubers in terms of following parameters:

3.10.3.1.1 Sprout size

Great variations have been found in sprouts size within different potato germplasm. According to UPOV guidelines the sprouts size has been categorized as –small, medium and large.

3.10.3.1.2 Sprout shape

Sprouts shapes were varied significantly among potato germplasm. According to UPOV guidelines the sprouts shape has been categorized as- spherical, ovoid, conical, narrowly cylindrical, and broadly cylindrical.

3.10.3.1.3 Anthocyanin coloration at the base

According to UPOV guidelines anthocyanin coloration at base has been categorized as-red –violet and blue – violet.

3.10.3.1.4 Intensity of anthocyanin coloration at the base

Wide range of anothocyanin concentration can be found within different potato germplasm**.**. According to UPOV guidelines intensity of anthocyanin coloration at base of sprouts has been categorized as-very weak, weak medium, strong and very strong.

3.10.3.2 Leaf characteristics

A typical potato leaf stalk is consisted with terminal leaflet, lateral leaflets, and secondary leaflets. Leaves of potato are varied in leaf color, terminal leaves pattern, lateral leaf pattern, presence of secondary leaflets and amount of terminal three leaf

coalescence. Leaves were also varied in different shape and size also. (Plate 3.c.). Potato germplasm can be characterized on the basis of following parameters:

3.10.3.2.1 Leaf openness

It is defined as how leaves were combined or arranged on a certain leaf stalk. UPOV guidelines categorized leaf openness as closed, open, intermediate type.

3.10.3.2.2 Intensity of green color

According to UPOV guidelines the intensity of color has been classified as light, medium and dark color.

3.10.3.2.3 Presence of secondary leaflets

A typical potato leaf is composed of two to four pairs of primary leaflets arranged on the midrib with a terminal leaflet at the end. Between the primary leaflets some smaller leaflets were called secondary leaflets (Plate 2) which were often placed irregularly along the midrib. The tiny inconspicuous rudimentary or tertiary leaflets can also be evident on the base of secondary leaflets. UPOV guidelines categorized as weak, strong and medium type.

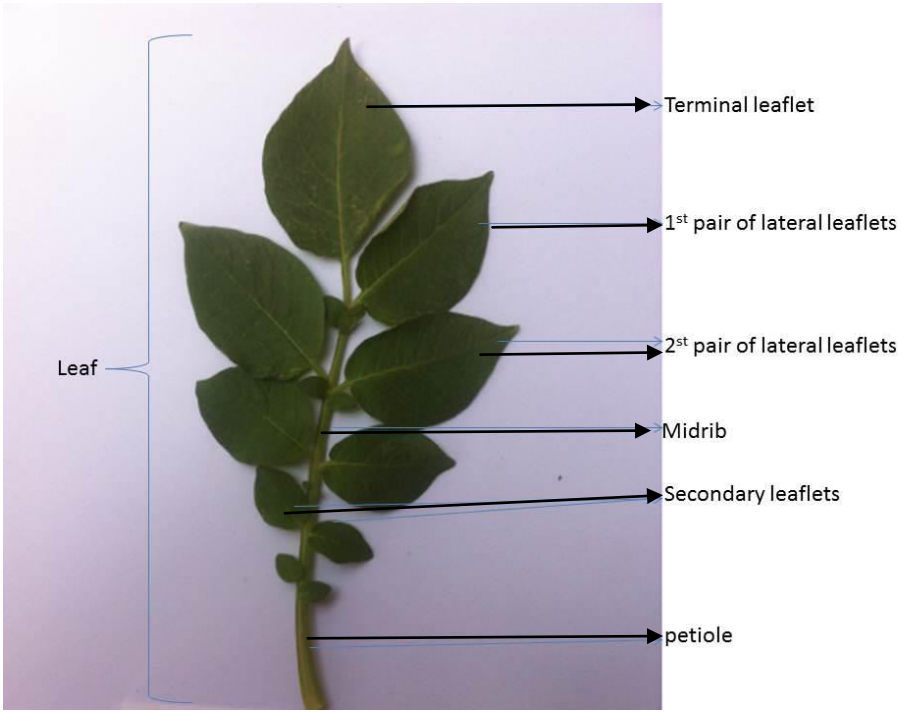

Plate 2. A typical potato leaf stalk

3.10.3.2.4 Frequency of secondary leaflets

According to UPOV guidelines potato leaflets have been categorized as nil or very low, low, medium, high, very high.

3.10.3.2.5 Frequency of leaf coalescence

Apical leaves in a stalk of potato plant were termed as terminal leaves. Terminal leaves when unite together to form a group or mass of leaves this pattern is combined as terminal leaf coalescence. According to UPOV guidelines it is categorized as coalescent and not coalescent type.

3.10.3.2.6 Terminal leaflet shape

Terminal leaflet shape varied significantly within germplasm to germplasm. According to UPOV guidelines it has been categorized as narrowly ovate, medium ovate, broadly ovate, lanceolate, elliptical, obovate, oblong.

3.10.3.2.7 Terminal leaflet tip shape

Terminal leaflet tip shapes were varied significantly. So UPOV categorized them as – acute, cuspidate, acuminate, obtuse and other.

3.10.3.2.8 Terminal leaflet base shape

Terminal leaflet base shapes were varied significantly within germplasm. According to UPOV it has been categorized as cunneate, acute, obtuse, cordate, truncate lobed on the basis of visual observation**.**

3.10.3.2.9 Lateral leaflet shape

Lateral leaflet shape were varied significantly germplasm to germplasm. According to UPOV guidelines it has been categorized as narrow, medium, broad.

3.10.3.2.10 Lateral leaflet tip shape

Lateral leaflet tip shape were varied significantly germplasm to germplasm. According to UPOV it has been categorized as acute, cuspidate, acuminate, and obtuse.

3.10.3.2.11 Lateral leaflet base shape

Lateral leaflet base shape were varied significantly gemplasms to germplasm. According to UPOV it has been categorized as – cuneate , acute, obtuse, cordate , truncate , lobed.

3.10.3.2.12 Size of secondary leaflets

Sizes of secondary leaflets were varied significantly within gerplasms. UPOV guidelines were categorized size of secondary leaflets as – small, medium, large, mixed.

3.10.3.2.13 Number of primary leaflet pairs

Number of primary leaflet pairs were varied significantly germplasm to germplasm.

3.10.3.3 Plant characteristics

3.10.3.3.1 Foliage structure

Masses of leaves and stems which make up a plant considered as foliage structure. This is varies significantly plant to plant even in germplasm to germplasm within same species. According to UPOV guideline foliage structure has been classified as:

3.10.3.3.1.1 Stem type

In this type clusters of leaves were open and so stems were clearly visible.

3.10.3.3.1.2 Intermediate type

Foliage or clusters of leaves were half open which showed stems partly and so they have been classified as intermediate type.

3.10.3.3.1.3 Leaf type

In this class cluster of leaves were closed it means stems were hardly visible due to the leaf compactness.

3.10.3.3.2 Canopy structure

It varies significantly within germplasm. According to UPOV canopy structure of potato plants were classified. (Plate 3. c.)

3.10.3.3.2.1 Compact

In plants where leaf type foliage structure found those were considered as compact canopy structure.

3.10.3.3.2.2 Medium compact

In this class cluster of leaves were arranged moderately along the stem. The plants which show intermediate type of foliage structure were categorized as medium compact type of canopy.

3.10.3.3.2.3 Open

In open canopy structure foliage were scattered and open which showed stems clearly so they have been classified as open type. Open type canopy structure is similar to stem type foliage structure.

3.10.3.3.3 Growth habit

Potato germplasm were varied significantly in terms of growth habit. UPOV guidelines expressed growth habit of potato plants.

3.10.3.3.3.1 Erect or upright

Plants which were raised vertically or upward creating angles more than 45 ˚ were termed as erect or upright.

3.10.3.3.3.2 Semi erect or semi upright

Those potato germplasm were neither upward nor spreading and those create angle between 30˚ to 45˚ with ground level.

3.10.3.3.3.3 Spreading

Some potato germplasm were bending from vertical position can be characterized as spreading

3.10.3.4 Tuber characteristics

Variation was observed within 22 potato germplasm in tuber shape, skin color, flesh color, depth of eyes .Visual observation was done to characterized tubers in terms of following parameters:

3.10.3.4.1 Tuber shape

Tuber shapes were varied significantly germplasm to germplasm. UPOV guidelines has been categorized potato tubers as round , short oval , long oval , long , very long (Plate 3.f.).

3.10.3.4.2 Tuber skin color

Great variations have been found in tuber skin color of different potato germplasm. According to UPOV guidelines the color of skin has been categorized as – light, yellow, red, blue, reddish brown (Plate 3.f.).

3.10.3.4.3 Tuber flesh color

Flesh color of potato tubers were varied significantly in potato germplasm .According to UPOV guidelines it has been classified as – white, cream, light yellow, medium yellow, dark yellow, red, blue.

3.10.3.4.4 Depth of eyes

Variation in depth of eyes in potato tubers were found among different germplasm. According to UPOV it has been classified as very shallow, shallow, medium, deep, very deep.

3.11 Data Analysis

The data obtained for different characters were statistically analyzed to fine out differences among potato germplasm following MSTAT-C computer package program. Significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) test at 5% level of significance.

Plate 3: a. Measurement of tuber length and diameter using Digital Calliper -515 in millimeter; b.Tuber weight measurement using Electronic Precision Balance in gram; c. Phenotypic observation; d. Plant height measurement; e. Harvesting; f.Tuber shape and skin color observation.

CHAPTER IV

RESULT AND DISCUSSION

Potato has become a high value tuber crop now-a-days. Vast tuber production create challenge for potato breeder in searching further technology concerning tuber morphology and quality. Good tuber quality paves a way to export tubers and industrial uses like french fries, chips, dehydrated can potato. However our need increases to characterize potato germplasm to find out that specific germplasm which could face this challenge. Current experiment have been conducted on growth related, yield attributing parameters and later twenty two potato germplasm have been characterize on morphological parameters by following phenotypic descriptors authorized by UPOV. The results have been discussed under following sub headings:

4.1 Growth related parameters

4.1.1 Emergence percentage

Twenty two potato germplasm were mostly emerged within 10 DAP. Emergence percentages of potato germplasm were showed significant variation (Appendix I). The emergence percentages were ranged from 91.8 to 64.4%. Maximum emergence percentage was found from G_{22} (91.8%) and minimum from G_8 (64.4%) (Table 3). Similar result also found in another experiment that showed most of the potato varieties emerged within 20 DAP and emergences of seed tubers were ranged from 28 to 97% (Awal *et al*., 2007). Qasim *et al*. (2013) found in an experiment that maximum percent emergence (88.7%) was observed in potatoes planted on plain land covered with soil from one side, while the minimum emergence (54.9%) was observed in

potatoes planted in furrows without ridges. Fareed *et al*. (2012) also studied emergence percentage and found locally developed advanced line SH-19 showed maximum emergence percentage (92.33%) which showed similar result with current experiment.

4.1.2 Plant height

Plant height showed significant variation among potato germplasm (Appendix I). Plant height empirically varied from 49.8 to 107.0 cm. The Tallest plant was found from G_1 (107.0 cm) while the shortest from G_{11} (49.8 cm) which was statistically identical with G_{12} and G_{19} (Table 3). Among twenty germplam G_1 and G_{15} can be characterized as tall plant while G_{11} potato germplasm characterized as short plant and other germplasm G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9, G_{10}, G_{12}, G_{13}, G_{14}, G_{16}, G_{17}, G_{18}, G_{19}, G_{20}, G_{21}, G_{22} were can be characterized as medium plant height according to UPOV guideline (Appendix XIII). Awal *et al*. (2007) also worked with morphological variation on potato cultivars where he found plant height varied from 37.2 cm to 76 cm which showed statistically similar with current experiment. Hasan *et al*. (2013) found that tallest plant (85.71 cm) was observed in the germplasm LB6 and the shortest (44.23 cm) in the Diamont whereas 76 cm plant height was observed in Diamont from current experiment which showed dissimilar. Houqe *et al*. (2015) found the highest plant height (69.43 cm) observed from the 'BARI TPS-1' with As_0 treatment combination. The lowest plant (26.63 cm) obtained from the 'Lady Rosetta' with 50 mg As kg^{-1}while statistically dissimilar results. Al-Abdullah *et al*. (2014) also found similar range of plant height in four CIP varieties and reported that CIP 396244.12 produced the tallest plant (73.50 cm and 69.78 cm) and CIP 391004.18 produced the smallest (51.00 cm and 51.47 cm). Plant height was found maximum 48.38 cm with FYM while minimum was 38.33 cm in control. Ayyub *et al*. (2011)

showed dissimilar result with tallest plant from current experiment. Qasim *et al*. (2013) found tallest plants (53.4 cm) in potato varieties when potatoes were sown on the ridges. Maity and Chatterjee (1977); Ahmed *et al*. (2000) also studied plant height in potato germplasm where they found variation within cultivars.

4.1.3 Chlorophyll percentage

Chlorophyll percentages (%) were varied significantly among potato germplasm (Appendix I). Percentage of chlorophyll content varied between 30.3 to 53.6%. Maximum chlorophyll content was found from G_{17} (53.5%) whereas minimum from G_{18} (30.3%) (Table 3). Variation in chlorophyll content was also observed previously in Rose (Ahmad *et al*., 2011), in Mustard (Datta *et al.,* 2011). The difference in chlorophyll percentage among the cultivars might be due to influence of the genetic makeup of cultivars. Chlorophyll is a pigment associated with photosynthesis process. The process photosynthesis has taken place only in presence of this pigment. The variation in total chlorophyll content may be a good indicator of stress in plants that have been caused by environmental factors.

4.1.4 Days to maturity

Days to maturity were varied significantly among potato germplasm (Appendix I). Maximum day to maturity was found from both G_{10} and G_{22} (96.0) and minimum from G_1 and G_4 (89.0) (Table 3). Among twenty two germplasm according to UPOV guideline G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, $G_{11,}$ G_{12}, G_{13}, G_{14}, G_{15},G_{16}, G_{17}, G_{18}, G_{19}, G_{20} can be characterized as medium days to maturity and G_9, G_{10}, G_{21}, G_{22} can be characterized as late days to maturity germplam (Appendix XIII).

Tesfaye *et al.,* (2012) found the earliest days to 50% maturity (106.91 days) was observed at the closer intra row spacing of 10 cm but it was extended (113.33 days) at the wider intra row spacing of 40 cm. For earthing up, the earliest days to 50% maturity (108.75 days) was occurred at the control (no earthing up) treatment but it was extended (112.33 days) at earthing up of 15 days after complete plant emergence which showed dissimilar result with present study. Masarirambi *et al*., (2012); Dam *et al*., (1999); Musa *et al*., (2009) also observed days to maturity where they found similar result with present study.

4.1.5 Number of stems hill^{-1}

Numbers of stems hill^{-1} showed significant variation among potato germplasm (Appendix II). Number of stems hill^{-1} was found ranged from 5.00 to 1.33. Maximum stems hill^{-1} was found from G_{19} (5.00) while minimum from G_{11} (1.33) (Table 3). According to UPOV guidelines it can be characterized that among twenty two germplasm G_4, G_{13}, G_{14} were found medium number of stems hill^{-1} and rest of germplasm G_1, G_2, G_3, G_5, G_6, G_7, G_8, G_9, G_{10}, $G_{11,}$ G_{12}, G_{15},G_{16}, G_{17}, G_{18}, G_{19}, G_{20} G_{21}, G_{22} can be characterized as few number of stems hill^{-1} (Appendix XIII). Similar result also found in a research where this range varied from 3.5 to 1.9 (Qasim *et al.* 2013). Awal *et al*. (2007) found the sprouts produced per hill ranged from 2.73 in the variety Ladyolympic to 8.53 in Diamont which is statistically dissimilar with 4.667 number of stem per hill in Diamont variety. Ayyub *et al*. (2001) found maximum number of stem per plant was 5.13 with the application of sulphate of potash while minimum was found 4 with the application of Murate of potash and in control it was 4.06. Shayanowako *et al*. (2014); Khan *et al*. (2012); Amanullah *et al*. (2010) also studied number of stem per hill where they found variation within potato germplasm.

Number of stem hill^{-1} affect total number of leaves which subsequently produce more photosynthates that affect final yield of tubers.

4.1.6 Number of leaves hill^{-1}

Number of leaves hill^{-1} showed variation in twenty two potato germplasm (Appendix II). It ranged from 58.3 to 29.9. Maximum number of leaves was found from G_9 (58.3) and minimum from G_{13} (29.9) (Table 3). Haque *et al*. (2015) found maximum number of leaves in Jam alu (167.3) and minimum number of leaves found in courage (26.67) where as in current experiment number of leaves per plant was recorded in jam alu 45.3 and in courage it was found 40.7 which showed dissimilar result.Khan *et al*. (2012) found number of leaves per hill variation in potato germplasm and found it varied from 75 to 126 within different germplasm. Ayyub *et al.* (2001) also observed maximum number of leaves 42.46 with application of ½ MP and ½ FYM which showed similar result. Number of leaves affect net tuber yield.

4.1.7 Number of tubers hill^{-1}

Number of tuber/hill varied significantly among twenty two potato germplasm (Appendix II). The current study revealed that tuber number per hill was varied from 17 to 4. The highest number of tuber found in G_4 (17) and lowest found in G_{12} (4). The highest tuber number (57.52) per plant was found in 'Daisy' germplasm and the lowest number of tubers (8.82) per plant was recorded in red varieties found by (Karim *et al*., 2011).that support current experiment. Tuber number per plant ranged from 5.76 to 10.80 in 2010-11 and 7.23 to 10.42 in 2011-12, respectively found by (Mahmud *et al*. 2014). Maity and Chatterjee (1977); Mamun *et al*. (2016); Ranjbar *et al*. (2012) also observed variation in different potato germplasm.

Table 3. Performance of potato germplasm to different growth attributes**

*Germplasm	Emergence (%)	Plant height (cm)	Chlorophyll percentage (%)	Days to maturity	No. of stems hill^{-1}	No. of leaves hill^{-1}	No. of tuber hill^{-1}
G_1	86.3 d	107.0 a	39.2 e	89.0 f	2.3 fghi	40.1 cde	08 df
G_2	84.5 e	98.0 bcd	50.0 b	90.0ef	2.3 fghi	40.7 cde	04 h
G_3	82.9 f	98.7 abc	46.1 c	89.3 f	3.0 efg	42.1 cde	13 b
G_4	82.3 f	85.0 efg	40.3 de	89.0 f	4.0 bcd	44.7 bcd	17 a
G_5	84.5 e	87.0 ef	46.0 c	90.0 ef	3.7 cde	45.3 bcd	14 a
G_6	72.4 i	89.7 cde	39.4 e	92.3 d	2.3 fghi	40.2 cde	16 a
G_7	79.2 g	92.3 cde	43.7 c	91.3 de	3.0 efg	41.2 cde	09 cd
G_8	64.6 j	64.3 j	45.9 c	92.3 d	2.3 fghi	34.6 ef	10 c
G_9	79.3 g	93.3 bcde	51.0 ab	95.7 ab	3.7 cde	58.3 a	06 fg
G_{10}	82.0 f	92.7 cde	52.3 ab	96.0 a	2.3 fghi	46.3 bc	06 fg
G_{11}	79.7 g	49.8 k	40.5 de	94.0 c	1.3 i	33.8 ef	05 gh
G_{12}	76.2 h	55.1 k	40.5 de	95.7 ab	2.0 ghi	37.4 cdef	04 h
G_{13}	88.0 c	76.0 hi	44.2 c	92.0 d	4.7 ab	29.9 f	07 ef
G_{14}	91.0 ab	78.4 fgh	43.2 cd	89.7 f	4.3 abc	46.4 bc	09 cd
G_{15}	87.7 cd	101.9 ab	35.1 f	94.3 bc	3.0 efg	40.7 cde	14 b
G_{16}	82.7 f	88.7 de	44.7 c	90.0 ef	3.0 efg	42.0 cde	10 c
G_{17}	86.7 d	71.7 hij	53.5 a	95.7 ab	3.0 efg	40.7 cde	09 cd
G_{18}	90.1 b	68.7 ij	30.3 g	91.3 de	2.7 efgh	40.7 cde	08 de
G_{19}	89.5 b	50.0 k	45.6 c	91.7 d	5.0 a	53.8 ab	09 cd
G_{20}	78.4 g	75.5 hi	43.8 c	91.4 de	1.7 hi	36.2 def	08 de
G_{21}	90.7 ab	72.4 hij	53.6 a	95.0 abc	3.3 def	43.2 cde	08 de
G_{22}	91.8 a	76.3 ghi	40.5 de	96.0 a	3.0 efg	39.9 cde	10 c
CV%	**1.1**	**6.2**	**4.05**	**0.87**	**18.2**	**12.18**	**10.77**
LSD(0.05)	**1.5**	**8.3**	**2.94**	**1.32**	**0.9**	**8.37**	**1.65**

**In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

* G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

4.2 Yield attributing parameters

4.2.1 Tuber length

Tuber lengths were varied significantly among potato germplasm (Appendix III). Among 22 potato germplasm it has been observed that some potato tubers were large sized while some were found medium and others were small sized. Maximum tuber length among the large sized tubers was found in G_{14} (8.3 cm) while 7.0 cm was found in medium sized tubers in G_{16} and maximum tuber length among small sized tubers was found in G_{16} (4.0 cm). Minimum tuber length among the large sized tubers was found in G_{19} (6.2 cm) which was statistically identical with $G_{11,}$ G_{17} ,G_{21} and G_{22} while G_3 (3.3 cm) showed minimum length among medium sized tubers which was statistically identical with G_{12} and minimum tuber length among small sized tubers was found in G_{13} (2.2 cm) which was statistically identical with G_{11} (Table 4). Hasan *et al*. (2013) also studied tuber length within potato clones which shows statistical identical results. Ganga *et al.* (2014) also found statistically similar result and found tubers mean length varied significantly ($p \leq 0.01$) between the cultivars ranging from 5.9 cm in J/99-242 to 7.6 cm in Kufri Ashoka. Tuber length is a crucial criteria to establish a potato industry. Large sized tubers are considered in French fry making industry while medium sized tubers can be used in chips making industry and small sized tubers could be considered as using in canned and dehydrated product making industry.

4.2.2 Tuber diameter

Tuber diameters were varied significantly among potato germplasm (Appendix IV). Among 22 potato germplasm it has been observed that some potato tubers were large sized while some found medium and others were small sized. Maximum Tuber diameter among the large sized tubers was found in G_{18} and G_{21} (59.4 mm) while 49.4 mm found in G_{17} in medium sized tubers and maximum Tuber diameter among small sized tubers found in G_{15} 34.4 (mm). Minimum tuber diameter among the large sized tubers was found in G_5 (29.9 mm) while G_8 (23.6 mm) showed minimum tuber diameter among medium sized tubers which was statistically identical with G_4 and minimum tuber diameter among small sized tubers was found in G_{12} (14.5 mm) which was statistically identical with G_5 and G_8 (Table 4). Among twenty two germplasm G_1, G_2, G_3, G_6, G_9, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, $G_{19,}$ G_{21}, G_{22} these potato germplasm found tuber diameter within 40 to 50 mm so these germplasm could be characterized as a potential germplasm for making French fry and chips while rest of germplasm can be used in canned and dehydrated product (Appendix XIV). Pulok *et al*. (2016) studied tuber diameter for grading potato tubers in small, medium, large size. An in–row spacing of 25 cm can be used by seed producers since the highest number of medium sized tuber was obtained in the study found by (Mangani *et al*., 2015). Taha (1961);Rumhungwe *et al*. (2016) ; Khan *et al*. (2011) also studied tuber size and they found variation in tuber diameters. Bansal and Trehan (2011) conducted an experiment on the potassium nutrition influences tuber size. Tuber diameter also observed by Lopes *et al*. (2013) to classify tubers in different classes. Tuber diameter is an important criterion to determine a germplasm for industrial uses. The tubers of 6-8cm diameter are preferred for making chips .Round shape is preferred to produce

uniformly round chips .For French fries the oblong or long (more than 90 mm in length) tubers are desired. Eye depth is an inherited trait of a cultivar and should be shallow so that peeling loss is low before slicing.

4.2.3 Percentage of tubers hill^{-1}

Percentage of tubers showed variation among twenty two potato germplasm (Appendix V). The highest amount of larger tubers found in G_{12}, G_{13} and lowest amount found in G_7 and G_8. The highest amount of medium tubers found in G_{10} and lowest amount found in G_6. The highest amount of smaller tubers found in G_6 and G_7 and lowest amount found in G_{13} (Table 4).

Table 4: Performance of potato germplasm on yield attributing characteristics: Tuber length, tuber diameter and percentage of tubers hill^{-1}:**

*Germplasm	Tuber length (cm)			Tuber diameter (mm)			Percentage of tuber		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
G_1	8.0 abc	5.6 c	3.5 cd	53.8 bcd	43.1 c	29.4 d	13 i	32 d	55.0 d
G_2	8.2 ab	6.2 b	3.3 de	54.9 b	45.2 b	24.9 e	25 d	25 f	50.0 e
G_3	3.8 k	3.3 j	1.9 i	50.1 f	25.7 j	15.8 i	21 ef	42 b	37.0 i
G_4	7 .0 f	4.8 de	3.6 c	34.1 k	24.5 kl	19.4 h	25 d	32 d	42.0 g
G_5	5.3 i	4.1 fgh	3.0 f	29.9 l	24.8 jk	15.0 j	40 b	27 e	33.0 j
G_6	4.5 j	4.3 efg	2.6 g	53.5 cd	34.1 g	33.8 b	06 k	19 i	76.0 a
G_7	5.8 h	3.8 hi	3.0 f	39.2 i	34.7 g	33.3 b	04 l	21 h	76.0 a
G_8	3.1 l	1.9 k	1.0 k	29.5 l	23.6 l	14.5 j	04 l	23 g	74.0 b
G_9	6.9 f	3.8 hi	2.9 f	50.2 f	33.7 g	25.0 e	14 i	43 b	43.3 g
G_{10}	8.0 abc	5.0 d	3.0 f	47.4 g	29.3 i	19.4 h	16 h	50 a	34.0 j
G_{11}	6.2 g	4.0 gh	2.0 hi	39.4 i	34.5 g	19.3 h	40 b	40 c	20.0 l
G_{12}	4.8 j	3.4 ij	1.5 j	37.4 j	24.9 jk	14.5 j	50 a	25 f	25.0 k
G_{13}	7.8 cd	3.9 gh	2.2 h	51.6 e	31.4 h	22.3 g	50 a	33 d	17.0 m
G_{14}	8.3 a	6.4 b	3.1 ef	54.5 bc	42.4 c	23.1 f	08 j	25 f	67.0 c
G_{15}	7.6 de	6.0 bc	3.8 abc	53.1 d	45.4 b	34.4 a	19 g	25 f	56.0 d
G_{16}	8.0 abc	7.0 a	4.0 a	53.4 cd	38.9 e	31.4 c	30 c	20 hi	50.0 e
G_{17}	6.4 g	4.8 de	3.9 ab	54.8 b	49.4 a	29.6 d	22 e	33 d	45.0 f
G_{18}	7.2 ef	4.0 gh	3.6 cd	59.4 a	41.3 d	31.0 c	14 i	43 b	43.0 g
G_{19}	6.2 g	4.5 def	3.1 ef	51.4 e	42.7 c	29.4 d	22 e	33 d	45.0 f
G_{20}	7.8 bcd	4.9 d	3.7 bc	44.5 h	34.0 g	19.4 h	20 fg	40 c	40.0 h
G_{21}	6.2 g	5.6 c	3.7 c	59.4 a	37.5 f	33.3 b	20 fg	40 c	40.0 h
G_{22}	6.4 g	3.7 hij	3.0 f	54.4 bc	39.5 e	29.7 d	20 fg	40 c	40.0 h
CV %	**3.3**	**5.7**	**5**	**1.3**	**1.7**	**1.3**	**4.64**	**3.17**	**2.06**
$LSD_{(0.05)}$	**0.4**	**0.4**	**0.2**	**1.1**	**1**	**0.5**	**1.67**	**1.68**	**1.55**

**In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

** G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

4.2.4 Individual tuber weight

Individual tuber weights were varied significantly among potato germplasm (Appendix VI). Maximum weight within large sized single tubers was found in G_{14} (195.1 g) and maximum tuber weight within medium sized single tubers was found was found in G_{16} (60.8 g) while maximum tuber weight in small single tubers was found in G_{20} (38.5 g). Whereas minimum weight in large single tubers was found in G_3 (17.9 g) and G_5 (19.0g) which followed by G_8 (25.1 g) and G_{11}(31.3 g), minimum weight in medium single tuber weight was found in G_5 (8.1 g) and minimum weight in small single tubers was found in G_5 (4.7 g) (Table 5). Awal *et al*. (2007) found variation in individual tuber weight. Maximum large sized tubers were produced by 150 kg ha^{-1} with rice straw mulch and application of 125 kg ha^{-1} with rice straw produced maximum seed potato and tuber for French fry studied by (Pulok *et al*., 2016). Average tuber weight of potato plant contributed maximum (31.76%) studied by (Datta *et al*., 2015).

4.2.5 Yield $hill^{-1}$

Potato yield $hill^{-1}$ was varied significantly among potato germplasm (Appendix VII). Maximum yield $hill^{-1}$ was found from G_{19} (0.8 kg) followed by G_2, G_9, G_{10} and G_{13} whereas minimum from G_3, G_4, G_7, G_8 (0.1 kg) which was statistically similar with rest of the germplasm (Table 5). It was observed that tuber yield per hill were gradually increased when tuber were harvested later. It varied sixty days to eighty days after planting and the variation are changed when potatoes are harvested lately.

4.2.6 Yield ha^{-1}

Potato yield per hector were varied significantly among potato germplasm (Appendix VII). Maximum yield t/ha was found from G_{13} (29.9 t ha^{-1}) while minimum from G_8 (12.3 t ha^{-1}) (Table 5). The highest tuber yield (20.0 t ha^{-1}) was recorded in the Variety Diamant followed by Markies, Espirit and Ladyrosetta while the lowest was recorded in the Eldina (9.2 t ha^{-1}) which statistically support current experiment (Awal *et al*., 2007). The highest yield (49.69 t ha^{-1}) was produced by LB-7 followed by LB3 seen by (Hasan *et al*., 2013). The interaction between planting date and density had no significant effect on the yield *(p*<5%).However, planting dates, May 15 and 25 cm density of the product was obtained the highest yield (29.92 t ha^{-1}) observed Taheri *et al*. (2013) that showed similar result with present study. Higher yield increase was observed in all germplasm in well watered control condition and ranging from 25.79 to 32.57 t ha^{-1} in 2010-11 and 22.08 to 28.61 t ha^{-1} in 2011-12. (Mahmud *et al*., 2014). Ahmed *et al*. (2000) observed yield in cardinal variety which shows dissimilar results. Yield was found to increase with the increase in seed tuber size and the maximum yield (39.34 t ha^{-1}) was obtained from the large seeds (17.5g) found by (Sultana *et al.,* 2001).

Table 5. Performance of twenty two potato germplasm on yield related characteristics::Individual tuber weight, yield hill^{-1}and yield ha^{-1} **:

*Germplasm	Individual tuber weight (g)			Yield hill^{-1} (kg)	Yield ha^{-1}(t)
	Large	Medium	Small		
G_1	87.7 g	42.5 e	16.4 gh	0.3 b	28.6 b
G_2	99.3 ef	52.4 cd	18.3 ef	0.5 ab	24.9 fg
G_3	17.9 p	9.8 j	3.7 n	0.1 b	26.3 d
G_4	46.9 jk	34.6 f	26.3 c	0.1 b	25.1 efg
G_5	19.0 p	8.1 j	04.7 n	0.3 b	27.8 bc
G_6	50.8 jk	22.5 h	10.3 jk	0.2 b	26.1 de
G_7	36.8 mn	16.4 i	10.5 jk	0.1 b	15.0 m
G_8	25.1 op	20.9 h	15.5 h	0.1 b	12.3 n
G_9	44.4 kl	33.9 f	6.9 m	0.5 ab	24.4 g
G_{10}	39.2 lm	28.8 g	24.6 cd	0.4 ab	24.5 fg
G_{11}	31.3 no	16.7 i	09.8 jkl	0.3 b	27.5 c
G_{12}	33.2 mn	15.6 i	08.2 lm	0.3 b	25.2 efg
G_{13}	93.6 fg	20.1 h	09.2 kd	0.5 ab	29.9 a
G_{14}	195.1 a	55.4 b	13.1 i	0.4 ab	26.4 d
G_{15}	140.3 c	53.5 bc	23.3 d	0.3 b	21.5 ij
G_{16}	115.2 d	60.8 a	28.7 b	0.3 b	22.5 hi
G_{17}	173.2 b	50.3 d	18.2 ef	0.3 b	20.8 jk
G_{18}	63.3 i	34.2 f	17.3 fg	0.3 b	19.9 k
G_{19}	52.1 j	34.0 f	19.6 e	0.8 a	18.0 l
G_{20}	72.5 h	54.9 b	38.5 a	0.4 ab	25.5 def
G_{21}	103.4 e	52.5 cd	25.0 cd	0.3 b	20.7 jk
G_{22}	92.1 fg	30.1 g	11.5 ij	0.3 b	22.7 h
CV%	**5.7**	**4**	**6.4**	**6.9**	**2.5**
$LSD_{(0.05)}$	**6.9**	**2.2**	**1.7**	**0.4**	**1**

**In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

*G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

4.3 Phenotypic parameters

4.3.1 Sprout characteristics

Sprouts were varied in size, shape, anthocyanin coloration at base and intensity of anthocyanin coloration at base. Visual observation was done to characterized sprout characters in terms of following parameters:

4.3.1.1 Sprout size

Miniscule part of potato tuber that produce viability to germinate into a new plant. According to UPOV guidelines the sprouts size has been categorized as –small, medium and large (Appendix VIII). Among 22 potato germplasm G_1, G_3, G_6, G_8, G_{20} these potato germplasm can be categorized as small while G_2, G_4, G_5, G_7, G_9, G_{10}, G_{22} and G_{11}, G_{12}, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, G_{19}, G_{21} can be categorized as medium and large, respectively (Table 6); (Plate 4) .

4.3.1.2 Sprout shape

Different pattern in tuber shape can be observed in wide range of potato germplasm. According to UPOV guidelines the sprouts shape has been categorized as- spherical, ovoid, conical, narrow cylindrical, broad cylindrical (Appendix VIII). Among 22 potato germplasm G_3, G_6, G_8, G_{11}, G_{12}, G_{13}, G_{15}, G_{18}, G_{20} these potato germplasm can be categorized as spherical. G_1, G_2, G_5, G_{16}, G_{17}, G_{21}, G_{22} can be categorized as ovoid G_7 as conical and G_9, G_{10}, G_{14}, G_{19} were as broad cylindrical. G_4 as narrowly cylindrical type (Table 6); (Plate 4).

4.3.1.3 Anthocyanin coloration at base

According to UPOV guidelines anthocyanin coloration at base has been categorized as-red –violet and blue – violet (Appendix VIII). Among 22 potato germplasm $G_{1,}$ G_2, $G_{3,}$ G_5, $G_{6,}$ G_8, G_{14}, G_{17}, G_{18}, G_{22} and $G_{4,}$ G_7, $G_{9,}$ G_{10}, G_{11}, $G_{12,}$ G_{13}, G_{15}, $G_{16,}$ G_{19}, G_{20}, G_{21} potato germplasm can be categorized as red –violet and blue – violet, respectively (Table 6); (Plate 4).

4.3.1.4 Intensity of anthocyanin colorartion at the base

Wide range of anothocyanin concentration can be found within different potato germplasm. According to UPOV guidelines intensity of anthocyanin coloration at base of sprouts has been categorized as-very weak, weak Medium, strong and very strong (Appendix VIII). Among 22 potato germplasm G_{20} can be categorized as very weak, G_7 as weak G_2, $G_{3,}$ $G_{6,}$ $G_{8,}$ $G_{11,}$ $G_{12,}$ $G_{15,}$ $G_{18,}$ $G_{19,}$ $G_{21,}$ G_{22} as medium .$G_{4,}$ $G_{13,}$ $G_{14,}$ $G_{16,}$ G_{17} as strong and $G_{1,}$ $G_{5,}$ $G_{9,}$ G_{10} as very strong intensity of anthocyanin coloration at base of sprouts (Table 6); (Plate 4).

Table 6. Morphological characterization of twenty two potato germplasm :Sprout Characteristics:

Characteristics	Types	Germplasm*
Sprouts size	Small	G_1, G_3, G_6, G_8, G_{20}
	Medium	G_2, G_4, G_5, G_7, G_9, G_{10}, G_{22}
	Large	G_{11}, G_{12}, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, G_{19}, G_{21}
Sprouts shape	Spherical	G_3, G_6, G_8, G_{11}, G_{12}, G_{13}, G_{15}, G_{18}, G_{20}
	Ovoid	G_1, G_2, G_5, G_{16}, G_{17}, G_{21}, G_{22}
	Conical	G_7
	Broad Cylindrical	G_9, G_{10}, G_{14}, G_{19}
	Narrowly Cylindrical	G_4
Anthocyanin coloration at base	Red –violet	G_1, G_2, G_3, G_5, G_6, G_8, G_{14}, G_{17}, G_{18}, G_{22}
	Blue – violet	G_4, G_7, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{15}, G_{16}, G_{19}, G_{20}, G_{21}
Intensity of anthocyanin coloration at base	Very weak	G_{20}
	Weak	G_7
	Medium	G_2, G_3, G_6, G_8, G_{11}, G_{12}, G_{15}, G_{18}, G_{19}, G_{21}, G_{22}
	Strong	G_4, G_{13}, G_{14}, G_{16}, G_{17}
	Very strong	G_1, G_5, G_9, G_{10}

* G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

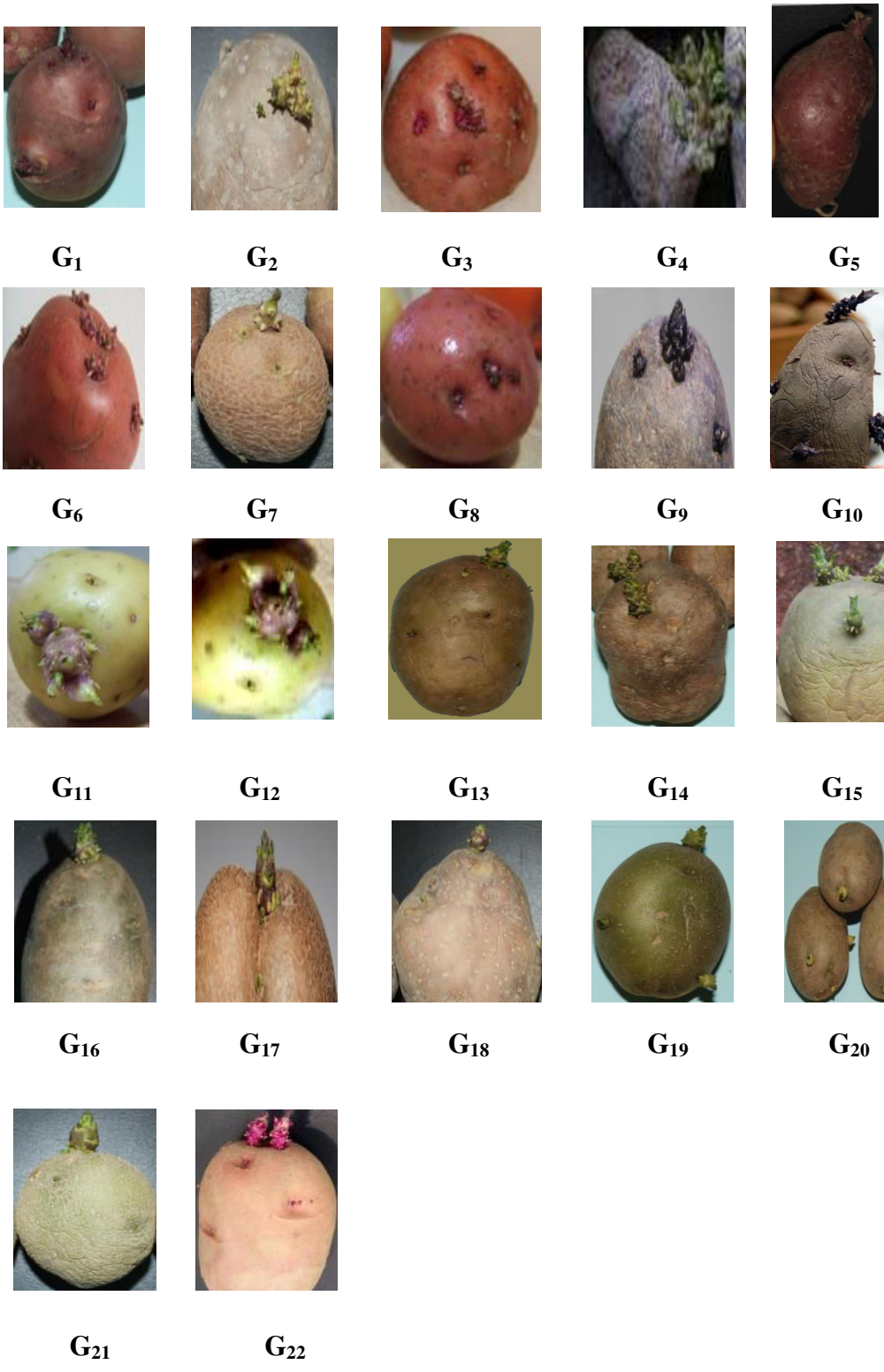

Plate 4. Color and size variation are showing in twenty two potato germplasm (G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53)

4.3.2 Leaf characteristics

Variation have found in leaf color, terminal leaves pattern, lateral leaf pattern, presence of secondary leaflets and amount of terminal three leaf coalescence. Morphological characterization of potato leaves were also observed by (Kesaulya *et al*., 2015). Leaves are one of the most conspicuous and important organs of all seed plants. A fundamental source of morphological diversity in leaves is the degree to which the leaf is dissected by lobes found by (Holtan *et al.,* 2003). Leaves were also varied in different shape and size. Leaf morpho-anathomical characteristics have been studied by (Bisognin *et al*., 2006). Leaf stalk of twenty two potato germplasm can be characterized on the basis of following parameters:

4.3.2.1 Leaf openness

It is defined as how leaves were combined or arranged on a certain leaf stalk. UPOV guidelines categorized leaf openness as closed, open, intermediate type (Appendix IX). Among 22 potato germplasm $G_{2,}$ $G_{4,}$ $G_{9,}$ $G_{10,}$ $G_{13,}$ G_{22} these 6 potato germplasm showed firm attachment within primary leaves. Primary leaves were densely connected to the midrib so they can be categorized as closed type of leaf openness. Primary leaves were distantly arranged around the midrib. $G_{3,}$ $G_{6,}$ $G_{8,}$ $G_{11,}$ $G_{12,}$ $G_{17,}$ $G_{19,}$ G_{20} these 8 potato germplasm can be categorized as opened type of leaf openness. Another type of leaf openness have found in potato germplasm among 22 germplasm. Primary leaves around the midrib were observed moderately arranged neither densely nor sparsely. $G_{1,}$ $G_{5,}$ $G_{7,}$ G_{14}, G_{15}, $G_{16,}$ $G_{18,}$ G_{21} these germplasm can be categorized as intermediate type of leaf openness (Table 7); (Plate 5).

4.3.2.2 Intensity of green color

Intensity of green color are showed variation which can be an important characteristics to determined a particular germplasm. According to UPOV guidelines the intensity of color has been classified as light, medium and dark color (Appendix IX). Among 22 potato germplasm G_3,G_6, G_8, G_{11}, G_{12}, G_{15}, G_{16}, G_{18} can be categorized as light where G_1, G_2, G_{13}, G_{14}, G_{19}, G_{21},G_{22} can be categorized as dark color and G_4, G_5, G_7, G_9, G_{10}, G_{17},G_{20} can be categorized as medium level of green color (Table 7); (Plate 5).

4.3.2.3 Presence of secondary leaflets

The tiny inconspicuous rudimentary or tertiary leaflets can also be evident on the base of secondary leaflets. UPOV guidelines categorized as weak, strong and medium type (Appendix IX). G_1, G_4, G_6, G_7, G_8, G_{11}, G_{12}, G_{13}, G_{19}, G_{20}, G_{22} these 12 germplasm among 22 potato germplasm could be fallen in weak type presence of secondary leaflets as these germplasm were showed limited number of secondary leaflets. Only G_{18} germplasm showed overcrowding presence of secondary leaflet so this can be categorized as strong type. Among 22 potato germplasm G_2, G_3, G_5, G_9, G_{10},G_{14},G_{15}, G_{16}, G_{17}, G_{21} above listed ten potato germplasm were found average amount of secondary leaflet so they have been categorized as medium and G_{18} found as strong.(Table 7); (Plate 5).

4.3.2.4 Frequency of secondary leaflets

According to UPOV guidelines potato leaflets have been categorized as nil or very low, low, medium, high, very high (Appendix IX). Frequencies of secondary leaflets were varied germplasm to germplasm. Among 22 potato germplasm G_2, G_3, G_4, G_8,

G_{11}, G_{12}, G_{16}, G_{19}, G_{20} can be characterized as low type while G_1, G_7, G_{15}, G_{21}, G_{22} can be characterized as medium and G_5, G_6, G_9, G_{10}, G_{13}, G_{14}, G_{17}, G_{18} in high type frequency of secondary leaflets (Table 7); (Plate 5).

4.3.2.5 Frequency of leaf coalescence

According to UPOV guidelines it is categorized as coalescent and not coalescent type (Appendix IX). Among 22 potato germplasm in these 20 germplasm G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{15}, G_{16}, G_{17}, G_{19}, G_{20}, G_{21} , G_{22} terminal leaves were loosely unite with each other so they could be categorized as not coalescent pattern of terminal leaves. Moreover in G_{14} and G_{18} terminal three leaves were closely attached to form a group of leaves so they can be categorized as Coalescent type leaf pattern (Table 7); (Plate 5).

4.3.2.6 Terminal leaflet shape

According to UPOV guidelines it has been categorized as narrowly ovate, medium ovate, broadly ovate, lanceolate, elliptical, obovate and oblong (Appendix X). In present experiment G_4, G_5, G_6, G_8 can be categorized in narrowly ovate leaf. G_2, G_{14}, G_{15}, G_{16}, G_{17} can be categorized as medium ovate. G_1, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{19}, G_{20}, G_{21}, G_{22} these were observed as broadly ovate and G_3, G_7, G_{18} can be categorized as elliptical leaf shape type (Table 7); (Plate 5).

4.3.2.7 Terminal leaflet tip shape

UPOV categorized them as – acute, cuspidate, acuminate, obtuse and other. They have been categorized on the basis of visual observation (Appendix X). Among 22 potato germplasm G_2, G_4, G_5, G_6, G_8 , G_{14},G_{15}, G_{16}, G_{17} were observed as acuminate terminal leaf shape while G_1, G_9, G_{10}, G_{11}, G_{12}, G_{13} , G_{19}, G_{20}, G_{21}, G_{22} were categorized

as cuspidate tip shape and acute category have found within G_3, G_7, G_{18} potato germplasm (Table 7); (Plate 5).

4.3.2.8 Terminal leaflet base shape

According to UPOV it has been categorized as cunneate, acute, obtuse, cordate, truncate lobed on the basis of visual observation (Appendix X). Among 22potato germplasm G_4, G_5, G_6, G_8 can be fallen under obtuse base category. G_2,G_{14}, G_{15}, G_{16}, G_{17} can be categorized as cordate base shape. G_9, G_{10}, G_{11}, G_{12}, G_{13},G_{19}, G_{20}, G_{21}, G_{22} can be categorized as lobed base shape while G_1, G_3, G_7, G_{18} were found cunneate type terminal leaf base shape (Table 7); (Plate 5).

4.3.2.9 Lateral leaflet shape

According to UPOV guidelines it has been categorized as narrow, medium, broad (Appendix X).Among 22 potato germplasm it can be categorized as narrow in V_8, V_9, G_{10}. Medium found in G_4 , G_5, G_7, G_{11}, G_{12}, G_{17} and broad shape found in G_1, G_2, G_3, G_6, G_{13}, G_{14}, G_{15}, G_{16}, G_{18}, G_{19}, G_{20}, G_{21}, G_{22} (Table 7); (Plate 5).

4.3.2.10 Lateral leaflet tip shape

According to UPOV it has been categorized as acute, cuspidate, acuminate, and obtuse (Appendix X). Among 22 potato germplasm G_8 , G_9, G_{10} have categorized as acute tip while G_4 , G_5 ,G_7,G_{11} , G_{12} ,G_{17} have categorized as acuminate and G_1,G_2,G_3,G_6 , G_{10} , G_{13} , G_{14}, G_{15} , G_{16}, G_{18} , G_{19} , G_{20} , G_{21} , G_{22} germplasm can be categorized as cuspidate lateral leaflet tip shape (Table 7); (Plate 5).

4.3.2.11 Lateral leaflet base shape

According to UPOV it has been categorized as – cuneate, acute, obtuse, cordate, truncate, lobed (Appendix X). Among 22 potato germplasm G_8, G_9, G_{10} have categorized as obtuse base. G_4 , G_5 ,G_7, G_{11} , G_{12} ,G_{17} have been categorized as truncate base while G_1, G_2, G_3, G_6, G_{10}, G_{13}, G_{14}, G_{15}, G_{16}, G_{18}, G_{19}, G_{20}, G_{21}, G_{22} germplasm can be categorized as cordate base (Table 7); (Plate 5).

4.3.2.12 Size of secondary leaflets

According to UPOV guidelines size of secondary leaflets as were categorized – small, medium, large, mixed (Appendix X). Among 22 potato germplasm it can be categorized as small which found in G_1, G_8, G_{21}, G_{22} germplasm. Medium found in G_2, G_3, G_4, G_5, G_6, G_7, G_{11}, G_{12}, G_{15}, G_{16}, G_{17}, G_{19}, G_{20} and mixed size found in G_9, G_{10}, G_{13}, G_{14}, G_{18} potato germplasm (Table 7); (Plate 5).

4.3.2.13 Number of primary leaflet pairs

Among 22 potato gemplasm two pairs of primary leaflets were found in G_8, G_{11}, G_{12}, G_{16}. Three pairs of primary leaflets were found in G_1, G_3, G_7, G_{17}, G_{21}, G_{22} . Four pairs of secondary leaflets were found in G_2 , G_3 , G_4 , G_5 ,G_9 ,G_{10}, G_{15} and five pairs of primary leaflets were found in G_6 , G_{13}, G_{14}, G_{18}, G_{19}, G_{20} potato germplasm (Table 7); (Plate 5).

Table 7. Morphological characterization of twenty two potato germplasm - Leaf Characteristics:

Characteristics	Types	Germplasm*
Leaf openness	Closed	G_2, G_4, G_9, G_{10},G_{13},G_{22}
	Intermediate	G_3, G_6, G_8, G_{11}, G_{12}, G_{17}, G_{19}, G_{20}
	Opened	G_1, G_5, G_7, G_{14}, G_{15}, G_{16}, G_{18}, G_{21}
Leaf intensity of green color	Light	G_3, G_6,G_8, G_{11}, G_{12},G_{16}
	Medium	G_4, G_5, G_7, G_9, G_{10}, G_{17},G_{20}
	Dark	G_1, G_2,G_{13}, G_{14}, G_{19},G_{21}, G_{22}
Presence of secondary leaflets	Weak	G_1, G_4,G_6 , G_7 ,G_8 , G_{11}, G_{12}, G_{13} , G_{19}, G_{20}, G_{22}
	Medium	G_2, G_3,G_5,G_9,G_{10}, G_{14}, G_{15}, G_{16}, G_{17}, G_{21}
	Strong	G_{18}
Frequency of secondary leaflets	Low	G_2, G_3, G_4, G_8 , G_{11}, G_{12}, G_{16}, G_{19}, G_{20}
	Medium	G_1, G_7, G_{15}, G_{21}, G_{22}
	High	G_5, G_6, G_9, G_{10},G_{13}, G_{14}, G_{17}, G_{18}
Frequency of leaf coalescence	Coalescent	G_{14}, G_{18}
	Not coalescent	G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9,G_{10}, G_{11}, G_{12}, G_{13}, G_{15}, G_{16}, G_{17}, G_{19}, G_{20}, G_{22} , G_{22}
Terminal leaflet Shape	Narrowly ovate	G_4, G_5, G_6, G_8
	Medium ovate	G_2, G_{14}, G_{15}, G_{16}, G_{17}
	Broadly ovate	G_1, G_9,G_{10}, G_{11}, G_{12}, G_{13}, G_{19}, G_{20}, G_{21}, G_{22}
	Elliptical	G_3, G_7, G_{18}
Terminal leaflet : Tip shape	Acute	G_3, G_7,G_{18}
	Cuspidate	G_1, G_9,G_{10},G_{11},G_{12}, G_{13} , G_{19},G_{20}, G_{21},G_{22}
	Acuminate	G_2, G_4,G_5,G_6, G_8 , G_{14},G_{15}, G_{16},G_{17}
Terminal leaflet : Base shape	Cuneate	G_1,G_3, G_7,G_{18}
	Obtuse	G_4,G_5,G_6, G_8
	Cordate	G_2 ,G_{14},G_{15}, G_{16}, G_{17}
	Lobed	G_9,G_{10},G_{11}, G_{12},G_{13}, G_{19} , G_{20},G_{21},G_{22}
Lateral leaflet Shape	Narrow	G_8, G_9,G_{10}
	Medium	G_4 , G_5, G_7, G_{11}, G_{12},G_{17}
	Broad	G_1, G_2, G_3, G_6, G_{10}, G_{13}, G_{14},G_{15}, G_{16},G_{18}, G_{19} , G_{20}, G_{21}, G_{22}
Lateral leaflet : Tip shape	Acute	G_8, G_9,G_{10}
	Acuminate	G_4 , G_5, G_7, G_{11}, G_{12},G_{17}
	Cuspidate	G_1, G_2, G_3, G_6, G_{10}, G_{13}, G_{14},G_{15}, G_{16},G_{18}, G_{19} , G_{20}, G_{21}, G_{22}
Lateral leaflet : Base shape	Obtuse	G_8, G_9,G_{10}
	Truncate	G_4 , G_5, G_7, G_{11}, G_{12},G_{17}
	Cordate	G_1, G_2, G_3, G_6, G_{10}, G_{13}, G_{14},G_{15}, G_{16},G_{18}, G_{19} , G_{20}, G_{21}, G_{22}
Number of primary leaflet pairs	Two pairs	G_8, G_{11},G_{12}, G_{16}
	Three pairs	G_1, G_3, G_7, G_{17}, G_{21}, G_{22},
	Four pairs	G_2, G_4,G_5, G_9, G_{10}, G_{15}
	five pairs	G_6,G_{13}, G_{14}, G_{18}, G_{19}, G_{20}
Size of secondary leaflets	Small	G_1, G_8, G_{21}, G_{22}
	Medium	G_2, G_3,G_4, G_5, G_6 , G_7, G_{11},G_{12}, G_{15} , G_{16},G_{17}, G_{19},G_{20}
	Mixed	G_9, G_{10},G_{13},G_{14}, G_{18}

* G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

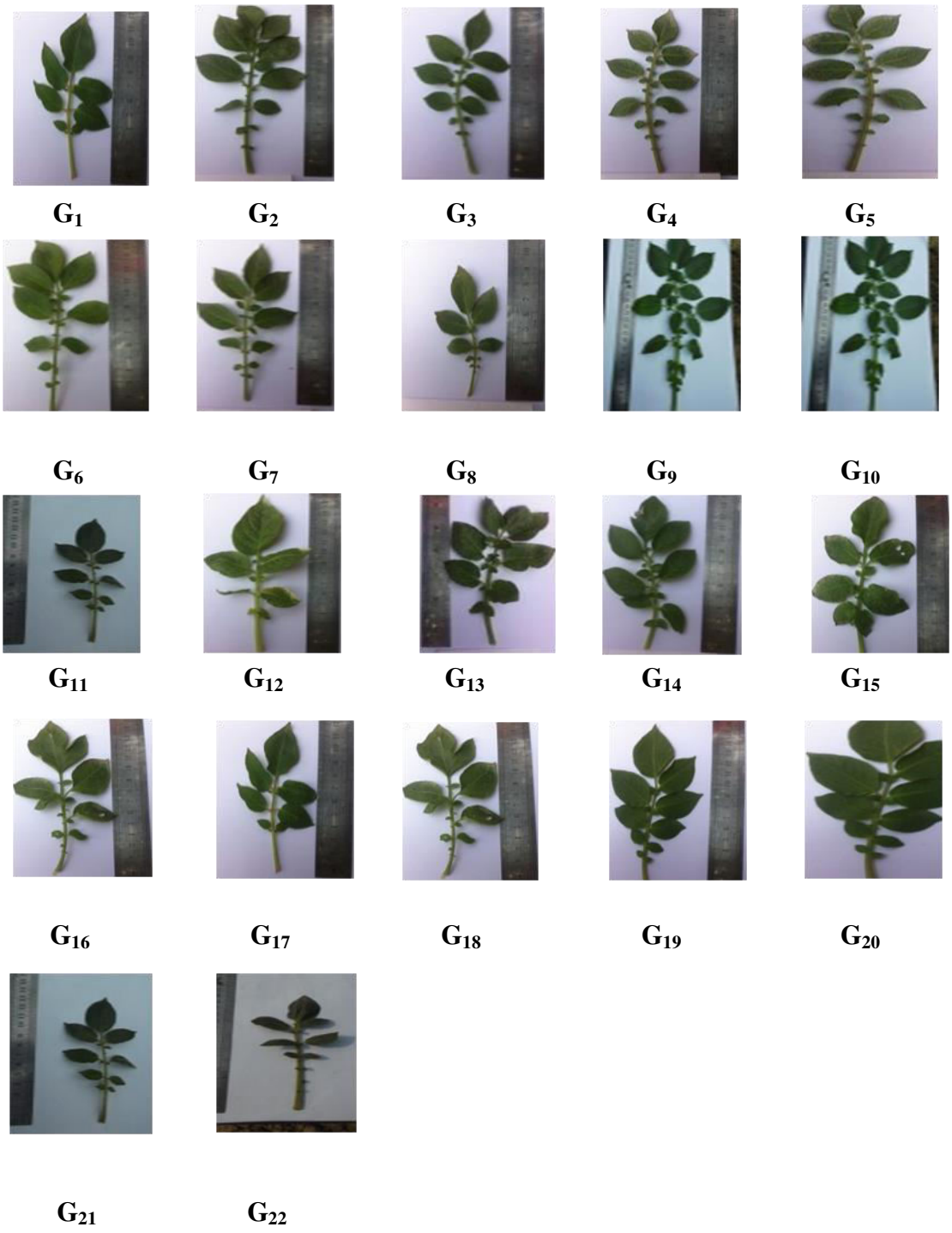

Plate 5. Leaf stalk variation showing in twenty two potato germplasm (G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53)

4.3.3 Plant characteristics

4.3.3.1 Foliage structure

Masses of leaves and stems which make up a plant considered as foliage structure. According to UPOV guideline foliage structure has been classified as stem type, intermediate type, leaf type. (Appendix XI). G_1, G_9, $G_{10,}$ G_{11}, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, G_{19}, $G_{20,}$ G_{22} these 12 potato germplasm can be classified in stem type while G_2, G_3, G_4, G_6, G_7, G_8, G_{12}, G_{21} these 8 germplasm observed as intermediate type and only G_5 potato germplasm showed leaf type foliage structure (Table 8). Joseph *et al*. (2005) also found variation in potato germplasm in terms of foliage structure.

4.3.3.2 Canopy Structure

Canopy structure is the upper layer or habitat zone which covered by leaves. According to UPOV canopy structure of potato plants were classified as compact, medium compact, open type (Appendix XI). G_1, G_9, $G_{10,}$ G_{11}, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, G_{19}, $G_{20,}$ G_{22} potato germplasm can be categorized as open type while G_2, G_3, G_4, G_6, G_7, G_8, G_{12}, G_{21} potato germplasm were categorized as medium compact and only G_5 germplasm can be categorized as compact type canopy structure (Table 8).

4.3.3.3 Growth Habit

Growth habit indicates plant shape, height, appearance which determined a genetic pattern of a particular germplasm. According to UPOV guidelines growth habit of potato plants expressed as erect or upright, semi erect or semi upright and spreading (Appendix XI) Among twenty two germplasm G_2, G_3, G_5, G_6, G_7, G_8, G_9, G_{10}, G_{11}, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, G_{19}, $G_{20,}$ G_{22} were observed erect (>45˚ with ground) or

upright; G_1, G_{12}, G_{21} were found semi erect (30˚- 45 ˚) with ground or semi upright and G_4 was found spreading (Table 8).

Table 8. Morphological characterization of twenty two potato germplasm :Plant Characteristics:

Characteristics	Types	Germplasm*
Foliage Structure	Stem	G_1, G_9, G_{10}, G_{11},G_{13}, G_{14}, G_{15}, G_{16},G_{17},G_{18},G_{19},G_{20},G_{22}
	Intermediate	G_2,G_3 ,G_4 ,G_6,G_7,G_8, G_{12},G_{21}
	Leafy	G_5
Canopy Structure	Compact	G_5
	Medium compact	G_2, G_3, G_4, G_6, G_7 ,G_8, G_{12}, G_{21}
	Open	G_1, G_9, G_{10}, G_{11}, G_{13}, G_{14}, G_{15},G_{16}, G_{17}, G_{18}, G_{19}, G_{20}, G_{22}
Growth habit	Erect (>45˚ with ground) or Upright	G_2, G_3, G_5, G_6, G_7, G_8, G_9, G_{10}, G_{11}, G_{13}, G_{14}, G_{15}, G_{16}, G_{17}, G_{18}, G_{19}, G_{20}, G_{22}
	Semi erect (30˚- 45 ˚) with ground or semi upright	G_1, G_{12}, G_{21}
	Spreading	G_4

* G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

4.3.4 Tuber Characteristics

A potato tuber is a modified underground stem, not a swollen root. Variation was observed within 22 potato germplasm in tuber shape, skin color, flesh color, depth of eyes. Liao *et al.* (2015) studied size and shape of potato tubers to reduce the error and faster classification by mechanizing. Visual observation was done to characterized tubers in terms of following parameters:

4.3.4.1 Tuber Shape

Tuber forms from stolons. Tuber shape is an important parameter to determine tuber quality. Different types of tuber shape are used in different purposes. Different pattern of tuber shape are found in wild germplasm. According to UPOV guidelines has been categorized potato tubers as round , short oval, long oval, long, very long (Appendix XII). G_8, G_{15}, G_{17} and G_{22} were found short oval ; G_2, G_6, G_7, G_{10}, G_{19}, G_{21} found as oval, Long oval found in G_1, G_9, G_{13}, G_{14}, G_{20}. Long found in G_{11}, G_{12}, G_{16} .Very long in G_4, G_5. Round in G_3, G_{18} potato germplasm (Table 9); (Plate 6). For processing these products certain quality parameters are taken into consideration including morphological characteristics like tuber shapes, tuber size, depth of eyes and chemical constituents such as dry matter and reducing sugars in tubers. Round to round oval tubers are ideally suited for chips, long oval for French fries and small size tubers are preferred for canning. G_1, G_9, G_{11}, G_{12}, G_{13}, G_{14}, G_{16}, G_{20}, germplasm looked like oblong shape of tubers as they were showed long oval to long tuber shape so they can be considered as a potential germplasm to use in french fry industry while oval germplasm G_2, G_6, G_7, G_8, G_{10}, G_{15}, G_{17} G_{19}, G_{21} and G_{22} might be suitable for chips making industry and rest of germplasm G_3, G_4, G_5, G_{18} can be considered as canning

and dehydrated product making industry. Genet (1992) studied tuber size and shape to identify quality characteristics of potato germplasm using for industrial raw material.

4.3.4.2 Tuber Skin color

Tuber skin has five basic colors. According to UPOV guidelines the color of skin has been categorized as – light, yellow, red, blue, reddish brown (Appendix XII).Among 22 potato germplasm G_1, G_{17}, G_{18} have been categorized as red skin. G_{12} as yellow. G_{11} as light yellow G_{13}, G_{15} as pale yellow G_2, G_{14}, G_{16}, G_{19}, G_{22} have found as light pink. G_3, G_{21} can be categorized as light yellow with pink eyes. G_4 as greenish ash, G_5 as dark purple. G_6, G_7 as red with yellow patches, G_8 as pink with yellow patches, G_{20} as reddish yellow and G_9, G_{10} as blue skin color (Table 9). Various skin color in twenty two potato germplasm showed in (Plate 6). Kaspar *et al*. (2013) studied on Pigmented potato cultivars and observed Purple potatoes anthocyanin concentration was 20-fold greater ($P < 0.001$) than in yellow potatoes. Carotenoid concentrations in white and purple potatoes were similar, while yellow potatoes had a 45-fold greater carotenoids concentration compared to white and purple potatoes. Ganga *et al.* (2014) also studied tuber skin color where he observed variation within potato germplasm.

4.3.4.3 Tuber Flesh Color

Tuber flesh color varied in different germplasms. According to UPOV guidelines it has been classified as – white, cream, light yellow, medium yellow, dark yellow, red, blue (Appendix XII). Among 22 potato germplasm G_6, G_7, G_9, G_{10} can be categorized as medium yellow. G_1, G_3, G_8, G_{14}, G_{15}, G_{16}, G_{17}, G_{22} can be categorized as light yellow. G_2, G_{11}, G_{12}, G_{13}, G_{18}, G_{19}, G_{20}, G_{21}, can be categorized as cream. G_4 as greenish cream and G_5 as reddish cream (Table 9);(Plate 7). Different types of color

found in tuber flesh color showed in (plate 6). Genet, (1992) studied flesh color of tubers using for French fry and chips industry in New Zealand. Lachman and Hamouz, (2005) have studied red and purple potatoes are in addition contained acylated anthocyanins and pigmented potatoes display two to three times higher antioxidant potential in comparison with white-flesh potato. Ganga *et al*. (2014) also observed variation in flesh color in ten potato germplasm.

4.3.4.4 Depth of Eyes

The eyes of potato tubers are stem buds, similar to buds on the nodes of a stem. Each potato tuber has several eyes, and each eye is capable of producing a separate stem. Variation in depth of eyes in potato tubers were found among different germplasm. According to UPOV it has been classified as very shallow, shallow, medium, deep, very deep (Appendix XII). Among 22 potato germplasm $G_{1,}$ G_8, $G_{9,}$ G_{11}, G_{12}, G_{22} these potato germplasm have found very shallow eye depth. $G_{2,}$ G_7, $G_{13,}$ G_{14}, G_{16}, G_{21} these can be categorized as shallow. G_5, $G_{10,}$ $G_{15,}$ G_{18}, G_{19} can be found medium depth of eyes and G_3, $G_{6,}$ G_{17}, G_{20} were found deep while G_4 was observed very deep (Table 9); (Plate 6). Shallow to very shallow depth of eyes in potato tubers can be considered as a good quality tuber for using chips and French fry making industry as peeling losses in potatoes with deep eyes are much greater than in potatoes with shallow eyes. So $G_{1,}$ G_8, $G_{9,}$ G_{11}, G_{12}, $G_{22,}$ $G_{2,}$ G_7, $G_{13,}$ G_{14}, G_{16}, G_{21} can be suitable for French fry and chips making industry.

Table 9. Morphological characterization of twenty two potato germplasm: Tuber Characteristics

Characteristics	Types	Germplasm*
Tuber Shape	Short oval	G_8, G_{15}, G_{17}, G_{22}.
	Oval	G_2, G_6, G_7, G_{10}, G_{19}, G_{21}
	Long oval	G_1, G_9, G_{13}, G_{14}, G_{20}.
	Long	G_{11}, G_{12}, G_{16}
	Very long	G_4, G_5
	Round	G_3, G_{18}
Tuber Skin Color	Red skin	G_1, G_{17}, G_{18}
	Yellow	G_{12}
	Light yellow	G_{11}
	Pale yellow	G_{13}, G_{15}
	Light pink	G_2, G_{14}, G_{16}, G_{19},G_{22}
	Light yellow with pink eyes	G_3, G_{21}
	Greenish ash	G_4
	Dark purple	G_5
	Red with yellow patches	G_6, G_7
	Pink with yellow patches	G_8
	Reddish yellow	G_{20}
	Blue skin	G_9, G_{10}
Tuber Flesh Color	Medium yellow	G_6, G_7, G_9,G_{10}
	Light yellow	G_1, G_3, G_8, G_{14}, G_{15}, G_{16}, G_{17}, G_{22}
	Cream	G_2, G_{11}, G_{12},G_{13}, G_{18}, G_{19}, G_{20}, G_{21},
	Greenish cream	G_4
	Reddish cream	G_5
Depth of Eyes	Very shallow	G_1, G_8 ,G_9 ,G_{11} ,G_{12} ,G_{22}
	Shallow	G_2 ,G_7 ,G_{13} ,G_{14} ,G_{16} ,G_{21}
	Medium	G_5 ,G_{10}, G_{15} ,G_{18} ,G_{19}
	Deep	G_3,G_6 ,G_{17},G_{20}
	Very deep	G_4

* G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53

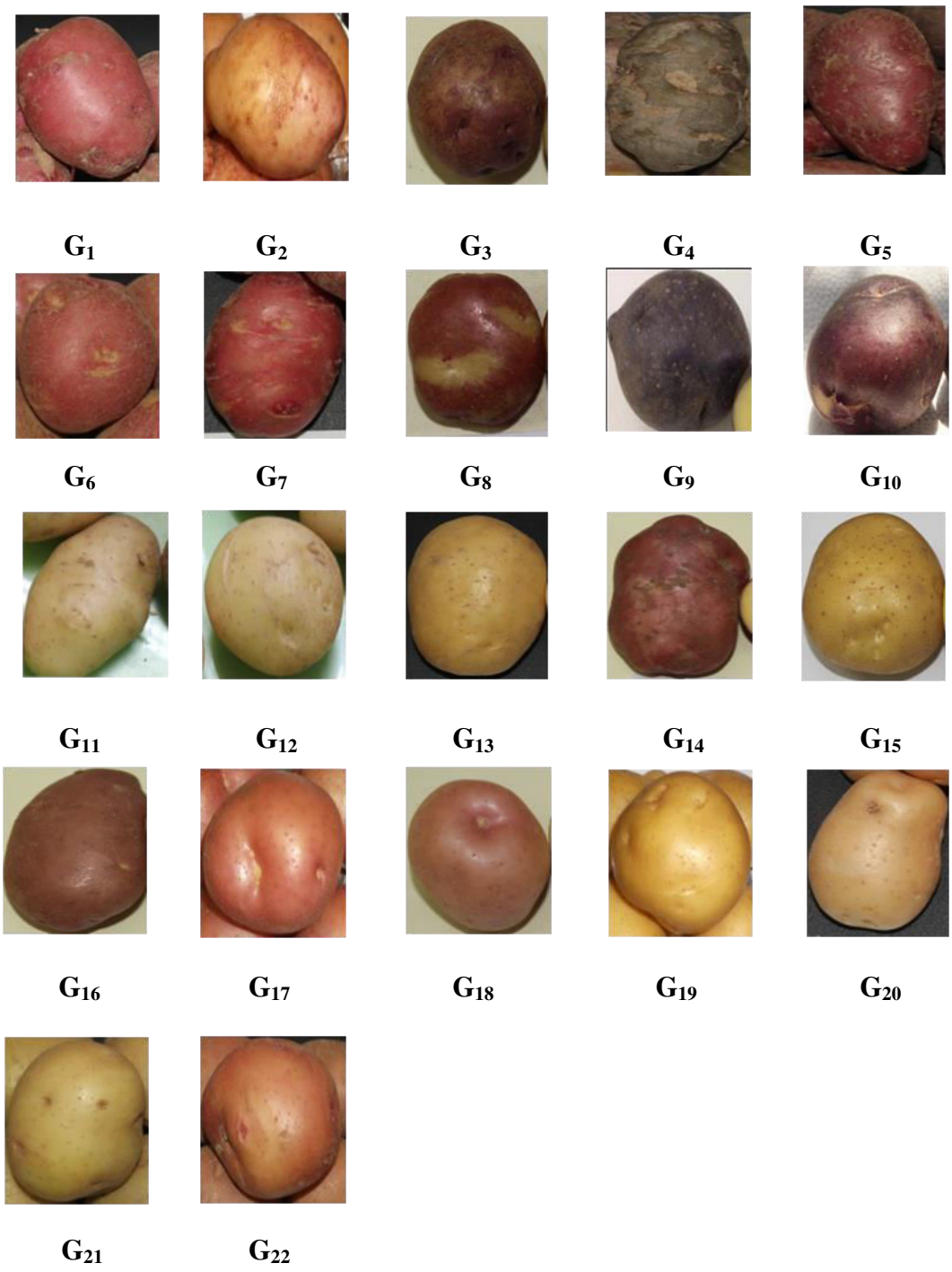

Plate 6. Tuber skin color and shape variation showing in twenty two potato germplasm (G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53)

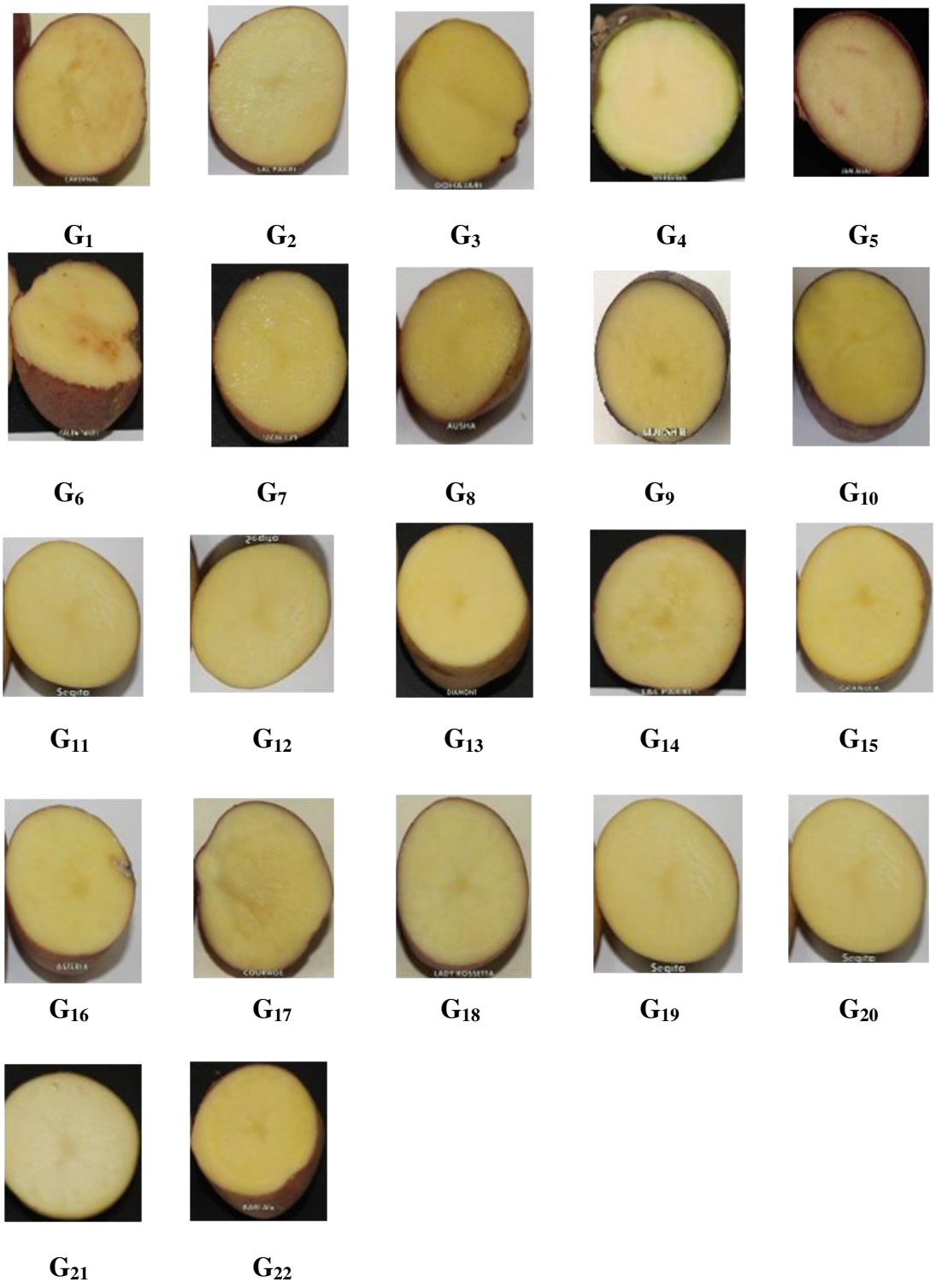

Plate 7. Tuber flesh color variation showing in twenty two potato germplasm (G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53)

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

Potato is considered as king of all vegetables. More than 5000 potato germplasm are available worldwide. Among them few germplasm are consumed as table potato purposes and some germplasm can be utilized as industrial raw material. Now-a-days potato not only have been taken as table item but also its potentiality of making French fry, chips, flakes, starch, food coloring industry have been realized. Bangladesh has surplus potato productions which create an opportunity to identify those germplasm which can be suitable to use as industrial raw material.

In order to study morpho-physiological characterization of twenty two potato germplasm fro different sources a field study have been conducted at Horticultural farm, Sher-e-Bangla Agricultural University during the period from October to April 2015. Single factorial experiment which included twenty two potato grmplasm - G_1:Lal Pakri 1; G_2:Lal Pakri 2; G_3:Dohajari; G_4:Shilbilati; G_5:Jam Alu; G_6:Fauta Pakri; G_7:Bogra Guti; G_8:Ausha; G_9:Blue white; G_{10}:Blue Yellow; G_{11}:Burma 1; G_{12}:Burma 2; G_{13}:Diamont; G_{14}:Cardinal; G_{15}:Granula; G_{16}:Asterix; G_{17}:Courage; G_{18}:Lady Rosetta; G_{19}:Segita; G_{20}:Sharpo Mira; G_{21}:BARI ALOO 46; G_{22}:BARI ALOO 53. The experiment was conducted using RCBD with three replications.

Collected data observing growth related and yield related parameters were statistically analyzed for studying morpho-physiological characterization of potato germplasm. Phenotypic parameters have been characterized following UPOV guidelines. Summary of the results and conclusion have been described in this chapter.

Considering the growth related characteristics of potato germplasm it has been observed that among twenty two potato germplasm maximum emergence percentage was found from G_{22} (91.8%) and minimum from G_8 (64.4%). Maximum plant height was found from G_1 (107.0 cm) while minimum was from G_{11} (49.8 cm) which was statistically identical with G_{12} and G_{19}. Among twenty germplam G_1 and G_{15} can be characterized as tall plant while G_{11} potato germplasm characterized as short plant and other 19 germplasm were can be characterized as medium plant height (Appendix XIII). Maximum chlorophyll content was found from G17 (53.5%) whereas minimum from G18 (30.3%). Maximum day to maturity was found from both G_{10} and G_{22} (96.0) and minimum from G_1 (89.0). Among twenty two 18 germplasm can be characterized as medium days to maturity and rest of germplasm G_9, G_{10}, G_{21}, G_{22} can be characterized as late days to maturity germplasm. Maximum stems hill^{-1} was found from G_{19} (5.00) while minimum from G_{11} (1.33). Maximum number of leaves was found from G_9 (58.3) and minimum from G_{13} (29.9). The highest number of tuber found in G_4 (17) and lowest found in G_{12} (4).

Considering yield attributing parameters it has been observed that Maximum tuber length among the large sized tubers was found in G_{14} (8.3 cm). while 7.0 cm was found in medium sized tubers in G_{16} and maximum tuber length among small sized tubers was found in G_{16} (4.0cm). . Maximum Tuber diameter among the large sized tubers was found in G_{18} and G_{21} (59.4 mm) while 49.4 mm in G_{17} found medium sized tubers and maximum Tuber diameter among small sized tubers was found in G_{15} 34.4 (mm). Highest amount of larger tubers found in G_{13} and lowest amount found in G_7, G_8. Highest amount of medium tubers found in G_{10} and lowest amount found in G_6. Highest amount of smaller tubers found in G_6, G_7 and lowest amount found in G_{13} Maximum weight within large sized single tubers was found in G_{14} (195.1 g) and

maximum tuber weight within medium sized single tubers was found was found in G_6 (60.8 g) while maximum tuber weight in small single tubers was found in G_{20} (38.5 g). Maximum yield hill^{-1} was found from G_{19} (0.8 kg) followed by G_2, G_9, G_{10} and G_{13} whereas minimum from G_3 (0.1 kg). Maximum yield t/ha was found from G_3 (29.9 t ha^{-1}) while minimum from G_8 (12.3 t ha^{-1}).

Phenotypic characterizations have been done following the morphological parameters. Sprouts of twenty two potato germplasm were characterized in four categories - size, shape, anthocyanin coloration at base and intensity of anthocyanin coloration at base. It has been observed that among 22 potato germplasm 10 germplasm can be categorized as red –violet and 12 germplasm as blue – violet.

Leaf stalk variations among twenty two potato germplasm have been characterized with 13 categories - leaf openness, intensity of green color, presence of secondary leaflets, frequency of secondary leaflets, frequency of leaf coalescence, terminal leaflet shape, terminal leaflet tip shape, terminal leaflet base shape, lateral leaflet shape, lateral leaflet tip shape, lateral leaflet base shape, size of secondary leaflets, number of primary leaflet pairs. Among 13 parameters terminal leaflet shape was found narrowly ovate in 4 germplasm while in 5 were medium ovate, 10 germplasm were found as broadly ovate and rest of 3 germplasm can be categorized as elliptical terminal leaf shape.

12 potato germplasm can be classified in stem type while 8 germplasm observed as intermediate type and only G_5 potato germplasm showed leaf type foliage structure.

Among twenty two germplasm 18 germplasm were observed erect (>45˚ with ground) or upright; 3 germplasm (G_1, G_{12}, G_{21}) were found semi erect (30˚- 45 ˚) with ground or semi upright and G_4 was found spreading growth habit.

Tubers from twenty two potato germplasm were found as short oval in G_8, G_{15}, G_{17} and G_{22}. Oval in G_2, G_6, G_7, G_{10}, G_{19}, G_{21}. Long oval in G_1, G_9, G_{13}, G_{14}, G_{20}. Long in G_{11}, G_{12}, G_{16}. Very long in G_4, G_5. Round in G_3, G_{18} potato germplasm. Among 22 potato germplasm G_1, G_{17}, G_{18} have been categorized as red skin. G_{12} as yellow. G_{11} as light yellow G_{13}, G_{15} as pale yellow G_2, G_{14}, G_{16}, G_{19}, G_{22} have found as light pink. G_3, G_{21} can be categorized as light yellow with pink eyes. G_4 as greenish ash, G_5 as dark purple. G_6, G_7 as red with yellow patches, G_8 as pink with yellow patches, G_{20} as reddish yellow and G_9, G_{10} as blue skin color. Among 22 potato germplasm G_1, G_8, G_9, G_{11}, G_{12}, G_{22} these potato germplasm have found very shallow eye depth. G_2, G_7, G_{13}, G_{14}, G_{16}, G_{21} these can be categorized as shallow. G_5, G_{10}, G_{15}, G_{18}, G_{19} can be found medium depth of eyes and G_3, G_6, G_{17}, G_{20} were found deep while G_4 was observed very deep eye depth.

5.2 Conclusion

After observing all the results it can be concluded that twenty two potato germplasm were showed significant variation in growth related and yield attributing parameters. Phenotypic variation also observed in terms of sprout characteristics, leaf characteristics, plant habit and tuber appearance. It can be further concluded that tuber from G_1, G_9, G_{11}, G_{12}, G_{13}, G_{14}, G_{16}, G_{20} germplasm showed long oval to long tuber shape so they can be considered as a potential germplasm to use in french fry industry while oval germplasm G_2, G_6, G_7, G_8, G_{10}, G_{15}, G_{17} G_{19}, G_{21} and G_{22} might be suitable for chips making industry and rest of germplasm G_3, G_4, G_5, G_{18} can be considered as canning and dehydrated product making industry. Furthermore, among twenty two germplasm G_9 and G_{10} showed blue skin; G_5 showed dark purple skin; G_1, G_{17} and G_{18} showed red skin which could be utilized in food color industry as natural sources of food color by extracting color from potato skin.

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APPENDICES

Appendix I. Analysis of variance of the data on emergence percentage, plant height, chlorophyll percentage, days to maturity (%)of twenty two potato germplasm

Source of Variation	Degrees of freedom (df)	Mean square			
		Emergence Percentage	Plant Height	Chlorophyll Percentage (%)	Days To Maturity
Replication	2	0.711	7.382	7.039	0.51
Factor A	21	132.411*	799.69*	101.834*	18.826*
Error	42	0.804	25.248	3.187	0.648

* : Significant at 0.05 level of probability

Appendix II. Analysis of variance of the data on number of stems/hill, number of leaves/hill, number of tuber/hill of twenty two potato germplasm

Source of Variation	Degrees of freedom (df)	Mean square		
		Number of Stems/hill	Number of Leaves/hill	Number of tuber/hill
Replication	2	0.045	17.93	0.4349
Factor A	21	2.6358*	114.669*	38.1087*
Error	42	0.299	25.836	1.0043

* : Significant at 0.05 level of probability

Appendix III. Analysis of variance of the data on tuber length (large, medium, small) of twenty two potato germplasm

Source of Variation	Degrees of freedom (df)	Mean square		
		Large	Medium	Small
Replication	2	0.041	0.13	0.123
Factor A	21	6.616*	4.25*	1.997*
Error	42	0.046	0.069	0.022

* : Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on tuber diameter (large, medium, small) of twenty two potato germplasm

Source of Variation	Degrees of freedom (df)	Mean square		
		Large	Medium	Small
Replication	2	7.34	7.136	3.788
Factor A	21	247.36*	179.721*	143.389*
Error	42	0.409	0.372	0.109

* : Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on percentage of tubers (large, medium, small) of twenty two potato germplasm

Source of Variation	Degrees of freedom (df)	Mean square		
		Large	Medium	Small
Replication	2	0.318	0.026	2.561
Factor A	21	522.831	236.968	818.786
Error	42	1.032	1.04762	0.894

* : Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on individual tuber weight (large, medium, small) of twenty two potato germplasm

Source of Variation	Degrees of freedom (df)	Mean square		
		Large	Medium	Small
Replication	2	118.33	4.396	0.499
Factor A	21	7199.237*	823.374*	229.309*
Error	42	17.637	1.858	1.105

* : Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on Yield hill^{-1}, Yield (t ha^{-1})of twenty two potato germplasm

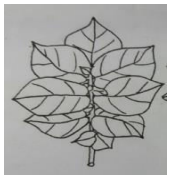
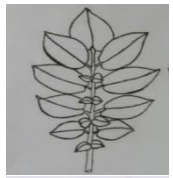
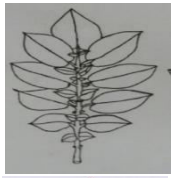
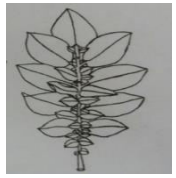
Source of Variation	Degrees of freedom (df)	Mean square	
		Yield hill^{-1}	Yield ha^{-1}
Replication	2	0.014	1.125
Factor A	21	0.083*	57.402*
Error	42	0.052	0.349

* : Significant at 0.05 level of probability

Appendix VIII. UPOV authorized descriptors for potato germplasm:: Sprout characteristics

Characteristics	**Types**					
Sprout size	Small	Medium	Large			
Sprout shape	Spherical 	Ovoid 	Conical 	Broad cylindrical 		Narrow cylindrical 
Sprout : Anthocyanin coloration of base	Red –Violet	Blue – Violet				
Sprout : intensity of anthocyanin coloration of base	Very weak	Weak	Medium	Strong	Very strong	

Appendix IX. UPOV authorized descriptors for potato germplasm: Leaf characteristics

Characteristics	Types							
Leaf openness	Closed		Intermediate		Open			
Presence of secondary leaflets	Weak		Medium		Strong			
Frequency of leaf coalescence	Coalescent		Not coalescent					
Leaf intensity of green color	Light		Medium		Dark			
Frequency of secondary leaflets	Nil		Low		Medium		High	Very high

Appendix X. UPOV authorized descriptors for potato germplasm:: Leaf Characteristics

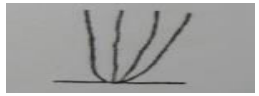
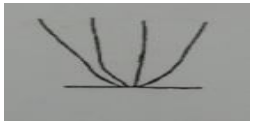
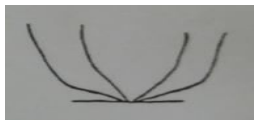
Characteristics	Types												
Terminal leaflet : Shape	a		b		c		d		e		f		g	
Terminal leaflet : Tip shape	A		B		C		D						
Terminal leaflet : Base shape	1		2		3		4		5		6		
Terminal leaflet : Size of secondary leaflets	Small		Medium		Large		Mixed						
Lateral leaflet : Shape	Narrow		Medium		Broad								
Lateral leaflet : Tip shape	A		B		C		D						
Lateral leaflet : Base shape	1		2		3		4		5		6		

a.Narrowly ovate
b.Medium ovate
c.Broadly ovate
d.Lanceolate
e.Elliptical
f.Obovate
g.Oblong

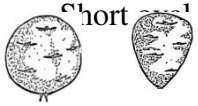
A.Acute
B.Cuspidate
C.Acuminate
D.Obtuse

1.Cuneate
2.Acute
3.Obtuse
4.Cordate
5.Truncate
6.Lobed

Appendix XI. UPOV authorized descriptors for potato germplasm: Plant Characteristics

Characteristics	Types	Figure
Foliage structure	Stem type	
	Intermediate type	
	Leaf type	
Canopy structure	Compact Medium compact Open	
Growth habit	Erect or upright (>45˚ with ground)	
	Semi erect or semi upright (30˚- 45 ˚) with ground	
	Spreading	

Appendix XII. UPOV authorized descriptors for potato germplasm: Tuber Characteristics

Characteristics	Types						
Tuber : Shape	Round 		Oval 	Long oval 	Long 	Very long 	
Tuber : Skin color	Light pink	Yellow	Red	Blue	White	Reddish brown	Dark pink
Tuber : flesh color	White	Cream	Light yellow	Medium yellow	Dark yellow	Red	Blue
Tuber : Depth of eyes	Very shallow	Shallow	Medium	Deep	Very deep		

Appendix XIII. UPOV authorized descriptors for potato germplasms : Plant height, plant maturity, Number of stem hill^{-1}

Characteristics	Types		
Plant height	Short (30 -50 cm)	Medium (50-100 cm)	Tall (100-150 cm)
Plant Maturity	Medium / normal (80 – 95 days)	Late (95 -100 days)	
Number of stems per hill	Few (1-3 stems)	Medium (4-8 stems)	

Appendix XIV. Size and shape requirement for industrial potato products

Industrial Products	Tuber Diameter in mm	Tubers shape
Dehydrated	30	Round to oval
French fry	50	Oblong
Chips	40-60	Round to oval
Canned	35	Round to oval