MORPHOLOGICAL CHARACTERIZATION AND VARIABILITY STUDY OF POTATO GERMPLASM

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This is to certify that the thesis entitled, *"MORPHOLOGICAL CHARACTERIZATION AND VARIABILITY STUDY OF POTATO GERMPLASM"* submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE (M.S.) in HORTICULTURE,* embodies the result of a piece of *bonafide* research work carried out by *SANJIDA BINTA SALAM, Registration No.: 05-01787* 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

Dated:

Place: Dhaka, Bangladesh

(Prof. Dr. Md. Ismail Hossain)
Supervisor

DEDICATED
TO
MY BELOVED PARENTS

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ABSTRACT

An experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2010 to March 2011 to characterize and to measure variability of potato germplasm. The experiment consisted of 24 potato germplasm and was laid out in RCBD with three replications. Germplasm showed significant variation in most of the characters. The highest tuber yield was from 'Carrage' (30.30 t/ha) and the lowest from 'Indurkani' (13.00 t/ha). In correlation analysis, plant height, tuber length and tuber weight had highly positive correlation with yield per plant. Path analysis revealed that plant height, leaves per plant, tuber length, tuber weight and tubers per plant had positive direct effect on yield per plant. For principal coordinate analysis plant height, tuber length, tuber weight and yield per plant were major characters that contributed to the genetic divergence. Multivariate analysis based on 15 agronomic characters showed that 24 germplasm were fallen into 4 clusters. The highest inter-cluster distance was observed between cluster II and IV (32.13) and the lowest was between cluster III and IV (7.00). Considering, performance of germplasms, 'Line 04','Line 02', 'Diamant' and 'Carrage' may be selected as better parents for future hybridization program.

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LIST OF ABBREVIATED TERMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
et al.	=	And others
TSP	=	Triple Super Phosphate
MoP	=	Murate of Potash
RCBD	=	Randomized Complete Block Design
DAP	=	Days After Planting
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max.	=	Maximum
Min.	=	Minimum
% CV	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L) ranks first among the vegetables in terms of area and production in Bangladesh. Potato is one of the most important food crops of Bangladesh as well as of many countries of the world. It produces more calories and protein per unit land with minimum time and water than most of the major food crops (Upadhya, 1995). It is also a world leading vegetable crop that furnishes appreciable amount of vitamin B and vitamin C as well as some minerals. Potato can be used in numerous ways, such as, boiled, baked and fried potatoes, dehydrated potatoes, canned potatoes and as starch for culinary purposes (Hoque, 1994). Because of its high yield potential and food value, compared to rice and wheat, potato is considered as a promising candidate crop for feeding the hungry people of the world (Pushkarnath, 1976).

In 2009-10, the area, production and average yield of potato in Bangladesh are 0.43 million hectare, 7.93 million tons and 18.24 tons per hectare, respectively (BBS, 2010). The yield level of this crop in Bangladesh is low compared to other potato growing countries of the world (Anon., 1997). Among the various factors responsible for low yield in Bangladesh, the performance of a germplasm plays a great role. There is a vast scope of increasing the yield per hectare through the introduction of high yielding potato germplasm possessing good keeping quality and resistant to pests and diseases. The local germplasm are in existence in Bangladesh have become degenerated on account of various reasons and give extremely low yield. On the other hand, the yields of high yielding germplasm are much better than the local ones under the identical conditions and cultural practices. Therefore, with a view to stepping up the degeneration gap and getting high yield, Bangladesh has to import seed-tubers of good germplasm from abroad at the cost of hard earned foreign exchange.

It is necessary to exploit the farmers interest in the best possible manner, ways and means for raising the per hectare yield to a significantly higher level. Germplasm differ greatly in respect of time of maturity, yield, quality, resistance to pests and diseases (Thompson and Kelly, 1957) and they also show differences in certain tuber characteristics which have a very important effect on the market-value and local popularity (Bell, 1948). Therefore, there is a need for conducting trial with different potato germplasm of exporting countries and finding out the germplasm most suitable for Bangladesh.

The progress of breeding is conditioned by the magnitudes, nature and interrelationship of genotypic and environmental variation in different characters. Hence, it becomes necessary to partition the observed variability into its heritable and non-heritable components with the help of suitable genetic parameter such as genotypic coefficient of variation (GCV), heritability estimates and genetic advance etc. Study of the association of characters is to identify the role of each individual character towards yield. Study of correlation between different quantitative characters provides an idea of association that could be effectively utilized in selecting a better plant type in potato breeding program. However, knowledge of correlation alone is often misleading, because when more germplasm are included in a study, the indirect association becomes more complex. ln such situation the path-coefficient analysis provides an effective means of finding direct and indirect causes of association.

Genetic variability with respect to genetic diversity has been considered as an important factor which is also essential prerequisite for crop improvement program for obtaining high yielding progenies. The quantification of genetic diversity through biometrical procedure made it possible to choose genetically diverse parents for a successful hybridization program. Evaluation of genetic diversity is important to know the source of genes for a particular trait within the available germplasm.

Hence, the present study was undertaken with the following objectives:

I. To study the morphological characterization of potato germplasm.
II. To estimate the magnitudes of genetic components of variation.
III. To measure the extent of direct and indirect influence of the components on yield.
IV. To study the genetic diversity among the germplasm for selecting parents for hybridization.

CHAPTER II

REVIEW OF LITERATURE

Information on genetic divergence among the plant materials is vital to a plant breeder for an efficient choice of parents for hybridization. It is an established fact that genetically diverse parents are likely to contribute desirable segregates and or to produce high heterotic crosses. More diverse are the parents, the greater are the chances of obtaining high heterotic F_1s and broad spectrum of variability in segregating generations. Improvement in yield and quality is normally achieved by selecting germplasm with desirable character combinations existing in the nature or by hybridization. The parents identified on the basis of divergence analysis would be more promising. To provide background of the present study available relevant literature have been reviewed and presented below.

2. 1 Genetic variability, heritability and genetic advance

Kishore (1979) stated that centre of origin of potato is the center of diversity. International Potato Centre (CIP), located at Lima, Peru, close to the centre of origin of potato, exploited this advantage and until then had collected about 12,000 germplasm. These samples have been grouped taxonomically and preserved for future use by various methods. Braunsweig Genetic Resources Centre (BGRC) maintains, evaluates, feeds information for a documental section and distributes material in cooperation with CIP. These diversified materials are utilized by the breeders for evolving new cultivars of desirable characters. Generally the breeders work on priority basis and the sequence of utilization is also maintained with respect to the species.

Ahmad (1980) reported that twelve and 16 exotic germplasm of potato in their first and second generations, respectively were tested at Jamalpur in 1979-80.

The overall mean per acre yield in the first and second generations were 260 and 246 maunds, respectively. Estima was found to produce the highest per-acre yield in the first generation followed by 'Vulkano', ' Mirka', 'Kronia' and 'Sinaeda' which produced above-average yields. Cardinal topped the list in the second generation followed by 'Kronia', 'Colmo', 'Estima' and ' Resy' which produced above-average yields.

Hossain (1980) conducted eight demonstration trials with the 1st and 2nd generation seeds of the recommended potato germplasm, namely 'Baraka', 'Cardinal', 'Kronia', 'Mirka', 'Multa' and 'Patrones' at different locations in 1980-81. In respect of the 1st generation seed, 'Kronia' was the top-most yielder followed by 'Cardinal', while 'Multa' and 'Patrones' produced lesser than the average. In the 2nd generation, 'Cardinal' was at the top of the list followed by 'Mirka', whereas 'Kronia', 'Multa' and 'Baraka' were around the average, and 'Patrones' was the last.

Rahman (1981) reported that an attempt was made to study the performances of exotic germplasm of potato in their different generations at the BARI substation, Bogra in 1980-81. ln the case of 1st generation trial, 'Elvira', 'Trobadour' and 'Diamant' were the best yielder followed by 'Cardinal', 'Ajax', 'Multa' and 'Patrones', in 2nd generation 'Cardinal' topped the list followed by 'Ajax', 'Kronia', 'Diamant', 'Mirka' and 'Ukama'. Mirka gave the highest yield in third generation followed by 'Multa', 'Cardinal', 'Baraka' and 'Patrones'. Whereas, the highest yield was produced by 'Cardinal' in their 4th generation followed by 'Mirka', 'Baraka', 'Araka', 'Multa' and 'Estima'.

Hossain (1982) reported that an attempt was made with eleven germplasm of potato in their second generation at five potato research station in 1981-82. On the average, the germplasm produced 21.20 tons of tubers per hectare, 'Cardinal' produced the highest mean per-hectare yield of 24.60 tons followed by 'Diamant', 'Kufrisindhuri' and 'Multa'. The highest proportion of tubers of

grade 28-55 mm (seed size) were produced by ‘Kuifrisindhuri’, ‘Elvira’, ‘Troubadour’ and ‘Multa’.

Ahmad (1982) presented a paper with major thrusts on the importance of finding potato germplasm acceptable to both the consumers and producers. Attempts were made to try temperate-region germplasm, tropicalized germplasm, indigenous germplasm for crop raising using TPS and found some suitable germplasm per lines commercially acceptable by farmers. Trials of the temperate-region germplasm led to the selection of presently recommended germplasm, viz. ‘Cardinal’ ‘Kufrisindhuri’, ‘Multa’, ‘Patrones’, ‘Ukama’, ‘Diamant’ and ‘Elvira’. Heat-tolerant germplasm namely, ‘CIP 800169’, ‘CIP 720056’ and ‘CIP 800225’ were found promising, among about three thousand received from CIP. Prospects have been noticed for selecting and improving some of the numbers and so-called indigenous germplasm for commercial exploitation.

Hossain (1982) conducted trials with 23 freshly imported exotic germplasm of potato in search for germplasm suitable for Bangladesh at 5 potato Research sub·stations in the year 1981-82. Among the germplasm, ‘Multa’, ‘Hertha’, ‘Troubadour’, ‘Gigant’, ‘Cardinal’ and ‘Ukama’ were the earliest of all the varieties. The highest per-hectare yields were recorded by ‘Cardinal’, ‘Elvira’, ‘Eltra’ and ‘Diamant’ followed by ‘Alwin’, ‘Troubadour’, ‘Ukama’, ‘Hertha’ and ‘Multa’. The maximum proportion of medium grade tubers (28-45 mm) were produced by ‘Escort’, ‘Elvira’, ‘Veloka’, ‘Sante’ and ‘Patrones’.

Rahman and Hossain (1982) reported that with the view to selecting , some high yielding varieties (HYV), a study with 23 newly introduced Holland germplasm of Potato was conducted at the BARI sub-station, Bogra in 1981-82. Days to 1st and 80 percent (%) emergence were lesser in the cases of ‘Hertha’, ‘Cardinal’, ‘Multa’, ‘Troubadour’, ‘Alwin’ and ‘Ukama’. The germplasm ‘Elvira’, ‘Troubadour’, ‘Alwin’, ‘Cardinal’, ‘Multa’, ‘Hartha’, and

‘Morene’ produced more than three stems per hill, while lesser number of stem giving germplasm was ‘Fambo’, ‘Famosa’, ‘Ausonia’ and ‘Sante’. Long plant was produced by ‘Famosa’, ‘Gigant’, ‘Cardinal’, ‘Hertha’, ‘Diamant’ and ‘Veloka’ and the ‘Electra’ and ‘Constante’.

Hossain *et al.* (1984) conducted a comparative performance trial with sixteen exotic germplasm in their first generation were conducted at six locations. The germplasm ‘Elvira’ gave the highest yield (25.97 t/ha) but was closely followed by ‘Cardinal’, ‘Origo’, ‘Rod’, ‘Diamant’, ‘Morene’, ‘Kufri Lalima’. The highest proportion of medium grade tubers (38-45 mm) was produced by ‘Elvira’, ‘Kufri Lalima’ and ‘Patrones’.

Kabir *et al.* (1994) conducted trials at two stations of Potato Research Centre, namely Joydebpur and Bogra (1986-1987) to observe the yield potential of the local germplasm of potato. Yields of the germplasm ranged from 8.10 to 22.00 t/ha indicating that there are cultivars having reasonably good yield potential in spite of their being infected with various virus diseases. Although the relative yields of different germplasm were not consistent. There seems to exist a possibility of selecting local germplasm for higher yields.

Khan *et al.* (2000) conducted a trial to provide a preliminary evaluation of the performance of a wide range of 36 exotic germplasm of seed potatoes received from European suppliers and breeders, prior to a more detailed examination of their agronomic performance in subsequent years. All germplasm were planted on two dates, 15 November and 7 December 1998. There were significant differences in tuber yield between germplasm at both the first ($P<0.05$) and second planting dates ($P<0.05$). On the first planting date, the germplasm 91-2-101, ‘Bydand’ and 85-2-501 were the highest yielders, while the germplasm ‘Cycloon’, ‘Mirakel’ and Accord yielded poorly. On the second planting date, ‘Bydand’ was the highest yielding cultivar and 90-40-1 had the lowest yield. Bydand performed consistently on both planting dates, but among all

germplasm, yields were significantly greater in 8 germplasm on the second, than on the first planting date (90-35-08, ‘Cycloon’, ‘Accord’, ‘Ladyrosetta’, ‘Lady Claire’, ‘Mirakel’, ‘Lady Christl’ and ‘Turbo’), while for three germplasm (‘Claret’, 91-2-101, ‘Charlotte’, 90-40-1) yields significantly declined. Ten out of the 36 germplasm included in the trial failed to produce a measurable yield. Only 3 out of the 26 remaining germplasm showed a reduction in yield with later planting.

Luthra (2001) reported that a study with 29 germplasm showed favorable response to selection for plant type, dormancy period, average tuber weight, number of tubers and plant vigor based on high heritability estimates, high genetic advance for tuber yield, average tuber weight, plant height and number of leaves suggested scope of improvement for these traits. An association among different characters revealed that vigor, erect and tall with long and wider leaves, producing more number of tubers or average tuber weight, having shallow or medium eyes and oval or round regular shape etc. are to be considered for improvement in potato.

Anonymous (2003) conducted a study with 28 hybrid populations at Debiganj showed that, there were significant variations among the progenies which indicate that there is a scope of selection for improved germplasm. Tuber yield varied from 20.67 to 32.44 t/ha. Individual plants were selected from the progenies on the basis of tuber yield and size, shape and color of the tubers in the hill which will be evaluated in subsequent years for germplasm development.

Twenty six germplasm of potato were evaluated by Masoodi (2010) for yield and yield attributing traits during kharif of 2008. Analysis of variance indicated significant differences among the germplasm, that should enable their use in future improvement programs. Among the germplasm ‘PP-2500’, ‘HB/18-36’, ‘K. Jyoti’, ‘SM/90-68’ and ‘HB/82-18’ performed best in respect of yield and

most of the yield attributing traits and could be utilized for commercial growing and hybridization programs so as to bring future improvement in the available germplasm resources.

2. 2 Character association and path analysis

Rasul *et al*. (1990) reported the variability and some genetic parameters of 15 potato germplasm to select parents for a hybridization program. The germplasm 'Obelix' performed best in respect of yield, weight of tubers per hill and number of tubers per hill. Dry matter content, related to specific gravity and starch content was high in 'Produeent' and 'Origo'. Considering the genetic parameters, high GCV was observed for plant height, number of stem per hill, foliage coverage and number of tubers per hill. High heritability values were obtained from plant height, specific gravity and foliage coverage. Plant height exhibited the highest genetic gain followed by the number of tubers per hill, tubers yield and starch content. Correlation studies showed significant positive relationship of yield with all the characters except plant height and number of tubers per hill, while it was negatively correlated with all four qualitative characters, viz. dry matter content, starch content, specific gravity and insect infestation. However, starch content, dry matter and specific gravity to tubers were highly interrelated. Some of the germplasm may be selected as prospective parents in the hybridization program considering their qualitative and quantitative parameters.

Ramanjit *et al*. (2001) conducted a field study during autumn season of 1997-98, in Ludhiana, Punjab, India to determine the degree of correlation of different growth and yield bearing characters to potato germplasm 'Kufri Chandramukhi' tuber yield. Leaf area index, and dry matter of leaves, stems, roots + stolon, and tubers were recorded at 30, 60 and 90 days after planting. The number and weight of tubers were recorded at harvest. Tuber yield showed highly significant positive correlations with leaf area index, tuber number,

tuber weight, dry matter production of leaves, roots + stolon and tubers at 60 and 90 days after planting.

Nakitandwe *et al*. (2003) conducted selection of high yielding potato germplasm ('Torridon', 389746.2, 384866.5, 386040.9, 381381.20, 381390.30, 720118, 386056.7, 381381.13 386209.10, 'Victoria', 'Kisoro') from Standard International Field Trials (SIFT) at five locations in Uganda during 2001-02. Data were collected on number of leaves, number of stems, plant height, percentage (%) of tuber dry matter, number of tubers, mean tuber weight and yield. Phenotypic correlation and multiple regressions indicated that mean tuber weight ($r=0.61$, $P<0.001$) and number of tubers per plant ($r=0.47$, $P<0.001$) had the highest correlation values and were also retained in the regression equation across all locations, suggesting that these were the most important components of tuber yield. Path analysis was used to estimate the magnitude, significance and directions of causal relationships between these variables and yield; and thereafter an output path diagram was developed. Path analysis identified number of leaves, number of stems, percentage tuber dry matter, number of tubers and mean tuber weight as the main yield components, with mean tuber weight ($P=0.62$) and number of tubers per plant ($P=0.46$), having the highest direct path coefficients. Although the direct effect of plant height on tuber yield was negative, plant height and number of stems per plant were important components of mean tuber weight. Path coefficient analysis also showed that direct and indirect effects of plant traits on yield accounted for only 47 percent (%) of the total variation in fresh tuber yield probably due to environmental factors.

Ozkaynak *et al.* (2003) conducted a study to determine the correlation coefficients between tuber yield and 12 yield components and the direct and indirect effects on yield in various potato germplasm ('Ausonia', 'Binella', 'Concorde', 'Granolla', 'Jaerla', 'Marabel', 'Marfona', 'Satina' and 'Velox') at the research fields of Akdeniz University in Antalya, Turkey. Significant

positive correlations were found among tuber yield, plant height, node number, leaf length, leaf width, leaflet length, leaflet width, tuber number and average tuber weight. Path coefficient analysis indicated that tuber number (0.77 and at 85.25 %), followed by the average tuber weight (0.51 and at 69.27 %), were the most important components for tuber yield in potato.

Bhagowati and Saikia (2003) reported that thirty true potato seed germplasm including hybrids and open pollinated populations were laid out to study the trend of character association and path coefficients between yield and its five components. The correlation study revealed that tuber yield was significantly and positively associated with plant height, primary branch number, leaf number, number of tubers per plant and average tuber weight. The plant height was identified as an important yield attribute as it had positive significant correlation with all four remaining yield components. The negative association of tuber number and average tuber weight, as observed in the present study, indicated the need of breaking negative linkage among these characters before using them as selection criteria. On the other hand, the path analysis highlighted the importance of tuber number and average tuber weight as they exerted the highest direct effect on tuber yield. Plant height, primary branch number and leaf number showed high indirect effects via average tuber weight indicating their importance in the selection program. The leaf number and average tuber weight showed negative indirect effect via tuber number on yield, while tuber number showed a negative indirect effect on yield via leaf number and average tuber weight.

Roy and Singh (2006) conducted an experiment on correlation and path analysis involving eighteen germplasm of potato (*Solanum tuberosum*) under four different environments in the rabi season of 1999-2000 in Bihar, India. The result indicated positive significant association of the quantitative traits with total tuber yield. Selection for total tuber yield improvement based on plant height, number of branch per tuber, number of tuber per plant and tuber yield per plant has been suggested.

2. 3 Genetic Diversity

Exploring and understanding the extent of diversity in the genetic stock of a crop has been of considerable interest to the plant breeders for planning and execution of genetic improvement program for yield and its component characters. Statistical analysis popularly known as D^2 analysis outlined originally by Mahalanobis (1936) and extended by Rao (1952), is a unique tool in this regard. The method is used in classifying the naturally existing variabilities of different crop plants and helps in estimating the extent of genetic diversity among them. From the plant breeding point of view the degree or extent of genetic diversity between two parents is an index for determining the hybridity over parents or nature of segregants in the follow up generations. D^2 analysis can help in selecting desirable parents for achieving desired goal by the breeder.

Desai and Jaimini (1997) evaluated that thirty six of potato for genetic divergence by using the Mahalanobis D^2 statistic. The population distributed into 9 clusters of which cluster I was the largest accommodating 7. Cluster I, III, V, VI and VII showed larger genetic divergence. Clusters III found highest in tuber yield and other characters like number of stems, number of leaves, maturity, shoot fresh weight, number of tubers, average tuber weight, sugar content and harvest index while cluster I was higher for dry matter and starch content, cluster IV for dwarf plant height and early maturity and cluster VI for high protein content. They differed significantly for all the characters, suggesting a good scope of selection. On the basis of index score, the 'MS-82-345', 'Kufri Lalima', 'PS/M-75', 'JEX/C-166', 'Kufri Badshah', 'Kufri Chandramukhi', 'MS-82-279', 'JH-222', 'Kufri Bahar', 'KufriSindhuri', from cluster No. I, II, III, IV, V, VI, VII, VIII and IX, respectively may be utilized for creating wide spectrum of variability and improving the tuber yield of potato.

Kumar and Kang (1998) reported that multivariate analysis for genetic divergence among thirty andigena accessions by D^2 statistics led to their grouping into seven clusters. D^2 estimates were based on eleven characters. The clustering pattern in pooled analysis was used for selecting diverse parents. Cluster VII and IV, VII and V, VII and VI, IV and I, IV and III and II and VII have high inter cluster distances. Cross involving parents from these cluster combinations are recommended for an Andigena breeding program.

Ahmed *et al.* (1998) investigated the genetic divergence of 90 germplasm of sweet potato. Multivariate analysis of divergence among the accessions for 12 characters (plant type, petiole length, vine growth rate, vine pigmentation, mature leaf shape, foliage colour, total vine length, storage root skin and flesh colour, yield of storage root at 115 and 140 days after planting (DAP), and dry matter content led to their grouping into 6 clusters. No relationship was found between the genetic divergence and geographic distribution of the germplasm. The highest contributions towards total divergence were made by the yield of storage root at 115 DAP (32.57 %) and at 140 DAP (19.42 %), which were the most important characters responsible for the grouping of the germplasm on a genetic basis. The next important characters were dry matter content (13.07 %) and petiole length (9.72 %). The inter-cluster D^2 values varied from 6.40 (between clusters III and V) to 830.59 (between clusters II and VI); the intra-cluster D^2 values varied from 1.77 (cluster IV) to 3.60 (cluster VI).

Joseph *et al.* (1999) reported that seventeen potato germplasm were studied separately both in the sub-tropical plains and the temperate hills for estimation of genetic divergence using Mahalanobis's D^2 statistic. The clustering pattern was different under the sub-tropical and the temperate conditions where the 17 were grouped into 8 and 6 clusters, respectively. There was very little common with regard to distribution of different clusters under the two conditions. Cluster I was the largest in both the growing conditions. The maximum genetic distance was between cluster II and V and the minimum genetic distance was

between cluster VI and VII under sub- tropical conditions, whereas, the maximum genetic distance was tuber yield under both the conditions. The genetic diversity was not related to geographic diversity as originating in different countries was grouped together in the same cluster.

Kumar and Kang (2000) studied genetic divergence in 45 potato germplasm (group Andigena) on the basis of 8 characters by non-hierarchical Euclidean cluster analysis during 1998-99 [place not given]. Germplasm were grouped into 10 clusters based on first 6 principal components which explained most of the variation. Grouping of germplasm of heterogenous origin in the same cluster indicated non-parallelism between genetic and geographical diversity. Cluster IV cultivars with high average tuber weight had high genetic distances to clusters I, III, VII, and IX. Leaf area index and tuber number per plant were major contributors toward genetic divergence.

Sandhu *et al*. (2001) evaluated three hundred accessions of andigena group of potato germplasm for genetic divergence based on 8 distinct traits, namely plant height, number of stems, number of nodes, internode length, leaflet index, tuber yield, tuber number and average tuber weight. Principal component analysis based on adjusted mean values yielded 8 each eigen vectors and eigen roots. The first 6 principal components accounted for 98.14 percent (%) of the variation. Based on these principal components, non-hierarchical Euclidean cluster analysis grouped 300 accessions into 6 distinct clusters. Cluster II and V were farthest from each other followed by I and II. Eight genetically diverse and agronomically promising genetic stocks were identified which may be involved in crossing program.

Sandhu (2005) aimed to characterize the potato germplasm (*Solanum tuberosum*) based on genetic divergence for morphological and tuber traits and their further distribution into well characterized clusters. One hundred and sixty (160) accessions of germplasm from 14 different countries were evaluated for

foliage traits comprising shoot height, number of shoots, number of leaves, number of nodes, internode length, foliage weight and tuber characters, viz., tuber number, tuber weight and average tuber number. The field evaluation was done in augmented Complete Block Design. Two characters namely foliage weight and average tuber weight exhibited high coefficient of variability. Eight eigen vectors based on principal component analysis, accounted for 96.55 percent (%) of total variation. Following the non-hierarchical Euclidean cluster analysis all the 160 accession were grouped into six clusters with variable number of germplasm. The maximum genetic distance was between cluster IV and V and minimum was between 1 and V. The cluster IV with maximum intra-cluster distances and the highest mean values for desirable agronomic traits was hence identified for selecting superior germplasm. Genetic diversity was not related to geographic diversity. Character association studies showed that selection of parents with high average tuber weight coupled with optimum foliage weight would result in progenies of high yield potential.

Sandhu and Gopal (2009) evaluated one hundred and ninety three germplasm of potato (*Solanum tuberosum*), from eight countries for nine characters under long day (14-15 hrs) and high temperature (max.19.00-40^{0}C and min.7.00-25^{0}C) conditions of spring crop. Experiment was laid out in a augmented incomplete block design with four potato germplasm as checks. Significant variability was observed for majority of the characters among checks as well as test genotypes. Non-hierarchical Euclidean cluster analysis followed by principal component analysis led to the classification of 193 germplasm into nine well-characterized groups. The maximum Euclidean distance was between cluster V and VIII followed by III and VIII. The cluster VIII was deemed good for selecting elite germplasm as the germplasm gathered in this cluster were not only diverse from each other but also had the highest mean values for plant height (57.50 cm), inter-node length (3.42 cm), number of leaves per plant (112), average tuber weight (27.30 gm) and tuber yield per plant (380 gm). Six a germplasm, viz., ‘CP1367’, 1438, 1513, 1551, 1558 and 1588 were identified

as genetically diverse and agronomically superior and thus recommended for exploitation in potato breeding program for spring season.

Verma *et al*. (2010) evaluated thirty germplasm of potato for two consecutive years from 2008-09 to 2009-10. These thirty potato germplasm under study were grouped into five different and diverse clusters; D^2 value noted for different parameters indicated the presence of appreciable genetic diversity in the germplasm included in the investigation. Genetic diversity study suggested that germplasm namely 'J/95-378', 'J/97-243', 'J/95-144', 'J/96-80', 'K. Pukhraj', 'K. Surya', 'DSP-7', 'K. Chipsona-1' and 'K. Chipsona- 3' possessed high performance. Thus, these potato germplasm may be included as a parent in hybridization program for getting superior hybrids and segregants suitable for Chhattisgarh.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment. It includes a short description of location of the experiment, characteristics of soil, climate, materials used, land preparation, manuring and fertilizing, planting, after care, harvesting and collection of data.

3.1 Location of the experiment field

The field experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from October 2010 to March 2011 to evaluate some 24 potato germplasm. The

location of the experimental site was at 23º75´ N latitude and 90º34´ E longitude with an elevation of 8.45 meter from the sea level (Anon., 1989).

3.2 Climate of the experimental area

The climate of the experimental area was subtropical in nature. It is characterized by heavy rainfall, high temperature, high humidity and relatively long day during kharif season (April to September) and a scanty rainfall associated with moderately low temperature, low humidity and short day period during rabi season (October to March). Details of the meteorological data in respect of monthly maximum, minimum and average temperature, rainfall, relative humidity, average sunshine hours and soil temperature during the period of experiment are presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, ECE 25.28 (FAO, 1988) The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Plant materials used

Tubers of 24 potato germplasm were used as experimental materials. Those were collected from various sources and were encoded as below:

Sl. No.	Germplasm	Place of Collection	Accession Number
1	Diamant	Bangladesh Agricultural Research Institute	P001
2	Cardinal	Bangladesh Agricultural Research Institute	P002

3	Granola	Bangladesh Agricultural Research Institute	P003
4	Provento	Bangladesh Agricultural Research Institute	P004
5	Ladyrosetta	Bangladesh Agricultural Research Institute	P005
6	Carrage	Bangladesh Agricultural Research Institute	P006
7	Jam Alu	Bangladesh Agricultural Research Institute	P012
8	Kufrisinduri	Bangladesh Agricultural Research Institute	P013
9	Asterix	Bangladesh Agricultural Research Institute	P014
10	Romana	Bangladesh Agricultural Research Institute	P021
11	Line 02	Dept. of Biotechnology, Sher-e-Bangla Agricultural University	P007
12	Line 04	Dept. of Biotechnology, Sher-e-Bangla Agricultural University	P008
13	Line 05	Dept. of Biotechnology, Sher-e-Bangla Agricultural University	P009
14	Line 06	Dept. of Biotechnology, Sher-e-Bangla Agricultural University	P010
15	Line 07	Dept. of Biotechnology, Sher-e-Bangla Agricultural University	P011

continued

Sl. No.	**Germplasm**	**Place of Collection**	**Accession Number**
16	Shahebpakri	Bangladesh Agricultural Development Corporation	P015
17	Lalpakri	Bangladesh Agricultural Development Corporation	P016
18	Paharipakri	Bangladesh Agricultural Development Corporation	P017
19	Shilpakri	Bangladesh Agricultural Development Corporation	P018
20	Shilbilaty	Bangladesh Agricultural Development Corporation	P019
21	Katapakri	Bangladesh Agricultural Development Corporation	P020
22	Mondira	Local	P022
23	Buri	Local	P023
24	Indurkani	Local	P024

3.5 Design of the experiment

The experiment was laid out in Randomized complete Block Design **(RCBD)** with three replications. Each germplasm was planted in each unit plots.

3.6 Layout of the experiment

An area of 37.5 m × 14 m was divided into three equal blocks. Each block consisted of 24 plots where 24 germplasm allotted randomly. There were 72 unit plots altogether in the experiment. The size of each plot was 4 m × 1 m. The distance between two blocks and two plots were l m and 0.5 m respectively. Piece of tubers with two eyes were planted on the plots with 60 cm × 25 cm spacing (Fig. 1).

3.7 Cultivation procedure

3.7.1 Land preparation

The soil was well prepared and good tilth was ensured for potato crop production. The land of the experimental field was ploughed with a power tiller up to a depth of 6-8 inches. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed. Finally, the unit plots were prepared as ridges and furrows. Furrows were made in each plot with 60 cm distance.

3.7.2 Manuring and Fertilizing

Manure and fertilizers were applied in the experimental field as per recommendation of BARI (2005).

Manure/Fertilizer	Dose per hectare
Cowdung	10 ton
Urea	300 kg
TSP	200 kg
MoP	300 kg
Gypsum	120 kg
Magnesium Sulphate	120 kg
Borax	10 kg

The entire amount of cowdung , gypsum, magnesium sulphate , borax, TSP and half of urea and MoP were applied as basal during land preparation. The rest of urea and MoP were used as top dressing in two equal installments. First and second installments were done at 30 and 60 days after planting.

3.7.3 Planting of potato tubers

Tuber pieces with two eyes were planted in the furrows of experimental plots on 05 October, 2010 maintaining a plant to plant spacing of 25 cm. Then tubers were covered with soils of ridges.

3.7.4 Intercultural operations

Intercultural operations such as weeding and earthing up were done manually at 30 days. After spading the soil between the rows, weeds were removed. Then urea and MoP were broadcasted between the rows, which was followed by earthing up soil at 20 cm from the base. Irrigation was applied four times, first one was one week after planting, second one was just after earthing up, third one was at 52 days and the last one was at 65 days after planting. A general dose of 0.2 percent (%) Asataf (systemic insecticide) was used at every 15 days and

0.02 percent (%) Dithane M-45 was used at every 15 days interval, starting at 35 days of planting to prevent any late blight infection.

3.7.5 Harvesting

All the germplasm were harvested on 2nd February 2011 when the crop was at full maturity. The whole plot was harvested. Data on tuber characters were collected from the each plot.

3.8 Data collection

Five plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.8.1 Color and shape of tuber

Color and shape of tuber was measured through eye observation in each germplasm and was recorded.

3.8.2 Color of sprout

Color of sprout was measured at top and bottom through eye observation in each germplasm and was recorded.

3.8.3 Number of eyes and sprouts per tuber

Eyes and sprouts were counted for each germplasm and their average was taken.

3.8.4 Branch of sprout

Branches per sprout were counted and recorded for each germplasm.

3.8.5 Length of sprout

Length of sprout for each germplasm was measured by using slide-calipers and their average was taken in cm.

3.8.6 Plant height

Plant height at 25 and 45 DAT was measured from sample plants in centimeter from the ground level to the tip of the longest stem and the mean value for each germplasm was calculated. Plant height was also recorded at 20 days interval starting from 25 days of transplanting up to 85 days to observe the growth rate of plants.

3.8.7 Leaves per plant

Total number of leaves was counted from selected plants and their average was taken as the number of leaves per plant.

3.8.8 Leaflets per leaf

The number of leaves of the sample plants was counted at the time of 50 DAT and the average number of leaflets produced per leaf was recorded.

3.8.9 Branch color

Color of branch was measured through eye observation in each germplasm and was recorded.

3.8.10 Branch diameter

Diameter was measured at the middle portion of large branches of 5 selected plants of each germplasm with slide-calipers and their average was taken in cm.

3.8.11 Leaves per plant

Total number of leaves was countered from selected plants and their average was taken as the number of leaves per plant.

3.8.12 Tuber length

The length of tuber was measured with slide-calipers for 20 selected marketable tubers from each plot and their average was taken in cm.

3.8.13 Tuber diameter

The diameter of tuber was measured with slide-calipers for 20 selected marketable tubers from each plot and their average was taken in cm.

3.8.14 Tuber weight

The weight of tuber was measured with electric balance for 20 selected marketable tubers from each plot and their average was taken in gm.

3.8.15 Tubers per plant

Total number of tubers was counted from selected plants and their average was taken as the number of tubers per plant.

3.8.16 Yield per plant

It was measured by the following formula:

$$\text{Yield per plant} = \frac{\text{Total weight of tubers in 5 sample plants}}{5}$$

3.8.17 Yield per plot

It was measured by weighing total tubers harvested from each unit plot.

3.8.18 Yield per hectare

Yield per hectare was calculated by converting the plot yield and expressed in ton.

3.9 Data Analysis

3. 9. 1 Univariate Analysis

The collected data were statistically analyzed. The mean, range and standard deviation (σ_x) for each character have been calculated and analysis of variance (within and between germplasm) for each of the character was performed through Microsoft Office Excel 2007 and MSTAT-C. The mean square (MS) at error and phenotypic variances were estimated as per Johnson *et al*. (1955). The error mean square (EMS) was considered as error variance (σ^2_e). Genotypic variances (σ^2_g) were derived by subtracting EMS from the genotypic MS and dividing by the number of replication as shown below:

$$\text{Genotypic variance, } \sigma^2_g = \frac{GMS - EMS}{r}$$

Where, GMS = Genotypic mean square

EMS = Error mean square

r = Number of replication

The phenotypic variances (σ^2_p), were derived by adding genotypic variances (σ^2_g) with the error variances (σ^2_e), as given by the following formula:

$$\text{Phenotypic variance, } \sigma^2_p = \sigma^2_g + \sigma^2_e$$

3. 9. 1. 1 Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation was calculated by the formula suggested by Burton (1952) as-

$$\text{Genotypic co-efficient of variation (GCV)} = \frac{\sigma_g \times 100}{\overline{X}}$$

Where, $\pm_g$ = Genotypic standard deviation

$\bar{x}$ = Population mea

Similarly, the phenotypic co-efficient of variation was calculated from the following formula:

$$\text{Phenotypic co-efficient variation (PCV)} = \frac{\sigma_p \times 100}{\bar{X}}$$

Where, $\pm_p$ = Phenotypic standard deviation

$\bar{x}$ = Population mean

3. 9. 1. 2 Estimation of heritability

Broad sense heritability was estimated by the following formula, suggested by Hanson *et al.* (1956) and Johnson *et al.* (1955).

$$\text{Heritability in broad sense, } h^2_b (\%) = \frac{\pm^2_g}{\pm^2_p} \times 100$$

Where, h^2_b = Heritability in broad sense

$\pm^2_g$ = Genotypic variance

$\pm^2_p$ = Phenotypic variance

3. 9. 1. 3 Estimation of genetic advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Johnson *et al.* (1955).

$$\text{Genetic advance, } GA = K.\, h^2.\, \pm_p$$

$$= K. \frac{\pm^2_g}{\pm^2_p} . \pm_p$$

Where, K = Selection differential, the value which is 2.06 at 5% selection

$\pm_p$ = Phenotypic standard deviation

Genetic advance as percentage of mean was calculated from the following formula:

$$\text{Genetic advance (\% of mean)} = \frac{\text{Genetic advance}}{\text{Population mean}} \times 100$$

3.9. 1. 4 Estimation of genotypic and phenotypic correlation co-efficient

For calculating the genotypic and phenotypic correlation coefficient for all possible combination the formula suggested by Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted.

The genotypic covariance components between two traits and of the phenotypic covariance component were derived in the same way as for the corresponding variance components. The covariance components were used to compute genotypic and phenotypic correlation between the pairs of the characters as follows:

$$\text{Genotypic correlation, } r_{gxy} = \frac{\sigma^2_{gxy}}{\sqrt{\sigma^2_{gx} \times \sigma^2_{gy}}}$$

Where, σ^2_{gxy} = Genotypic covariance between the traits x and y

σ^2_{gx} = Genotypic variance of the trait x

σ^2_{gy} = Genotypic variance of the trait y thus

$$\text{Phenotypic correlation, } r_{phxy} = \frac{\sigma^2_{phxy}}{\sqrt{\sigma^2_{phx} \times \sigma^2_{phy}}}$$

Where, σ^2_{phxy} = Phenotypic covariance between the traits x and y

σ^2_{phx} = Phenotypic variance of the trait x

σ^2_{phy} = Phenotypic variance of the trait y

3.9. 1. 5 Estimation of path coefficients

Correlation coefficient was further partitioned into components of direct and indirect effects by path coefficient analysis, described by Dewey and Lu (1959).

3. 9. 2 Multivariate analysis (D^2 Statistics)

Mean data for each character was subjected to multivariate analysis methods, viz. Principal component analysis (PCA), Principal coordinate analysis (PCO), Canonical variate analysis (CVA) and Cluster analysis (CLSA) using GENSTAT - 5.

3. 9. 2. 1 Principal component analysis (PCA)

Principal component analysis is one of the multivariate techniques to know the interrelationships among several characters and can be done from the sum of squares and product matrix for the characters. Principal components were computed from the correlation matrix and genotypic scores obtained for the first component and succeeding components with latent roots greater than unity (Jager *et al.* 1983).

3. 9. 2. 2 Principal coordinate analysis (PCO)

Principal coordinate analysis is equivalent to PCA but it is used to calculate inter-unit distances. Through the use of all dimensions of p it gives the minimum distances between each pair of n points using similarity matrix Digby *et al*. (1989). Inter-distances between germplasm were studied by PCO.

3.9. 2. 3 Canonical variate analysis (CVA)

The canonical variate analysis is based upon the roots and vectors of W-IB, where W is the pooled within groups covariance matrix and B is the among

groups covariance matrix. It provides two-dimensional plots that helped in separating different populations involved.

3. 9. 2. 4 Cluster analysis (CLSA)

Cultivars were divided into groups on the basis of a data set into some number of mutually exclusive groups. The clustering was done using non-hierarchical classification. In GENSTAT, the algorithm is used to search for optical values of the chosen criterion. The optimal values of the criteria followed by some initial classification of the genotypes into required number of groups, the algorithm repeatedly tra2nsfers genotypes from one group to another so long as such transfer improved the value of the criterion. When no further transfer can be found to improve the criterion, the algorithm switches to second stage that examine the effect of swopping two genotypes of different classes and so on.

3. 9. 2. 5 Computation of average intra-cluster distance

Computation of average Intra-cluster distance for each cluster was calculated by taking possible D^2 values within the members of a cluster obtained from the PCO after the clusters are formed. The formula utilized was $\sum D^2/n$, where $\sum D^2$ is the sum of distances between all possible combinations (n) of the genotypes included in a cluster. The square root of the average D^2 values represents the distance (D) within cluster.

3. 9. 2. 6 Cluster diagram

It was drawn using the values between and within cluster distances, which present a momentary idea of the pattern of diversity among the genotypes included in a cluster.

3. 9. 2. 7 Computation of average inter-cluster distances

The procedures of calculating inter-cluster distance between cluster II and I and between cluster III and I and between I and IV, between II and IV and so on. The clusters were taken one by one and their distances from other clusters were calculated.

CHAPTER IV

RESULTS AND DISCUSSION

Performance of 24 germplasm of potato was investigated in winter season and the findings of the present study have been discussed in this chapter under

separate headings. The results of the study showed marked variation in different characters, those are presented in the tables, figures and plates.

4.1 Morphological characterization of potato germplasm

As per the description for Potato, the characterization of potato germplasm were made.

4.1.1 Tuber color

Tuber color of different germplasm exhibited moderate variation (Table 1). Among the germplasm studied germplasm ‘Diamant’, ‘Granola’, ‘Provento’, ‘Line 04’ and ‘Mondira’ were yellowish, and ‘Jam Alu’, and ‘Indurkani’ were dark brown while rest of the germplasm were light reddish to dark reddish.

4.1.2 Tuber shape

Tuber shape of different germplasm exhibited moderate variation (Table 1). Among the germplasm studied germplasm ‘Diamant’ and ‘Line 06’ were oval to oblong; ‘Cardinal’, ‘Granola’ and ‘Line 04’ were round to oval; ‘Mondira’ were oval; ‘Jam Alu’, ‘Asterix’ and ‘Indurkani’ were oblong while rest of the germplasm were round.

Table 1. Morphological characteristics of potato tuber

Germplasm	Tuber characteristics				
	Color	Shape	Eyes/ tuber (no.)	Sprouts/ tuber (no.)	Percent (%) of sprouting
Diamant	Light Yellowish	Oval-Oblong	12.33	9.33	75.67

Cardinal	Reddish	Oval-Round	14.67	14.00	95.43
Granola	Light Yellowish	Round-Oval	12.67	10.00	78.93
Provento	Light Yellowish	Round	10.33	9.67	93.61
Ladyrosetta	Reddish	Round	4.67	3.00	64.24
Carrage	Reddish	Round	4.00	3.33	83.25
Jam Alu	Dark Brown	Oblong	9.00	7.00	77.78
Kufrisinduri	Reddish	Round	9.33	4.00	42.87
Asterix	Reddish	Oblong	16.00	14.00	87.50
Romana	Reddish	Round	10.33	9.67	93.61
Line 02	Reddish	Round	13.00	9.50	73.08
Line 04	Light Yellowish	Round-Oval	10.00	6.33	63.30
Line 05	Reddish	Round	7.00	5.67	81.00
Line 06	Reddish	Round-Oval	17.67	11.83	66.95
Line 07	Reddish	Round	11.67	4.67	40.02
Shahebpakri	Reddish	Round	21.33	16.00	75.01
Lalpakri	Reddish	Round	7.33	6.00	81.86
Paharipakri	Reddish	Round	9.00	7.33	81.44
Shilpakri	Reddish	Round	6.00	5.00	83.33
Shilbilaty	Reddish	Oblong	30.00	7.67	25.57
Katapakri	Reddish	Round	4.67	2.67	57.17
Mondira	Yellow	Oval	10.33	2.33	22.56
Buri	Reddish	Round	14.67	3.67	25.02
Indurkani	Dark Brown	Oblong	6.00	4.67	77.83

4.1.3 Eyes per tuber

Moderate variation was exhibited by number of eyes per tuber (Table 1). Asterix, ‘Line 06’, ‘Shahebpakri’ and ‘Shilbilaty’ provided more number of eyes (>15); ‘Ladyrosetta’, ‘Carrage’ and ‘Katapakri’ provided less number of eyes (<5) while rest of the germplasm provided moderate number of eyes (5-15).

4.1.4 Sprouts per tuber

Moderate variation was exhibit;ted by number of sprouts per tuber (Table 1). Cardinal, ‘Asterix’, ‘Line 06’ and ‘Shahebpakri’ provided more number of sprouts (>10); ‘Ladyrosetta’, ‘Carrage’, ‘Kufrisinduri’, ‘Line 07’, ‘Katapakri’, ‘Mondira’, ‘Buri’ and ‘Indurkani’ provided less number of sprouts (<5) while rest of the germplasm provided moderate number of sprouts (5-10).

4.1.5 Percent of sprouting

Percent of sprouting of different germplasm exhibited moderate variation (Table 1). Cardinal, ‘Provento’ and ‘Romana’ provided higher rate of sprouting (>90%); ‘Kufrisinduri’, ‘Line 07’, ‘Shilbilaty’, ‘Katapakri’, ‘Mondira’ and ‘Buri’ provided lower rate of sprouting (<60%) while rest of the germplasm provided moderate rate of sprouting (60-90%).

4.1.6 Sprout color

Diamant, ‘Granola’ and ‘Provento’ were yellowish at both top and bottom; ‘Line 02’ and ‘Line 04’ was whitish and others were varied from greenish to pinkish (Table 2).

4.1.7 Branches per sprout

Branches per sprout showed significant variation among the germplasm (Appendix III). It was varied from 1 to 6.33 (Table 2). Cardinal, ‘Carrage’ and ‘Line 02’ provided higher number of sprouts (5 and above); ‘Line 04’, ‘Line 06’, ‘Shilpakri’, ‘Shilbilaty’ and ‘Katapakri’ provided the lowest number of sprout (1). Phenotypic coefficient of variation (39.33) was higher than

genotypic coefficient of variation (36.88), indicates that the character was mostly under the control of environment. This character showed high estimate of broad sense heritability (87.95) (Table 5) along with extreme genetic advance in percent of mean (71.25), thus provided opportunity for selection of high valued germplasm in breeding program.

4.1.8 Length of sprout

Length of sprout showed significant variation among the germplasm (Appendix III). It was varied from 1.12 cm to 3.53 cm (Table 2). Diamant and 'Jam Alu' provided higher length of sprouts (3 cm and above); 'Line 02', 'Line 04' and 'Ladyrosetta' provided lower length of sprout (<1.5 cm). Phenotypic coefficient of variation was (48.08) and genotypic coefficient of variation was (44.44). Phenotypic coefficient of variation was higher than genotypic coefficient of variation. It indicates that the expression of this character was mostly influenced by the control of environment. The heritability estimation showed high heritability (85.42) (Table 5) along with extreme genetic advance in percent of mean (84.60). Therefore, this character could be used in genetic gain through selection.

4.1.9 Stem color

Jam Alu and 'Indurkani' was reddish green; 'Cardinal', 'Line 04', 'line 05' and 'Line 06' was pinkish green and other germplasm were green in stem color.

Table 2. Morphological characteristics of sprout

Germplasm	Sprout characteristics			
	Color		Branches / sprout (no.)	Length of sprout (cm)
	at top	at bottom		
Diamant	Yellow	Yellow	3.00	3.00

Cardinal	Pinkish White	Pinkish White	5.00	2.55
Granola	Yellow	Yellow	4.67	1.82
Provento	Yellow	Yellow	4.00	2.22
Ladyrosetta	Brown	Brown	4.67	1.37
Carrage	Pink	Brown	6.33	2.00
Jam Alu	Pink	White	2.33	3.53
Kufrisinduri	Pink	Brown	4.00	1.72
Asterix	Green	Pink	3.33	2.54
Romana	Pink	Green	4.00	2.33
Line 02	White	Pink	5.00	1.43
Line 04	White	White	1.00	1.12
Line 05	Pinkish White	Pinkish White	3.50	2.33
Line 06	Pinkish Green	Pinkish Green	1.00	2.00
Line 07	Pink	White	2.00	1.47
Shahebpakri	Pink	Green	1.67	2.07
Lalpakri	Greenish White	Greenish White	2.00	2.53
Paharipakri	Pinkish White	Pinkish White	4.33	1.93
Shilpakri	Green	White	1.00	2.99
Shilbilaty	Green	Pink	1.00	2.17
Katapakri	Green	Pink	1.00	2.68
Mondira	Green	Pink	1.67	2.03
Buri	Pink	Green	2.00	1.93
Indurkani	Pink	White	2.00	2.00

Cardinal

Carrage

Diamant

Granola

Jam Alu

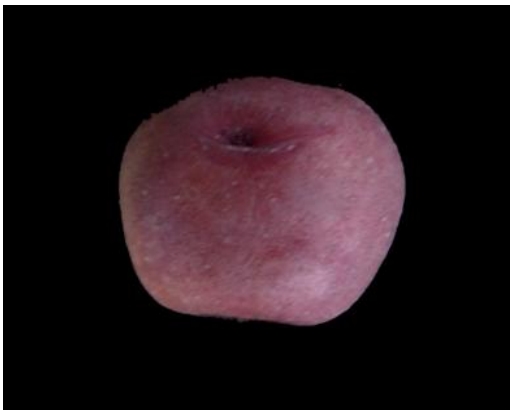
Kufrisinduri

Plate 1. Morphological features of sprouted tubers of potato germplasm

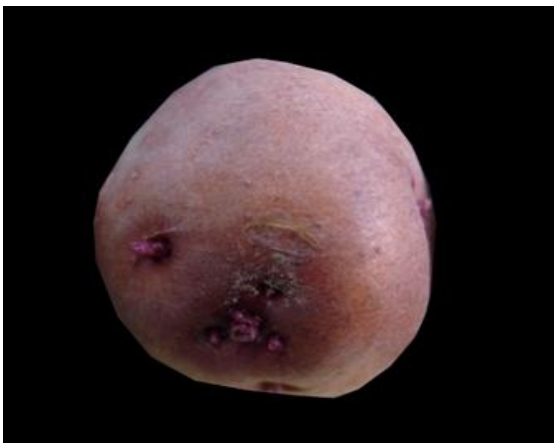
Ladyrosetta

Provento

Romana



Shilbilaty



Buri

Plate 2. Morphological features of sprouted tubers of potato germplasm

Line 02

Line 04

Line 05

Line 06

Plate 3. Morphological features of sprouted tubers of potato germplasm

4.1.10 Number of leaves per plant

Differences among the germplasm were significant for leaves per plant (Appendix IV). Shilbilaty showed the highest number (15) and 'Ladyrosetta' showed the lowest number (4.00) of leaves per plant (Table 3). Phenotypic coefficient of variation and genotypic coefficient of variation were (45.03) and (42.76) respectively, where the former was higher than the later indicating influence of environment on expression of this trait. This character showed high estimate of broad sense heritability (90.17) (Table 5) along with extreme genetic advance in percent of mean (83.64), thus provided opportunity for selection of high valued germplasm in breeding program.

4.1.11Number of leaflets per leaf

Germplasm showed significant variation for leaflets per plant (Appendix IV). Shilbilaty showed the highest number (43) and 'Carrage' showed the lowest number (5.33) of leaflets per plant (Table 3). Phenotypic coefficient of variation (23.99) was higher than the genotypic coefficient of variation (19.60), indicates that the character was mostly under the control of environment. This character showed medium estimate of broad sense heritability (66.80) (Table 5) along with lower genetic advance in percent of mean (33.01). Therefore this character could not be useful to achieve genetic gain through selection.

4.1.12 Stem diameter

Stem diameter showed moderate variation among the germplasm. It was varied from 0.08 cm to 0.50 cm (Table 3) at 25 DAP and 0.13 cm to 1.54 cm at 45 DAP. Diamant, 'Ladyrosetta' and 'Buri' showed higher branch diameter (0.70 cm and above) at 45 DAP; 'Lalpakri', 'Paharipakri', 'Katapakri', 'Shilpakri', 'Romana' and 'Indurkani' showed lower branch diameter (<0.30 cm).

Romana

Katapakri

Carrage

Buri

Shilbilaty

Ladyrosetta

Plate 4. Plant stalk of potato germplasm

Line 07

Provento

Line 04

Plate 5. Plant stalk of potato germplasm

4.1.13 Plant height

Differences among the cultivars were significant for plant height (Appendix III). Line 06 and 'Line 05' showed the highest plant height (34.87 cm and 63.67 cm) at 25 and 45 days after planting (DAP) respectively. 'Shahebpakri' (5.43 cm) and 'Indurkani' (20 cm) showed the lowest plant height at 25 and 45 DAP respectively (Table 3). Phenotypic coefficient of variation (29.90) was slightly higher than genotypic coefficient of variation (28.68) indicating minor influence of environment on expression of this character. The heritability estimation showed high heritability (92.00) (Table 5) along with along with medium genetic advance in percent of mean (56.67). Therefore, this character

could not be helpful to achieve genetic gain through selection. Rasul *et al*. (1990) observed high GCV, high heritability and high genetic gain for plant height.

4.1.14 Tuber length

Length of tuber showed significant variation among the germplasm (Appendix IV). The highest and lowest tuber length was found in 'Line 04' (7.33 cm) and 'Shahebpakri' (1.73 cm) respectively (Table 4). Phenotypic coefficient of variation (40.41) was higher than genotypic coefficient of variation (36.05), indicates that the character was mostly influenced by the control of environment. This character showed high estimate of broad sense heritability (79.60) (Table 5) along with medium genetic advance in percent of mean (66.27). Therefore, this character could be used in selection for genetic gain.

4.1.15 Tuber diameter

Diameter of tuber showed significant variation among the germplasm (Appendix IV). The highest and lowest tuber diameter was found in 'Line 06' (6.57 cm) and 'Indurkani' (1.70 cm) respectively (Table 4). Phenotypic coefficient of variation was (39.10) and genotypic coefficient of variation was (34.29). The former was higher than the later one, indicates that the character was mostly under the control of environment. This character showed high heritability estimation (76.93) (Table 5) with medium genetic advance in percent of mean (61.96), thus provided opportunity for selection of high valued germplasm in breeding program.

4.1.16 Individual tuber weight

Significant variation among the germplasm was found for individual tuber weight (Appendix IV). The highest and lowest tuber weight was found in 'Diamant' (92.00 g) and 'Shahebpakri' (18.00 g) respectively (Table 4). Phenotypic coefficient of variation (72.39) was higher than the genotypic

coefficient of variation (69.43), indicates that the character was mostly influnced by the control of environment. The heritability estimation showed high heritability (91.99) (Table 5) along with extreme genetic advance in percent of mean (137.18), thus provided high opportunity for selection of high valued germplasm in breeding program

Table 3. Morphological characteristics of potato stalk

Germplasm	Stem Color	Leaves / plant (no.)	Leaflets / leaf (no.)	Plant height (cm)		Stem diameter (cm)	
				25 DAP	45 DAP	25 DAP	45 DAP
Diamant	Green	6.67	8.00	24.33	53.67	0.36	0.70
Cardinal	Green with red dot	4.67	7.67	11.00	56.33	0.25	0.63
Granola	Green	4.20	7.33	8.33	51.33	0.22	0.53
Provento	Green	4.10	6.67	7.80	48.00	0.42	0.52
Ladyrosetta	Green	4.00	6.67	15.67	34.75	0.15	0.77
Carrage	Green	4.90	5.33	11.33	30.67	0.10	0.47
Jam Alu	Green with red dot	4.67	7.67	23.60	42.33	0.44	0.53
Kufrisinduri	Green	11.00	8.52	29.23	45.00	0.31	0.53
Asterix	Green	5.10	9.00	10.43	42.50	0.25	0.42
Romana	Green	5.33	11.00	13.47	34.33	0.15	0.25
Line 02	Green	10.67	9.88	13.50	60.50	0.32	0.55
Line 04	Green with red dot	5.00	12.50	11.50	58.00	0.45	0.55
Line 05	Green with red dot	6.00	11.00	14.27	63.67	0.50	0.60
Line 06	Green with red dot	9.00	9.10	34.87	47.67	0.50	0.60
Line 07	Green	8.50	6.67	25.67	38.00	0.14	0.50
Shahebpakri	Green	4.20	7.67	5.43	25.33	0.15	0.32
Lalpakri	Green	4.10	8.33	11.53	30.40	0.18	0.21
Paharipakri	Green	5.33	9.33	10.40	32.00	0.16	0.20
Shilpakri	Green	4.20	11.00	9.53	30.00	0.08	0.20
Shilbilaty	Green	15.00	43.77	12.47	39.00	0.18	0.34
Kata pakri	Green	4.20	9.67	11.50	28.33	0.13	0.13
Mondira	Green	5.00	12.00	12.47	40.00	0.23	0.67
Buri	Green	6.00	10.33	6.43	31.00	0.20	1.54
Indurkani	Green with red dot	4.67	8.00	6.23	20.00	0.16	0.23

4.1.17 Number of tubers per plant

Number of tubers per plant showed significant variation among the germplasm (Appendix IV). Shahebpakri showed the highest number (37.33) and 'Granolla', 'Ladyrosetta' and 'Line 06' showed the lowest number (7.33) of tubers per plant (Table 4). Phenotypic coefficient of variation (50.10) was higher than genotypic coefficient of variation (47.18), indicates that the character was mostly under the control of environment. This character showed high estimate of broad sense heritability (88.68) (Table 5) along with extreme genetic advance in percent of mean (91.53), thus provided opportunity for selection of high valued germplasm in breeding program.

4.1.18 Yield per plant

Significant variation was found among the germplasm for yield per plant (Appendix IV). The highest yield per plant was found in 'Carrage' (853.33 g) and the lowest was in 'Katapakri' and 'Lalpakri' (398.20 g) (Table 4). Phenotypic coefficient of variation and genotypic coefficient of variation were (22.04) and (20.04) respectively. Phenotypic coefficient of variation was higher than genotypic coefficient of variation indicates that the character was mostly under the control of environment. This character showed high estimate of broad sense heritability (76.32) (Table 5) along with low genetic advance in percent of mean (36.07).Therefore, this character could be helpful to achieve the genetic gain through selection.

Table 4. Yield related characteristics of potato

Germplasm	Tuber length (cm)	Tuber dia. (cm)	Individual tuber wt. (gm)	Tubers/ plant (no.)	Yield/ plant (gm)	Yield/ plot (kg)	Yield (t /ha)
Diamant	6.17	4.43	92.00	9.33	823.87	11.92	29.80
Cardinal	5.83	4.50	80.67	10.33	797.27	11.88	29.70
Granola	6.67	5.17	82.67	7.33	802.83	11.92	29.75
Provento	5.23	3.87	84.00	12.33	786.50	11.76	29.40
Ladyrosetta	4.00	3.67	76.67	7.33	586.83	10.00	25.01
Carrage	4.43	3.33	83.00	14.33	853.33	12.12	30.30
Jam Alu	5.43	2.60	31.00	32.33	681.70	11.40	28.50
Kufrisinduri	3.50	2.27	33.67	16.33	520.87	10.36	25.90
Asterix	5.67	3.03	36.33	15.33	828.43	11.96	29.90
Romana	3.50	3.33	20.78	22.33	481.33	10.36	25.90
Line 02	7.00	5.33	76.67	17.33	656.33	11.00	27.50
Line 04	7.33	6.17	81.67	9.33	788.10	11.60	29.00
Line 05	6.67	5.67	80.67	9.33	670.60	11.20	28.00
Line 06	6.50	6.57	78.33	7.33	685.50	10.96	27.40
Line 07	3.50	2.17	33.67	27.33	697.07	11.20	28.00
Shahebpakri	1.73	2.93	18.00	37.33	477.97	4.80	15.00
Lalpakri	3.80	3.60	20.78	18.33	398.20	4.50	14.80
Paharipakri	4.00	3.10	23.33	17.33	420.77	4.60	14.08
Shilpakri	2.33	2.73	19.72	22.33	442.57	4.96	15.01
Shilbilaty	2.23	2.70	18.78	22.33	431.83	4.20	14.24
Katapakri	3.80	3.60	20.78	18.33	398.20	4.30	14.50
Mondira	7.12	4.33	51.67	9.33	474.67	5.60	16.26
Buri	3.50	2.67	24.67	25.33	415.00	3.80	13.80

Indurkani	2.33	1.70	19.12	25.33	405.85	3.60	13.00

4.1.19 Yield per plot

There was significant variation among the germplasm found for yield per plot (Appendix IV). The highest and lowest yield was found in 'Carrage' (12.22 kg) and 'Indurkani' (3.60 kg) respectively (Table 4).

4.1.20 Yield per ha

Significant variation among the germplasm was found for yield per ha (Appendix IV). The highest tuber yield (30.30 t/ha) was found from the germplasm 'Carrage' (30.30 ton) whereas the lowest yield (13.00 t/ ha) from 'Indurkani' (13.00 ton) (Table 4).

4. 2 Correlation coefficient analysis

The correlation coefficients were determined to find out the inter-relationship among the characters studied. Phenotypic and genotypic correlation coefficient between yield per plant and its eight component characters are presented in Table 6 and Table 7.

Genotypic correlation among branches per sprout (0.26), plant height (0.70), leaves per plant (0.32), leaflets per leaf (0.23), tuber length (0.67), tuber diameter (0.58), tuber weight (0.77) and yield per plant were positive and significant but tuber length (-0.62), tuber diameter (-0.69) and tuber weight (0.60) showed significant negative correlation with tubers per plant (Table 7). Plant height showed significant and positive relation with tuber length (0.85), diameter (0.81) and weight (0.81), whereas significant and negative relation with tubers per plant (-0.47). Leaflets per leaf showed significant and positive relation with tuber diameter (0.32) and weight (0.22), whereas negative relation with tubers per plant (-0.02). Leaves per plant showed positive correlation with tuber length (0.12), diameter (0.10), weight (0.16) and tubers per plant (0.12). Branches per sprout showed significant and positive relation with leaves per plant (0.57) and sprout length showed significant and

positive relation with plant height (0.38) (Table 7). Ramanjit *et al*. (2001) recorded that tuber yield shows significant positive correlations with tuber number and tuber weight.

4. 3 Path analysis

In order to obtain a clear picture of the inter relationship between yield per plant and other yield components, direct and indirect effects were worked out using path analysis. The results are presented in Table 8 and Figure 2.

Path analysis revealed that plant height (0.14), leaves per plant (0.09), tuber length (0.13), tuber diameter (0.10), tuber weight (0.97) and tubers per plant (0.86) had positive direct effect on yield per plant (Table 8). Branches per sprout had negative direct effect on yield (-0.16) but positive indirect effect via leaves per plant (0.05), tuber length (0.01), tuber diameter (0.00), tuber weight (0.08) and tubers per plant (0.24), thus showed positive correlation with yield per plant (0.26). Plant height (-0.40), leaflets per leaf (-0.02), tuber length (-0.54), tuber diameter (-0.60) and tuber weight (-0.52) had negative indirect effect on yield via tubers per plant (Fig.2). Most of the characters except tubers per plant had positive indirect effect on yield via plant height, leaves per plant, tuber length, tuber diameter and tuber weight. Nakitandwe *et al*. (2003) and Ozkaynak *et al.* (2003) recorded number of leaves, number of stems, number of tubers and mean tuber weight as the main yield components, with number of tubers per plant and mean tuber weight having the highest direct path coefficients. Bhagowati and Saikia, (2003) observed the negative association of tuber number and average tuber weight, as observed in the present study, indicated the need of breaking negative linkage between these characters before using them as a selection criteria. They also observed plant height, primary branch number and leaf number showed high indirect effects via average tuber weight indicating their importance in the selection program. The leaf number and average tuber weight showed negative indirect effect via tuber number on yield, while tuber number showed a negative indirect effect on yield via leaf number and average tuber weight.

Table 5. Genetic parameters for yield contributing characters

	Branches/ Sprout (no.)	Sprout length (cm)	Plant height at 45 DAP	Leaves /plant (no.)	Leaflet /leaf (no.)	Tuber length (cm)	Tuber diameter (cm)	Tuber wt. (gm)	Tubers /plant (no.)	Yield /plant (gm)
GMS	2.94	2.16	40.95	5.26	8.95	4.70	3.63	57.00	17.21	762.15
σ^2_g	14.96	9.66	137.93	5.05	3.08	2.87	1.55	1566.14	65.92	23329.54
σ^2_p	17.01	11.31	149.92	5.61	4.61	3.61	2.01	1702.56	74.33	30567.71
σ^2_e	2.05	1.65	11.99	0.55	1.53	0.74	0.46	136.42	8.42	7238.17
GCV	36.88	44.44	28.68	42.76	19.60	36.05	34.29	69.43	47.18	20.04
PCV	39.33	48.08	29.90	45.03	23.99	40.41	39.10	72.39	50.10	22.94
ECV	13.65	18.36	8.46	14.12	13.82	18.25	18.78	20.49	16.86	11.16
h^2_b	87.95	85.42	92.00	90.17	66.80	79.60	76.93	91.99	88.68	76.32
GA (5%)	7.47	5.92	23.21	4.40	2.95	3.12	2.25	78.19	15.75	274.88
GA in % of mean (5%)	71.25	84.60	56.67	83.64	33.01	66.27	61.96	137.18	91.53	36.07

GMS – Genetic mean square; GCV – Genetic co-efficient of variation; PCV- Phenotypic co-efficient of variation; ECV- Environmrtal co-efficient of variation; σ^2_g – Genotypic variance; σ^2_p- Phenotypic variance; σ^2_e - Error variance; h^2_b – Heritability in board sence; GA- Genetic Advance.

Table 6. Phenotypic correlation among the yield contributing characters

	Sprout length (cm)	Plant height at 45 DAP	Leaves /plant (no.)	Leaflet /leaf (no.)	Tuber length (cm)	Tuber diameter (cm)	Tuber wt. (gm)	Tubers /plant (no.)	Yield /plant (gm)
Branches/ Sprout (no.)	0.64**	0.28*	0.51**	0.11	0.12	0.07	0.09	0.12	0.13
Sprout length (cm)		0.37**	0.17	-0.09	0.15	0.21	0.16	-0.00	0.10
Plant height at 45 DAP			0.40**	0.20	0.68**	0.73**	0.76**	-0.41**	0.61**
Leaves/plant (no.)				0.26*	0.09	0.10	0.15	0.13	0.25*
Leaflets/leaf (no.)					0.11	0.23*	0.17	0.01	0.15
Tuber length (cm)						0.76**	0.81**	-0.49**	0.60**
Tuber diameter (cm)							0.80*	-0.59**	0.50**
Tuber wt.(gm)								-0.55**	0.74**
Tubers/plant (no.)									0.03

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

Table 7. Genotypic correlation among the yield contributing characters and yield

	Sprout length (cm)	Plant height at 45 DAP	Leaves /plant (no.)	Leaflet /leaf (no.)	Tuber length (cm)	Tuber diameter (cm)	Tuber wt. (gm)	Tubers /plant (no.)	Yield /plant (gm)
Branches/ Sprout (no.)	0.75**	0.29*	0.57**	0.16	0.11	0.08	0.08	0.28*	0.26*
Sprout length (cm)		0.38**	0.19	-0.14	0.21	0.24*	0.12	0.00	0.14
Plant height at 45 DAP			0.40**	0.18	0.85**	0.81**	0.81**	-0.47**	0.70**
Leaves/plant (no.)				0.31**	0.12	0.10	0.16	0.12	0.32**
Leaflet/Leaf (no.)					0.21	0.32**	0.22*	-0.02	0.23*
Tuber length (cm)						0.89**	0.91**	-0.62**	0.67**
Tuber diameter (cm)							0.88**	-0.69**	0.58**
Tuber wt. (gm)								-0.60**	0.77**
Tubers/plant (no.)									0.01

* indicates significant at 5% level of significance, ** indicates significant at 1% level of significance

Table 8. Partitioning of genotypic correlation

	Branches/ Sprout (no.)	**Sprout length (cm)**	**Plant height (cm)**	**Leaves /plant (no.)**	**Leaflet /leaf (no.)**	**Tuber length (cm)**	**Tuber dia. (cm)**	**Tuber wt. (gm)**	**Tubers /plant (no.)**	**Genotypic correlation with yield**
Branches/ Sprout (no.)	**-0.16**	0.00	0.04	0.05	-0.01	0.01	0.00	0.08	0.24	0.26*
Sprout length (cm)	-0.12	**0.00**	0.05	0.01	0.00	0.02	0.02	0.12	0.00	0.14
Plant height (cm)	-0.04	0.00	**0.14**	0.03	-0.01	0.11	0.08	0.79	-0.40	0.70**
Leaves /plant (no.)	-0.09	0.00	0.05	**0.09**	-0.02	0.01	0.01	0.15	0.10	0.32**
Leaflet /Leaf (no.)	-0.02	0.00	0.02	0.02	**-0.06**	0.02	0.03	0.22	-0.02	0.23*
Tuber length (cm)	-0.01	0.00	0.12	0.01	-0.01	**0.13**	0.09	0.89	-0.54	0.67**
Tuber dia. (cm)	-0.01	0.00	0.11	0.01	-0.02	0.11	**0.10**	0.86	-0.60	0.58**
Tuber wt. (gm)	-0.01	0.00	0.11	0.01	-0.01	0.11	0.09	**0.97**	-0.52	0.77**
Tubers /plant (no.)	-0.04	0.00	-0.06	0.01	0.00	-0.08	-0.07	-0.59	**0.86**	0.01

** indicates significant at 1% level of significance; Residual effects=0.06,

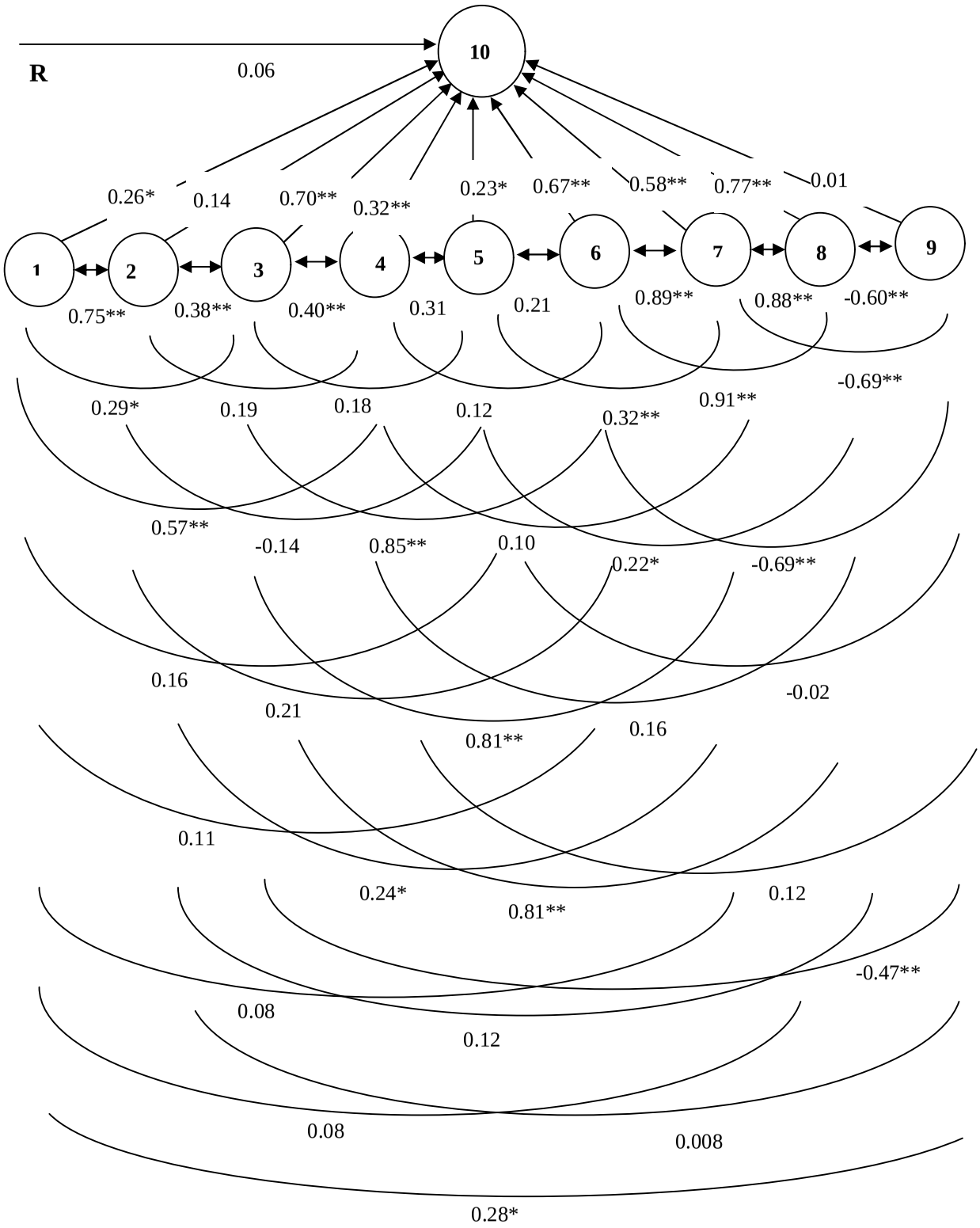


Fig. 2. Path diagram of 9 yield contributing traits in 24 potato germplasm

1= Branches/Sprout, 2= Sprout length, 3=Plant height at 45 DAS, 4=Leaves per plant, 5= leaflet per leaf, 6=tuber length, 7= tuber diameter, 8= tuber weight, 9= tuber per plant, 10= Yield per plant .

R= residual effect

4. 4 Multivariate analysis

The results of genetic diversity in 24 potato germplasm are presented in this section.

4. 4. 1 Principal component analysis (PCA)

Principal component analysis was carried out with 24 germplasm of potato. The eigen values for first two principal component axes of coordination of germplasm accounted for 54.47% variation (Table 9).

Table 9. Eigen values and percentage of variation for corresponding 15 component characters in 24 potato germplasm

Parameters	Eigen values	Percentag (%) of total variation accounted for individual characters	Percentage (%) of cumulative variation
Eyes/tuber (no.)	5.46	36.46	36.46
Sprouts/tuber (no.)	2.70	18.01	54.47
Branches/sprout (no.)	1.44	9.65	64.12
Length of sprout (cm)	1.32	8.8	72.92
PH at 25 DAP	1.02	6.84	79.76
PH at 45 DAP	0.97	6.49	86.25
Branch dia. at 25 DAP	0.81	5.40	91.65
Branch dia. at 45 DAP	0.60	4.03	95.68
Leaves/plant (no.)	0.23	1.58	97.26
Leaflets/leaf (no.)	0.12	0.85	98.11
Tuber length (cm)	0.10	0.73	98.84
Tuber diameter (cm)	0.08	0.58	99.42
Tuber wt. (gm)	0.05	0.39	99.81
Tubers/plant (no.)	0.018	0.12	99.93
Yield/pl (gm)	0.01	0.07	100

The first seven principal axes accounted for around 90% of the total variation among the 15 characters describing 24 potato germplasm (Table 9). A two

dimensional scattered diagram was developed on the basis of the principal component (Z_1 and Z_2) score of two principal coordinate axes I and II.

4. 4. 2 Non-Hierarchical Clustering

The computations from covariance matrix gave non-hierarchical clustering among twenty four germplasm and grouped them into four clusters. The clustering pattern obtained coincided with the apparent grouping patterns performed by PCA. So, the results obtained through PCA were confirmed by non-hierarchical clustering. Table 10 and Figure 2 represent the clusters occupied by 24 germplasm of potato. The cluster IV contained the highest number of cultivars (15) followed by cluster III (6), cluster I (2) and cluster II (1) (Table 10 and Figure 3).

Table 10. Distribution of 24 potato germplasm among 4 different clusters

Cluster	No. of member	Accession numbers	Germplasm
I	2	P008, P009	Line 04 and Line 05
II	1	P007	Line 02
III	6	P001, P002, P004, P011, P012,P022	Diamant, Cardinal, Provento, Line 07, Jam Alu and Mondira
IV	15	P003,P005,P006, P010,P013, P014, P015, P016,P017, P018, P019, P020, P021, P0 23, P024	Granola, Ladyrosetta, Carrage, Line 06, Kufrisinduri, Asterix, Shahebpakri, Lalpakri, Paharipakri, Shilpakri, Shilbilaty, Katapakri, Romana, Buri and Indurkani

Cluster I was composed of two germplasm (‘Line 04’ and ‘Line 05’). This cluster earned the highest cluster mean values for plant height at 45 DAP (60.83 cm), branch

diameter at 25 DAP (0.48 cm), leaflets per leaf (11.75), tuber length (7.00 cm), tuber diameter (5.92 cm) and tuber weight (156.17 gm) (Table 11). This cluster did not earn the highest cluster mean value for any other character.

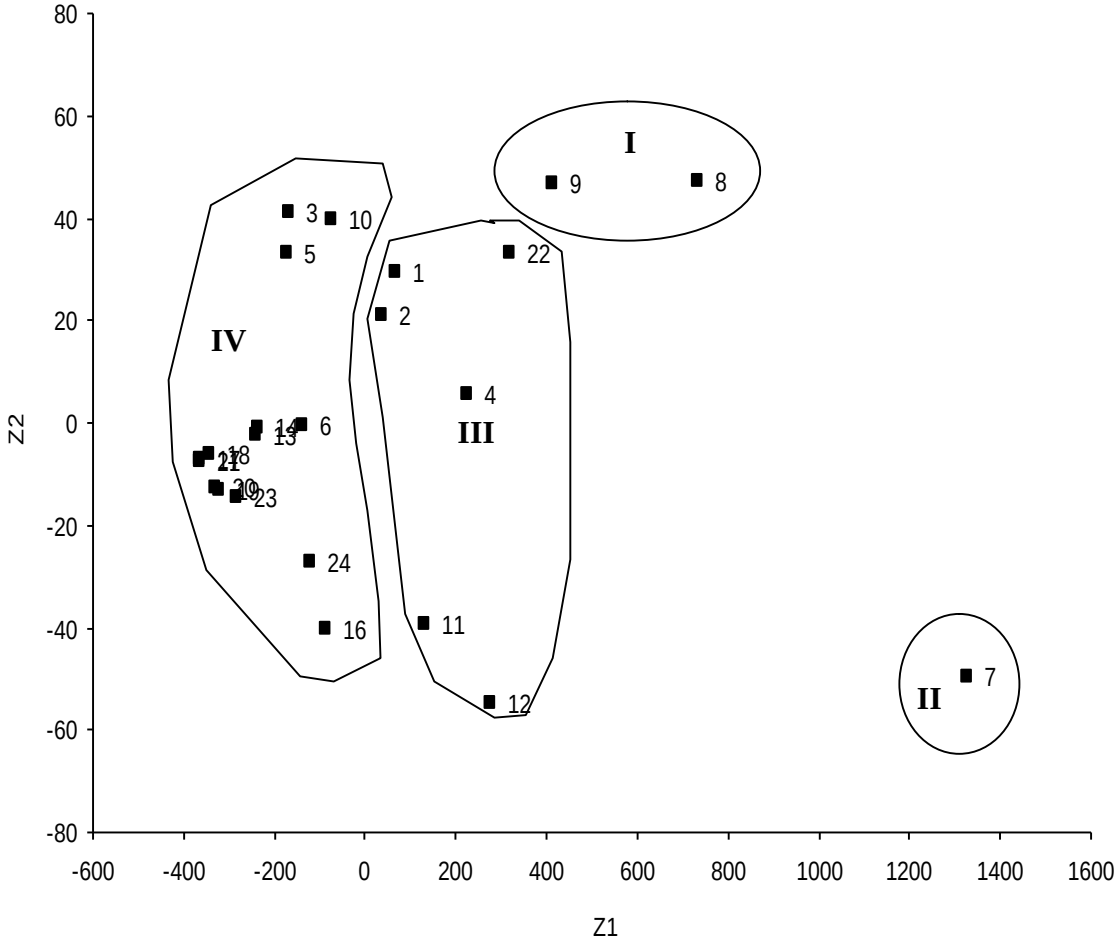


Fig. 3. Scatter distribution of 24 potato germplasm on the basis of Principal Component Score superimposed with clustering

Cluster II was formed by ‘Line 02’, where it leads in cluster mean values for eyes per tuber (13.00), sprouts per tuber (9.50), branches per sprout (5.00), leaves per plant (10.67), tuber length (7.00 cm) and yield per plant (2086.33 gm) (Table 11).

Cluster III composed of six germplasm viz. ‘Diamant’, ‘Cardinal’, ‘Provento’, ‘Line 07’, ‘Jam Alu’ and ‘Mondira’, where cluster mean was highest for length of sprout (2.47 cm), plant height at 25 DAP (17.48 cm) and branch diameter at 45 DAP (0.59 cm) (Table 11).

Cluster IV was established by 'Granola', 'Ladyrosetta', 'Carrage', 'Line 06', 'Kufrisinduri', 'Asterix', 'Shahebpakri', 'Lalpakri', 'Paharipakri', 'Shilpakri', 'Shilbilaty', 'Katapakri', 'Romana', 'Buri' and 'Indurkani', where the cluster mean leads only for tubers /plant (18.40) (Table 11).

Table 11. Cluster mean values for 15 characters of potato germplasm

Parameters	Cluster			
	I	II	III	IV
Eyes/tuber	8.50	13.00	11.39	11.58
Sprouts/tuber	6.00	9.50	7.99	7.26
Branches/ sprout	2.25	5.00	3.00	2.87
Length of sprout (cm)	1.73	1.43	2.47	2.14
Plant height at 25 DAP (cm)	12.88	13.50	17.48	13.12
Plant height at 45 DAP (cm)	60.83	60.50	46.39	34.82
Branch diameter at 25 DAP (cm)	0.48	0.32	0.31	0.19
Branch diameter at 45 DAP (cm)	0.58	0.55	0.59	0.44
Leaves/plant	5.50	10.67	5.43	5.41
Leaflets/leaf	11.75	9.88	8.11	11.00
Tuber length (cm)	7.00	7.00	5.64	3.87
Tuber dia. (cm)	5.92	5.33	3.65	3.26
Tuber wt. (gm)	156.17	126.67	73.83	36.84
Tubers/plant	9.33	17.33	16.83	18.40
Yield/plant (gm)	1329.35	2086.33	936.84	528.37

4. 4. 3 Principal coordinate analysis (PCO)

The highest intra-cluster distance was recorded in cluster IV (2.03) containing fifteen cultivars followed by cluster III (1.70) having six germplasm. The lowest intra cluster distance was found in cluster II (0.00) having only one germplasm followed by cluster I (1.08) having two germplasm (Table 12 and Figure 4).

Table 12. Intra (diagonal) and inter (off diagonal) cluster distances (D^2) among 24 germplasm of potato

Cluster	Cluster			
	I	II	III	IV
I	**1.08**			

II	21.86	**0.00**		
III	11.38	25.18	**1.70**	
IV	16.62	32.13	7.00	**2.03**

4. 4. 4 Canonical variate analysis

Canonical variate analysis was performed to obtain the inter cluster distances. The highest inter-cluster distance was observed (Table 12 and Figure 4) between cluster II and IV (32.13) followed by the distance between cluster II and III (25.18) and the lowest inter-cluster distance was observed between cluster III and IV (7.00) followed by the distance between cluster I and III (11.38) (Table 12 and Figure 4). The highest inter cluster distance between clusters indicated that the genotypes belonging to each pair of clusters were genetically diverse. Similarly the lowest inter cluster distance between clusters indicated the genotypes belonging to each pair of clusters were less diverse.

4. 4. 5 Contribution of characters towards divergence of germplasm

Vector 1 obtained from PCA (Table 13) expressed that plant height at 45 DAP (0.13), branch diameter at 25 DAP (0.39), tuber diameter (0.39), tuber weight (0.37), tubers per plant (0.39) and yield per plant (0.31) were major characters that contributed to the genetic divergence and vector 2 represented that length of sprout (0.26), plant height at 25 DAP (0.00), tuber diameter (0.09), tuber weight (0.02) and tubers per plant (0.05) were most important characters that play major roles to the genetic divergence (Table 13).

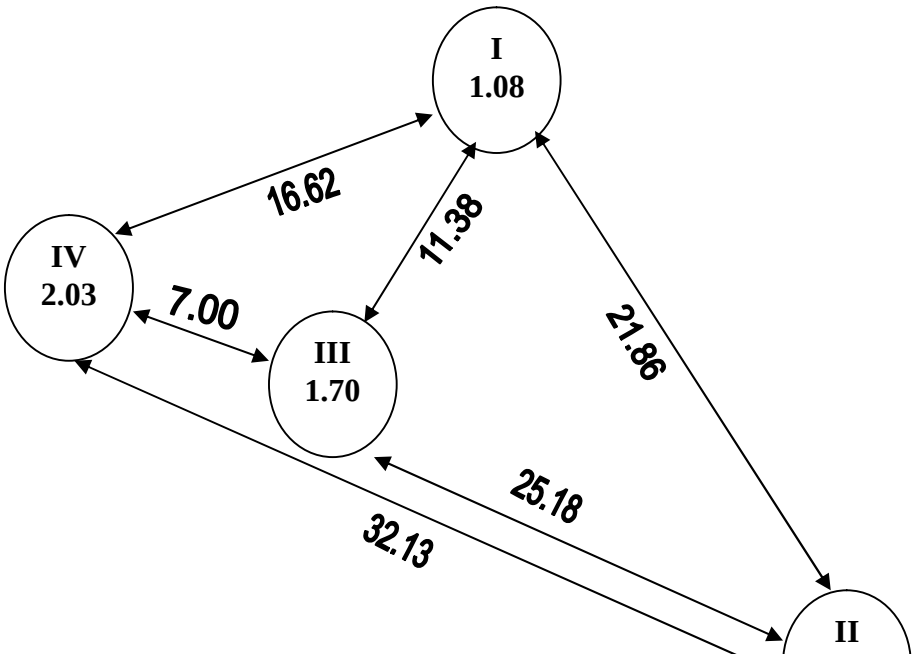


Fig. 4. Diagram showing intra (inside the circle) and inter (outside the circle) cluster distances of 24 potato germplasm

Table 13. Latent vectors for 15 principal component characters of potato

Parameters	Vectors 1	Vectors 2
Eyes/tuber	0.00	-0.55
Sprouts/tuber	0.07	-0.21
Branches/ sprout	0.10	0.26
Length of sprout (cm)	-0.11	0.00
Plant height at 25 DAP (cm)	0.13	-0.14
Plant height at 45 DAP (cm)	0.39	-0.10
Branch diameter at 25 DAP (cm)	0.33	-0.11
Branch diameter at 45 DAP (cm)	0.17	-0.02
Leaves/plant	0.08	-0.51
Leaflets/leaf	-0.05	-0.47
Tuber length (cm)	0.39	0.09
Tuber dia. (cm)	0.37	0.02
Tuber wt. (gm)	0.39	0.05
Tubers/plant	-0.30	-0.16
Yield/plant (gm)	0.31	-0.03

4. 4. 6 Selection of genotypes as parent for hybridization program

The highest inter-cluster distance was observed (Table 12 and Fig. 4) between cluster II and IV (32.13) followed by the distance between cluster II and III (25.18) and between some other clusters were more or less intermediate. To select cluster for more heterotic germplasm, three pairs of clusters to be considered for this purpose, they are I and II, I and III, and I and IV. Germplasm included in the cluster I was important for plant height at 45 DAP, branch diameter at 25 DAP,

leaflets per leaf, tuber length, tuber diameter and tuber weight; cluster II for eyes per tuber, sprouts per tuber, branches per sprout, leaves per plant, tuber length and yield per plant; cluster III for length of sprout, plant height at 25 DAP and branch diameter at 45 DAP, and cluster IV for tubers per plant. Considering cluster distance, cluster mean and mean performance of the germplasm, 'Line 04' and 'Line 05' from cluster I, 'Line 02' from cluster II, 'Diamant', 'Cardinal', 'Provento', 'Line 07', 'Jam Alu' and 'Mondira' from cluster III, and 'Granola', 'Line 06', 'Kufrisinduri', and 'Shahebpakri' from cluster IV may be selected as better parents for future hybridization program.

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was undertaken to study the variability, character association and diversity in 24 potato germplasm based on fifteen characters. The salient findings of the present study have been summarized on the basis of the characters studied.

The analysis of variance showed significant differences among the germplasm for all the characters. Hence, there was opportunity to select desirable germplasm with desired traits.

Asterix, 'Line 06', 'Shahebpakri' and 'Shilbilaty' provided more number of eyes (>15), whereas 'Cardinal', 'Asterix', 'Line 06' and 'Shahebpakri' provided more number of sprouts (>10), and 'Cardinal', 'Provento' and 'Romana' provided higher percent of sprouting (>90%). Shilbilaty showed the highest number (15) and 'Ladyrosetta' showed the lowest number (1.67) of leaves per plant . Shilbilaty showed the highest number (43.77) and 'Carrage' showed the lowest number (5.33) of leaflets per leaf. Line 06 and 'Line 05' showed the highest plant height (34.87 cm and 63.67 cm) at 25 and 45 days after planting (DAP) respectively. Shahebpakri (5.43 cm) and 'Indurkani' (20 cm) showed the lowest plant height at 25 and 45 DAP respectively. Diamant, 'Ladyrosetta' and 'Buri' showed higher branch diameter (0.70 cm and above) at 45 DAP. The highest and lowest tuber length was found in 'Line 04' (7.33 cm) and 'Shahebpakri' (1.73 cm). The highest and lowest tuber diameter was found in 'Line 06' (6.57 cm) and 'Indurkani' (1.20 cm) respectively. The highest and lowest tuber weight was found in 'Diamant' (92.00 gm) and 'Shahebpakri' (18.00 gm) respectively. Shahebpakri showed the highest number (37.33) of tuber while 'Granola', 'Ladyrosetta' and 'Line 06' showed the lowest number (7.33) of tubers per plant. The highest yield per plant was found in 'Carrage' (853.33 gm) and the lowest was in 'Katapakri' and 'Lalpakri' (398.20

gm). The highest and lowest yield per ha was found in ‘Carrage’ (30.30 ton) and ‘Indurkani’ (13.00 ton) respectively.

Genotypic correlation among branches per sprout (0.26), plant height (0.70), leaves per plant (0.32), leaflets per leaf (0.23), tuber length (0.67), tuber diameter (0.58), tuber weight (0.77) and yield per plant were positive and significant but tuber length (-0.62), tuber diameter (-0.69) and tuber weight (0.60) showed significant negative correlation with tubers per plant. Plant height showed significant and positive relation with tuber length (0.85), diameter (0.81) and weight (0.81), whereas significant and negative relation with tubers per plant (-0.47). Leaflets per leaf showed significant and positive relation with tuber diameter (0.32) and weight (0.22), whereas negative relation with tubers per plant (-0.02).

Path analysis revealed that plant height (0.14), leaves per plant (0.09), tuber length (0.13), tuber diameter (0.10), tuber weight (0.97) and tubers per plant (0.86) had positive direct effect on yield per plant (Table 8). Plant height (-0.40), leaflets per leaf (-0.02), tuber length (-0.54), tuber diameter (-0.60) and tuber weight (-0.52) had negative indirect effect on yield via tubers per plant (Fig.2). Most of the characters except tubers per plant had positive indirect effect on yield via plant height, leaves per plant, tuber length, tuber diameter and tuber weight.

Principal coordinate analysis, (PCA) (Vector 1 and Vector 2) expressed that plant height at 45 DAP (0.39), branch diameter at 25 DAP (0.33), tuber length (0.39), tuber diameter (0.37), tuber weight (0.39) and yield per plant (0.31) were major characters that contributed to the genetic divergence. The computations from covariance matrix gave non-hierarchical clustering among twenty four germplasm and grouped them into four clusters. The cluster IV contained the highest number of germplasm (15) followed by cluster III (6), cluster I (2) and cluster II (1). The highest intra-cluster distance was recorded in cluster IV (2.03) followed by cluster III (1.70). The lowest intra cluster distance was found in cluster II (0.00) followed by cluster I (1.08). The intra cluster distances indicated that the germplasm within

the cluster were less diverse. The highest inter-cluster distance was observed between cluster II and IV (32.13) followed by the distance between cluster II and III (25.18) and the lowest inter-cluster distance was observed between cluster III and IV (7.00) followed by the distance between cluster I and III (11.38). The highest inter cluster distance between clusters indicated that the germplasm belonging to each pair of clusters were genetically diverse. To select cluster for more heterotic cultivars, three pairs of clusters to be considered for this purpose, they are I and II, I and III, and I and IV.

Considering cluster distance, cluster mean and mean performance of the germplasm, the germplasm ; 'Line 04' from cluster I, 'Line 02' from cluster II, 'Diamant' from cluster III, and 'Carrage' from cluster IV may be selected as better parents for future hybridization program.

Conclusion :

I. Germplasm had significant influence on growth and yield contributing characters of potato.
II. Phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the yield contributing traits studied.
III. Correlation analysis revealed that the character plant height, tuber length and tuber weight had highly positive correlation with yield per plant.
IV. Path analysis revealed that plant height, leaves per plant , tuber length , tuber diameter, tuber weight and tubers per plant had positive direct effect on yield per plant.
V. Principal coordinate analysis expressed that plant height, tuber length, tuber diameter, tuber weight and yield per plant were major characters that contributed to the genetic divergence.
VI. Multivariate analysis showed that the highest intra-cluster distance indicated the genotypes within the cluster were less diverse. The highest inter-cluster distance indicated the genotypes within the cluster were more diverse.

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