2018

Agronomical Characters and Nutritional Quality Analyses in Selected Potato (SOLANUM TUBEROSUM L.) Genotypes

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University of Rajshahi

AGRONOMICAL CHARACTERS AND NUTRITIONAL QUALITY ANALYSES IN SELECTED POTATO (*SOLANUM TUBEROSUM* L.) GENOTYPES

THESIS SUBMITTED FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN THE

DEPARTMENT OF BOTANY

RAJSHAHI UNIVERSITY

RAJSHAHI 6205, BANGLADESH

BY

MD. YEASIN ALI

B.Sc. (Ag.), M.S. (Horticulture)

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MD. YEASIN ALI

June 2018

DEDICATED TO THE DEPARTED SOUL OF MY BELOVED PARENTS

DECLARATION

*I hereby declare that the whole work submitted as a thesis entitled "**Agronomical Characters and Nutritional Quality Analyses in Selected Potato (Solanum tuberosum L.) Genotypes**" in the Department of Botany, Rajshahi University, Rajshahi, Bangladesh for the degree of **Doctor of Philosophy** is the results of my own investigation and it has not previously been submitted in any form for any other degree. All quotations have been distinguished by quotation marks and all sources of information have been duly acknowledged by references to the authors.*

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CERTIFICATE

This is to certify that the thesis entitled ***"Agronomical Characters and Nutritional Quality Analyses in Selected Potato (Solanum tuberosum L.) Genotypes"*** *submitted for the degree of* ***Doctor of Philosophy*** *in the Department of Botany, Rajshahi University, Rajshahi, Bangladesh is a bonafide research work of Md. Yeasin Ali under our joint supervision and none of the part of this thesis has been submitted for any other degree.*

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ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude, ever indebtedness and profound sense of respect to my reverend teacher and supervisor Professor Dr. Md. Monzur Hosssain, Director, Institute of Biological Sciences, Rajshahi University, Rajshahi for his close supervision, constant and scholastic guidance, outstanding assistance, valuable suggestions and immense help in conducting the research and preparing dissertation. I am deeply grateful to him for his continuous inspiration throughout my study period.

It is a privilege and great pleasure for me to express my deepest sense of gratitude and indebtedness to my reverend teacher and co-supervisor Professor Dr. A. K. M. Rafiul Islam (Retd.), Department of Botany, Rajshahi University, Rajshahi for his technical and moral support, guidance, valuable suggestions, constructive comments and continuous encouragement during the entire study period and preparation of this dissertation.

I wish to express my profound sense of thanks and sincere gratitude to Dr. Md. Ibrahim, Principal Scientific Officer, Fruits and Food Processing & Preservation Research Division, Bangladesh Council of Scientific and Industrial Research (BCSIR) Laboratories, Rajshahi for his unreserved, excellent expert co-supervision, vital support during biochemical analysis, continuous assistance and encouragement.

I am grateful to Professor Dr. Nurul Amin, Chairman, Department of Botany, Rajshahi University, Rajshahi for providing facilities to carry out this research work.

I wish to express my sincere appreciation to Professor Dr. M. Firoz Alam, Department of Botany, Rajshahi University, Rajshahi for constructive suggestions and encouragement.

I deeply acknowledge and appreciate to the authority of the ***Department of Agricultural Extension (DAE) and Ministry of Agriculture, Bangladesh for providing me an in-country GOB funded scholarship and deputation to continue my study.***

I am grateful to the Director, BCSIR, Laboratories, Rajshahi for providing laboratory facilities to carry out the biochemical analysis of my research work.

Special thanks to Dr. Nasiruddin, Associate professor, Department of Botany, Rajshahi University, Rajshahi for his nice cooperation during the entire research work both at field experiment as well as in laboratory works, constructive suggestion during preparation of this manuscript and also his very cordial interaction in providing me with a wonderful working atmosphere to forward my research works.

Cordial thanks to Dr. Ahmad Humayan Kabir, Assistant Professor, Department of Botany, Rajshahi University, Rajshahi, Mr. Mahabubur Rahman, Senior Scientific Officer, Regional Laboratory, Soil Resource Development Institute, Rajshahi and Mr. Bodrul Alam, Senior Scientific Officer, BCSIR Laboratories, Rajshahi for their constant cooperation in laboratory works.

I humbly express my cordial thanks and extreme gratitude to all the respected teachers and officers of the Department of Botany, Rajshahi University, Rajshahi for their generous cooperation and time to time assistance.

Special thanks and sincere gratitude to Dr. Md. Shakhawat Hossain, Senior Scientific Officer, Mr. Enayet Ali Pramanik, Scientific Officer, On-Farm Research Division, Barind Station, Rajshahi, Dr. Mohammad Quamrul Islam Matin, Scientific Officer, BARI, Joydebpur, Gazipur for their generous cooperation and help during statistical data analysis.

Thanks are also to the authority of Akafuji Agrotechnologies Ltd., Namo Vadra, Padma Residential Area, Rajshahi for providing me the potato seed tubers.

Thanks are also due to my entire lab mates specially Humayra Nargis Azmiri and Tanziman Ara, Ph D fellows, Department of Botany, Rajshahi University, Rajshahi for their very cordial interaction and nice cooperation in providing me with a wonderful working atmosphere.

I am deeply obliged to my wife Sagorika Akter (Kanta) for boundless patience. Not only has she been a source of encouragement, prayers and unprecedented moral support throughout my study period, but also has cared for our children.

Finally I find no words to express my abundant and explicable affectionate gratitude to my late parents, beloved sons, family members, other relatives, friends, colleagues and all well wishers for their infinite support and believing in everything I do.

Every step in my life including completion of this study is by the will of the Almighty Allah. Nothing shall be impossible for Allah.

June 2018 *The Author*

ABSTRACT

The research works embodied in this thesis were aimed to explore the extent of genetic variation among the selected potato genotypes for important agronomic and nutritional quality characters and their possible exploitation in varietal improvement programme for desirable traits. Field experiment was conducted with 32 potato genotypes following RCBD with three replications. Data were collected on days to first shoot emergence, foliage coverage, number of stems/plant, number of leaves/plant, plant height, chlorophyll content in leaf, number of tubers/plant, tuber weight/plant, single tuber weight and tuber yield/ha at early (70 DAP) and late (90 DAP) harvest. Collected data were analyzed using both 1st degree statistics such as mean, SE, analysis of variance, DMRT and 2nd degree statistics such as coefficient of variability, heritability, genetic advance, correlation coefficients and path coefficient analysis. Analysis of variance revealed significant differences among the 32 potato genotypes for all the studied characters that indicate the presence of wide range of genetic variation among them. Mean performances of different characters of 32 potato genotypes were also found significantly different as revealed by the DMRT test. Foliage coverage, number of stems/plant, number of leaves/plant, plant height, chlorophyll content in leaf, number of tubers/plant, tuber weight/plant, single tuber weight and tuber yield/ha showed moderate to high heritability along with high genetic advance as percentage of means. Correlation and path coefficient analyses revealed that foliage coverage, chlorophyll content in leaf and single tuber weight showed significant positive genotypic correlation with tuber yield as well as employed positive direct effect on tuber yield both at early and late harvest suggesting that the selection for these traits would be helpful for the improvement of tuber yield. Among the genotypes G_9 (Granola) and G_{11} (Courage) were found to be the highest tuber yielder at early harvest and genotypes G_{20} (Cardinal), G_{22} (Diamont) and G_{28} (Ultra) showed the highest tuber yield at late harvest.

Freshly harvested potatoes from each genotype were analyzed in laboratory for the quantitative estimation of 20 nutritional quality characters *viz*., moisture, dry matter, specific gravity, ash, pH, total soluble solids, titratable acidity, total phenolics, β-carotene, vitamin C, starch, soluble protein, total sugar, reducing sugar, non-reducing sugar, iron (Fe), phosphorous (P), calcium (Ca), potassium (K) and zinc (Zn) contents. Chemical analysis were done separately for early (70 DAP) and late (90 DAP) harvested tubers. Analysis of variance revealed the existence of significant variation for all nutritional characters among the potato genotypes studied. Mean performances of different quality characters of 32 potato genotypes were also found significantly different as revealed by the DMRT test. The results of PCV and GCV analyses revealed the presence of wide range of variation among the potato genotypes for the studied nutritional quality

characters. Among the nutritional quality characters, dry matter, titratable acidity, total phenolics, vitamin C, starch, total sugar, reducing sugar, non-reducing sugar, soluble protein, Fe, P, Ca, K and Zn contents of tubers both at 70 and 90 DAP showed high heritability along with higher genetic advance as percentage of mean. The nutritional quality characters like dry matter, total phenolics, starch and minerals showed significant negative correlation with tuber yield/ha both at 70 and 90 DAP harvest and reducing sugar was negatively correlated with dry matter suggesting that the selection for these traits would be helpful for the improvement of nutritional quality of tuber. The results of principal component (PCA), principal coordinate (PCO), canonical variate (CVA) and cluster analyses revealed that the genotypes could be grouped into seven different clusters on the basis of 70 and 90 DAP harvesting situation. The results also revealed that the genotypes in cluster III were far diverse from genotypes of cluster VI (early harvest) and cluster V (late harvest) whereas the genotypes belong to cluster I and VII (early harvest) and II and VII (late harvest) were least diverse. Intra-cluster distances in both the harvesting time were being much lower than the inter cluster one's, suggesting heterogeneous and homogeneous nature between and within groups, respectively. The highest inter genotypic distance indicated that there is scope for improvement of nutritional quality characters by hybridization. Genotypes in cluster I showed the maximum dry matter, total phenolics, starch, total sugar, reducing sugar, soluble protein, Fe and Ca contents, where as the genotypes in cluster III showed the best mean performance for K and Zn contents and the genotypes under cluster IV showed the highest vitamin C and P contents when harvested at 70 DAP. In case of tuber harvested at 90 DAP cluster I showed the highest starch, total sugar, reducing sugar and Ca contents. However, the genotypes under cluster II showed the highest vitamin C content but the genotypes in cluster III showed the highest K and Zn contents. The highest amount of dry matter, total phenolics, soluble protein, Fe and P contents were found in the genotypes under cluster IV. Dry matter, total phenolics, reducing sugar, soluble protein, Fe, P, Ca, K and Zn contents were found to be contributed effectively towards genetic divergence among the genotypes. Therefore, these traits would offer a good scope for the improvement of nutritional quality through rational selection of parental genotypes in future potato breeding. The genotypes G_8 (Lady Rosetta), G_{12} (Hagrai), G_{13} (Indurkani), G_{21} (Vandarpur), G_{23} (JPR) and G_{24} (All Red) might be selected as better parents for improving different nutritional quality characters through hybridization programme with higher yielder genotypes like G_9 (Granola) and G_{11} (Courage) for early and G_{20} (Cardinal), G_{22} (Diamont) and G_{28} (Ultra) for late harvest potato varieties.

ABBREVIATIONS

%	Percentage
/	Per
@	At the rate of
µg	Microgram
^{0}C	Degree celsius
AEZ	Agro-Ecological Zone
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCSIR	Bangladesh Council of Scientific and Industrial Research
Ca	Calcium
Chl	Chlorophyll
CIP	International Potato Center
CLSA	Cluster analysis
cm	Centimeter
Cu	Copper
CV	Coefficient of variation
CVA	Canonical variate analysis
DAE	Department of Agricultural Extension
DAP	Days after planting
df	Degree of freedom
DFSE	Days to first shoot emergence
DM	Dry matter
DMRT	Duncan's multiple range test
DMSO	Dimethyl sulphoxide
DNS	Dinitrosalicylic acid
DW	Dry weight
EPADC	East Pakistan Agricultural Development Corporation
et al.	and others
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
FCR	Folin-ciocalteu's reagent
Fe	Iron

FM	Fresh matter
FW	Fresh weight
g	Gram
GA	Genetic advance
GCV	Genotypic coefficient of variation
h^2b	Heritability in broad sense
ha	Hectare
HYV	High yielding variety
i.e.	That is
IDA	Iron deficiency anemia
K	Potassium
Kg	Kilogram
LPV	Local potato variety
m	Meter
M	Moisture
Mg	Magnesium
mg	Milligram
ml	Milliliter
mm	Millimeter
Mn	Manganese
MOP	Muriate of Potash
N	Nitrogen
nm	Nanometer
no.	Number
NPK	Nitrogen Phosphorous Potassium
NRS	Non-reducing sugar
P	Phosphorous
PCA	Principal component analysis
PCO	Principal coordinate
PCV	Phenotypic coefficient of variation
pH	Negative logarithm of the hydrogen ion concentration
ppm	Parts per million
RCBD	Randomize complete block design
r_g	Genotypic correlation coefficient
RH	Relative humidity
r_p	Phenotypic correlation coefficient

rpm	Revolutions per minutes
RS	Reducing sugar
S	Sulphur
SC	Starch content
SDGs	Sustainable development goals
SE	Standard error
SG	Specific gravity
SP	Soluble protein
t/ha	Ton per hectare
TA	Titratable acidity
TCRC	Tuber Crops Research Center
TPC	Total phenolic content
TPS	True potato seed
TS	Total sugar
TSP	Triple super phosphate
TSS	Total soluble solids
VAD	Vitamin A-deficiency
VC	Vitamin C
viz	That is to say/in other words
WHO	World Health Organization
wt	Weight
Zn	Zinc
β-car	Beta carotene
δ^2e	Error Variance
δ^2g	Genotypic variance
δ^2p	Phenotypic variance

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Chapter I

1. GENERAL INTRODUCTION

1.1. THE CROP: POTATO

Potato (*Solanum tubarosum* L.) is a multiuse tuber crop. Potato is the third most economically important food crop in the world after rice and wheat in terms of human consumption. It has been cultivated as an important food crop from the very beginning of human civilization. It is a part of the diet of half a billion consumers in the developing countries (Ghislain *et al.*, 1999) and more than a billion of people world-wide eat potato. The crop provides roughly half of the world's annual production of all root and tuber based food crops, making it the leading non-cereal crop. It also ranks first among root and tuber crops followed by cassava, sweet potatoes and yams (Hawkes, 1990; FAO, 2008). The potato's potential for a beneficial role in world food production, owing to its status as a cheap and plentiful crop which can be raised in a wide variety of climates and locales (Ezekiel and Rani, 2006a). The potato is an important crop in both sub-tropical and temperate regions. Even in tropical region it is widely grown during the winter season. It is cultivated both in large tracts and in home gardens and provides a cheap and nutritious food. As potato is a cold climatic vegetable crop it is grown in Bangladesh in winter season only. The crop has high nutritional value and great yield potential. Almost every family in Bangladesh consumes it as a vegetable throughout the year.

1.2. ORIGIN, DISTRIBUTION AND EVOLUTION OF CULTIVATED POTATO

The potato originated in the mountains of South America, specifically in the Andes of Peru and Bolivia where wild prototypes still exist. However, multiple origins of cultivated potatoes have been suggested by different authors (Grun, 1990; Hawkes, 1994a; Huaman and Spooner, 2002). Recently, Rodriguez *et al.* (2010) described the hybrid origins of cultivated potatoes. The origin of potato in Europe has been controversial. Juzepczuk and Bukasov (1929) and Huaman and Spooner (2002) proposed that potatoes were originally introduced into Europe from the Chiloe region in Chile. Archaeological studies clearly show that the potato was already domesticated in South America for centuries before the Spaniards arrived. In Indian sub-continent the cultivation of potato was probably started during the 17th century

(Ahmad, 1977; Hawkes, 1978). The gene pool of potato is extremely large, providing a valuable source of genetic diversity to breeders. Its ancestor could have been the wild species of *Solanum leptophyes*. The name potato is derived from the native name *batata* (Hawkes, 1994b). The genus *Solanum,* to which the cultivated potato belongs, is an extremely large one, containing about 1,000 species. In addition to the widely cultivated *S. tuberosum, subsp. tuberosum and andigenum, seven other related species are cultivated, namely S. ajanhuriri, S. chaucha, S. curtilobum, S. goniocalyx, S. juzepcukii, S. phureja and S. stenotomum.* Over 230 wild species of potato are generally recognized (Hawkes, 1994b; Struik *et al.,* 1999).

The wild species of potato occur as diploids, triploids, tetraploids, pentaploids and hexaploids. Cultivated potato (tetraploids) originally was derived from the primitive diploids *S. stenotomum,* either by mutation, selection or hybridization. The evolution of cultivated potato began from *S. stenotonum* (Hawkes, 1994b). Hybridization of *S. stenotomum* with *S. sparsipihum,* the weedy species and the subsequent chromosome doubling produced the tetraploids *S. tuberosum* subs. *andigena* in the central Andes. However, others considered that tetraploid Andean potato is derived from simple chromosome doubling of *S. stenotomum* (Hawkes, 1994b).

1.3. BOTANICAL ASPECT OF *SOLANUM*

Potato belongs to the family Solanaceae, a group containing many species, which typically can produce underground tuber as a means of propagation (Turner and Evans, 1998). The family Solanaceae contains 84 genera and almost 3,000 species that occur on every vegetated continent of the world. The Solanaceae is split into three sub family; the Solanoideae, Cestroideae and the Nolanoideae. The Solanoideae contains 52 genera including *Atropa, Datura, Capsicum and Solanum*. The Cestroideae contains 30 genera including ornamental and cash crops such as *Nicotiana, Petunia, Salpiglossis* and *Schizanthus,* whereas the Nolanoideae contains 2 genera, *Alona* and *Nalona* **(Figure 1.1)** (Deljou, 1997).

The genus *Solanum* contain approximately 150 tuber-bearing species and is divided into two sub-genera: *Pachystemonum* and *Leptostemonum*. *Pachystemonum* contains five section including *Petota*, which contains two sub-sections *Basarthrum* (non-tuber bearing) and *Potatoe*, which includes the entire tuber bearing species. It is further sub-

divided into 18 series. The series *tuberosa* comprises 68 wild and 8 cultivated species including *Solanum tuberosum* and many closely related species (Ward, 1991).

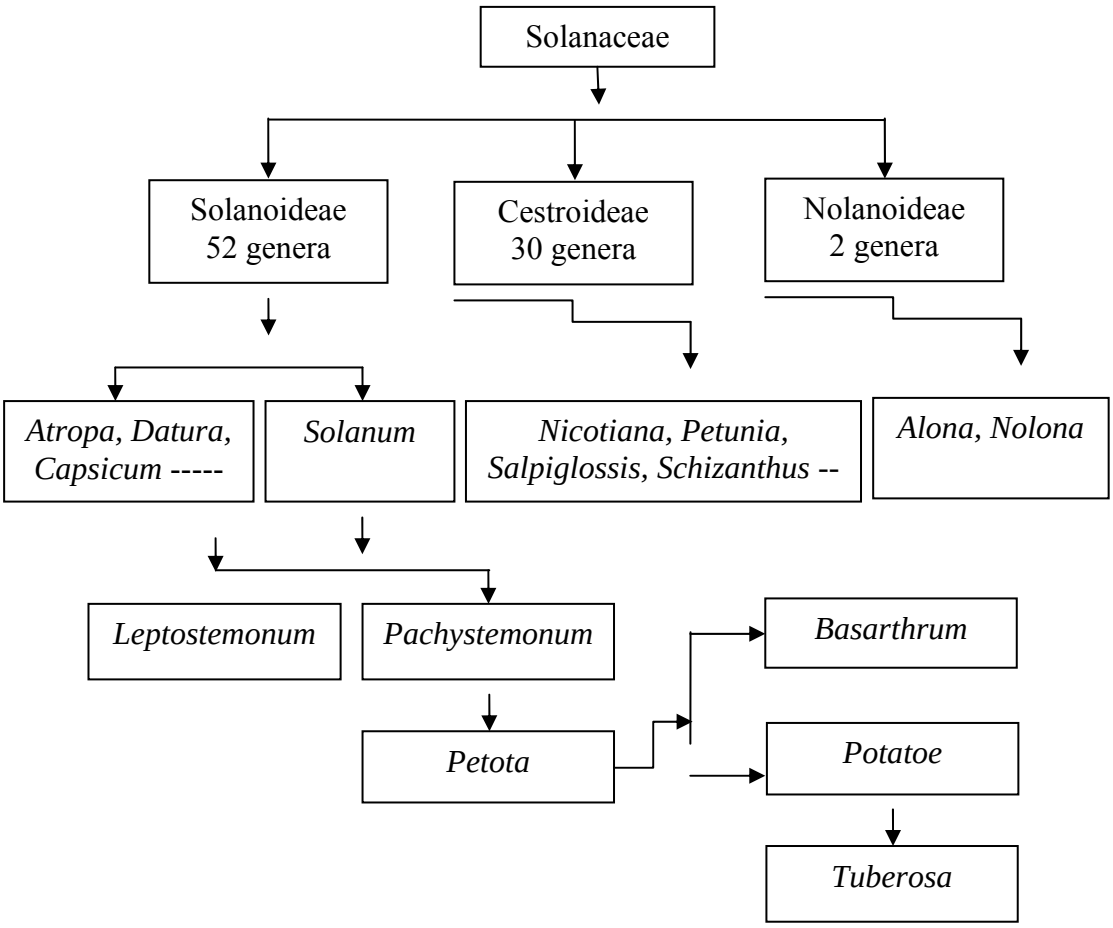

Figure 1.1 Classification of the genus *Solanum*
Source: Deljou, 1997

The CIP maintains the world's largest bank of potato germplasm, including some 1,500 samples of approximately 100 wild-type species and 3,800 traditional Andean cultivated potatoes (CIP Brochure, 2000). The basic chromosome number of Solanaceae is n=x=12 (Hawkes, 1992). Most (73%) of the species are diploids, very few (4%) are triploids with 15% tetraploids, 2% pentaploids and 6% as natural hexaploids (Hawkes, 1992). Cytological analysis of interspecies hybrids involving potato has indicated small differences between the constituent genomes. Lester (1965) confirmed very strong serological similarities between S. *acaule* and species in the series *tuberosa* and parts of Yungasensia (including for example, *S. chacoense*).

1.4. MORPHOLOGICAL FEATURES OF POTATO

Potato is a herbaceous tuber bearing plant. The potato (*Solanum tuberosum*) is greatly shortened and swollen part of an underground stem commonly grown as starchy tubers (Ekin, 2011). The stem of potato is either determinate or indeterminate depending upon the cultivar. The lower part of the stem is always hollow and triangular in cross-section (Struik and Wiersema, 1999). Potato leaf foliage is pinnately compound. Each leaf consists of a terminal leaflet and a few pairs of lateral leaflets. There is usually a pair of secondary leaflets between the two adjacent lateral leaflets. The midrib of the leaf consists of two sections, with the first part (rachis) holding the leaflets and the second part (petiole) connecting the rachis to the stem. At the contact point between the petiole and the stem two bracket-like stipules are seen surrounding half of the stem. There are varietal differences in the number, size and color of leaflets and secondary leaflets. Leaf form can be profoundly changed by day length and temperature (Cutter, 1992).

Depending upon the potato cultivar, flowers may or may not be produced. Flowering is always accompanied by tuber initiation. Flower color varies from white to purple and flowers may lead to berries or be aborted, which is either due to varietal differences or to strong self incompatibility of the flowers (Deljou, 1997). The plants bear white, pink, red, blue or purple flowers with yellow stamens. Tuber is the underground organ, which is botanically swollen stem tissues, since there cross-section shows a typical stem structure, at the end of the stolon. Tubers are highly organized for food storage and vegetative propagation. Tuber formation is a complex physiological phenomenon. It usually takes place in a short period of time (one or two weeks) depending upon the cultivar, similarly, color and shape of the tubers is genotype dependent. The first step in the formation of tubers is stolon formation (Jackson, 1999; Struik et al., 1999). The color of the cortex of the tuber varies from white, yellow, lemon, red, purple and blue. Stolon normally develop first at the most basal nodes and then at progressively higher ones. The number of the stolons/stem declines with increasing stems number. The number of nodes which subtend stolons and the length of the stolons are adversely affected by low levels of nutrients such as nitrogen. Irrigation during stolon formation is crucial to the manipulation of stolon number/stem. A much-branched fibrous root system is formed either by seedling

taproot, or by adventitious roots in tuber-bearing plants. In the early stage of growth the root system is restricted to the surface soil, the root turning downward after extending for some distance horizontally. Potato crop mature within 90-120 days providing small edible tubers with 60 days (Cutter, 1992).

1.5. AGRONOMICAL FEATURES OF POTATO

Potatoes are generally grown from seed tuber. In Bangladesh planting is undertaken in October through November, for harvesting in February through March. Potato growth period has been divided into five phases. During the first phase, sprouts emerge from seed tuber and root growth begins. In the second phase, photosynthesis begins as the plant develops leaves and branches. During the third phase stolons develop from lower leaf axils on the stem and grow downwards into the ground and on these stolons new tubers develop as swelling of the stolon. Tuber bulking occurs during the fourth phase, when the plant begins investing the majority of its resources in its newly formed tubers. The final phase is maturation. Potato has a wide range of seasonal adaptability. It is a cool season vegetable crop and is moderately tolerant to frost. The young plants grow best at a temperature of 24^0 C. Later growth is favored at a temperature of 18^0 C. Tuber production is the maximum at 17^0 C to 20^0 C and decrease the production with rise in temperature. Tuber production is the maximum at 20^0 C and at about 30^0 C the tuber production is totally stopped. Relative humidity (RH) is needed above 50%; photoperiod is about 14-16 hours.

It thrives in cool regions where there is sufficient moisture and fertile soil. The ideal soil for potato production is well-drained, well aerated, deep and having a pH range 5.2 to 6.4. So, potato can be produced on a wide range of soils ranging from sandy loam, silt, loam and clay soil. Well-drained sandy loam and medium loam soil rich in humus are most suitable for potato. Alkaline or saline soil is not suitable for potato cultivation. Application of proper doses of NPK is important for potato cultivation.

1.6. WORLD POTATO PRODUCTION STATUS

Potato is grown at a significant scale in about 163 countries (Anonymous, 2007). The annual diet of an average global citizen in the first decade of the 21st century included about 33 Kg of potato. However, the local importance of potato is extremely variable and rapidly changing. It remains as an essential crop in Europe (especially eastern and

central Europe) where per capita production is still the highest in the world, but the most rapid expansion over the past few decades has occurred in southern and eastern Asia including Bangladesh. The total world potato production was estimated 376.83 million metric tons during the year 2016 (FAO, 2016 In: FAOSTAT, Revision March, 2018). The global potato production trend from 2005 to 2016 is shown in **Figure 1.2.**

The world potato sector is undergoing major changes. Until the early 1990's most potatoes were grown and consumed in Europe, North America and countries of the former Soviet Union. Since then, there has been a dramatic increase in potato production and demand in Asia, Africa and Latin America. The area under potato cultivation has been increased in the developing countries than industrialized nations or developed countries. China is the biggest potato producing country and India ranks 2nd position among the top potato producing countries in the world **(Table 1.1).**

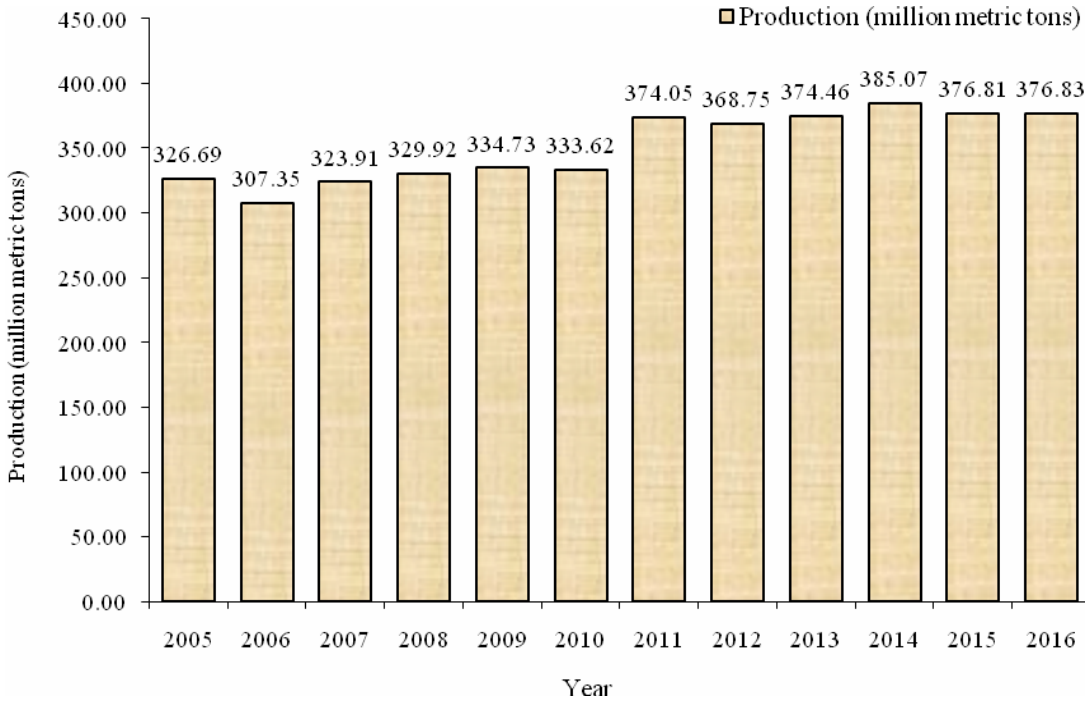

Figure 1.2 Global potato production trends from 2005 to 2016
Source: FAO, 2016 (FAOSTAT, Revision March, 2018)

Table 1.1 Top ten potato producing countries in the world during the year 2016

Rank	Country	Potato Production (million metric tons)
1	China	99.07
2	India	43.77
3	Russian Federation	31.11
4	Ukraine	21.75
5	United States	19.99
6	Germany	10.77
7	**Bangladesh**	**9.47**
8	Poland	8.87
9	France	6.83
10	Netherlands	6.53

Source: FAO, 2016 (FAOSTAT, Revision March, 2018)

1.7. POTATO PRODUCTION IN BANGLADESH

Bangladesh is primarily an agricultural country dominated by crop production. Bangladesh has been famous for growing large variety of tropical crops particularly rice, wheat, potato, jute, pulse, oilseeds, sugarcane and different type of vegetables. Potatoes have been grown in Bangladesh since 19th century. By the 1920s, the first commercial production of the crop was introduced in the country (Islam, 1983). Both high yielding varieties (HYV) and local potato varieties (LPV) are cultivated in Bangladesh. For the introduction and adaptation of HYV potatoes and production technology, the area and production of potato have been sharply increased after nineties. Now, potatoes have become increasingly an important vegetable and cash crop in Bangladesh. It ranks first among the vegetables and second most important crop after rice in terms of area and production. During the year 2014-15 area under potato production was about 3.09% of the total cultivated land (BBS, 2016). Still now the area and production of potato is increasing day by day due to its higher demand and profitability. The traditional major producing areas included northern Bangladesh such as Dinajpur, Rangpur, Bogra, Rajshahi, Pabna and Mymensingh (larger district), but rapid growth was observed in Dhaka (in particular Munshiganj) and Cumilla from

mid 1960's and especially after 1980s. The area and yield rate of potato is increasing every year significantly. The trend of area and production of potato in Bangladesh (From 2006-07 to 2016-17) are shown in **Figure1.3.**

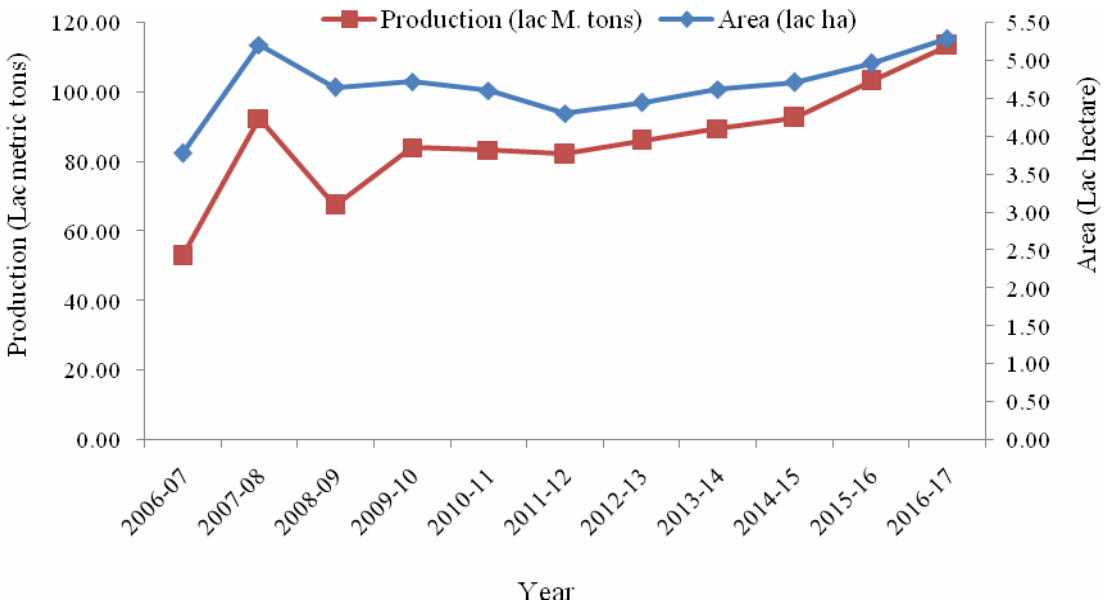

Figure 1.3 Trend of area and production of potato in Bangladesh
Source: DAE, 2018

According to the FAO report (FAO, 2016 In: FAOSTAT Revision March, 2018) at present Bangladesh is the 3rd largest potato producing country in Asia and ranks 7th (9.47 million metric tons) in the world (**Table 1.1**). During 2016-17 the area, production and average yield of potato in Bangladesh were 5.283 lac hectare, 113.327 lac metric tons and 21.45 tons/ha respectively (DAE, 2018).

1.8. PROSPECT OF POTATO PRODUCTION IN BANGLADESH

Potato has considerable potentiality in Bangladesh because, it is a short duration crop that helps free land for other crops and produces a large amount of calories in minimum time. Potato is a labor intensive crop which generates increased rural employment opportunities, an important consideration of rural economy. In addition, potato fits well into established cropping patterns. Potato does not require intensive irrigation like rice. At the consumption level, potato is a vegetable that most people like to eat. Consumers are increasingly aware of the potato's numerous culinary characters and its various nutritional attributes. Considering the trend of population

growth and consequently the increased demand for food in the country and dwindling cultivable land area, potato is likely to play a very important role in future. During the last 10-15 years potato has become relatively less expensive compare to other foods. This factor alone makes potato an attractive commodity for the growing of low income rural and urban consumers.

As exporting materials, potato is now highly potential for Bangladesh. Potato export has been rising since 2009-10, mainly to cater to the demands to the migrants in Malaysia, Singapore and the Middle East. The vegetable is also exported to Sri Lanka, Indonesia and several other countries and very recently to Russia. Low price in local market has encouraged the traders to look for marketing opportunities abroad. The export scenarios of potato during 2009-10 to 2016-17 are shown in **Figure 1.4.** Government has taken massive initiatives to increase potato export.

Potato has a good future in Bangladesh under the changed scenario of global economy. Globalization has resulted in many developing countries becoming much more integrated into the international potato trade. With the phasing out of quantitative restrictions on agricultural commodities, the imports and exports of potato would be based on the differences in price and production cost in the country. As a result of availability of cheap labor, Bangladesh will have competitive advantage in the international potato trade.

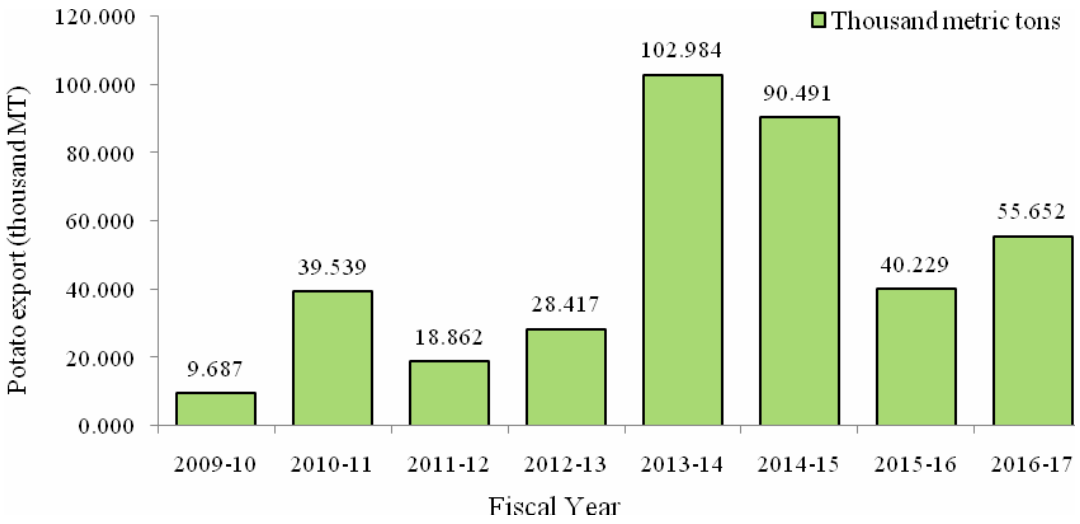

Figure 1.4 Potato exportation in Bangladesh from fiscal year 2009 - 10 to 2016 - 17
Source: Plant Quarantine Wing, DAE, 2018

1.9. IMPORTANCE AND USES OF POTATO

Potato is the main food crop in many countries of the world and provides high productivity per unit area (Simmonds, 1995; Spooner and Salas, 2006). Potatoes are the leading vegetable crop in the world and occupy the top-most position after rice and wheat both in respect of production and consumption (Thompson and Kelly, 1957). It is one of the most important vegetable and a part of daily food utilization of almost all the world population (Mathur, 2003). It is a balanced food containing high energy, protein, essential vitamins and minerals (Mehdi *et al.,* 2008). Because of the higher dry matter, edible energy and edible protein content, potato is considered nutritionally a superior vegetable as well as a versatile food item not only in our country but also throughout the world (Hossain and Miah, 2009). A processed potato is of more economic value than the raw, unprocessed one. Among the processed potato products, chips are the most popular form in different countries. A very small amount of potatoes are utilized by the processing industries. There is a great scope of increasing the use of potato through preparing processed foods. It is also essential to identify the variety suitable for processing (FAO and International Potato Center, 1995). Potato is one of the important vegetables as well as cash crop in Bangladesh. It ranks first among the vegetables in terms of area and production in Bangladesh. After rice potato is the second most important crop and recently has become the major food crop in Bangladesh because of its multiple uses as vegetables and delicious processed items (Saha and Hossain, 2011). Bangladesh is recognized as a rice eating nation; large quantities of potato are produced and consumed each year and gradually gaining popularity. So long, most of the people used to take potato as a vegetable only. But today the other forms of potato food like shingara, alu puree, alu chop, mashed potato, potato chips, potato French fries have been popular delicacies for long in the country. Again, alupayas, aluruti, aluluchee and various other innovative potato dishes are also gaining popularity among the people. This has opened the avenue to small-scale kitchen processing of potatoes at domestic level. Potato can also used for production of pectin, syrup and a by-product of high quality protein and fodder.

1.10. NUTRITIONAL ASPECTS OF POTATO

Potato is an excellent source of starch, protein, iron, phosphorus, calcium, carotene, thiamin, riboflavin, vitamin C and antioxidant (Bradbury and Holloway, 1988;

Wheatly *et al.,* 1995). Potato produces more calories and protein per unit area with minimum time and water than most of the major food crops (Upadhya, 1995). It is virtually free from fat and cholesterol. Potato tuber is also one of the richest sources of antioxidants in the human diet. Such nutritional values of tuber are the key driver for growth and development of potato all over the world (Buono *et at*., 2009). Per hectare nutrient yield of potato is higher than that of wheat and rice. Potato is superior to rice or wheat particularly in terms of supplying carbohydrates, minerals specially potassium, calcium and iron, vitamin A or β-carotene and vitamin C (Ahmed and Kamal, 1984). Potatoes are good source of some minerals and at least 12 essential vitamins and extremely high content of vitamin C in potato as compare to other food crops (Struik and Wiersema, 1999). The protein content of potato is high in that the protein produced is made of a high proportion of essential amino acids. The world average per hectare yield of potato is about 8 times than that of rice and wheat and it can also produce over twice as much as dry matter and calories on a unit area of land in shorter period of time compared to rice and wheat (Ahamed, 1982).

1.11. POTATO VARIETIES IN BANGLADESH

Potato in Bangladesh are sometimes designated as deshi, a term often treated as synonymous with local varieties or indigenous, generally referring to varieties introduced prior to India and Pakistan separation in 1947. Most of them are relatively low yielding and have somewhat longer vegetative cycles than more recently introduced varieties, but retained by farmers for their storage properties and cooking and culinary qualities. The indigenous varieties are in reality exotic varieties which were introduced at least six decades ago. They are mostly cultivated in the northwest part of Bangladesh and covered about 15% of total potato area during the production year 2014-15 (BBS, 2016). Their tubers are small with low yield but sold at a high price. Beginning in the 1970s potentially high yielding varieties have been introduced in Bangladesh. After the independence of Bangladesh, Tuber Crop Research Center (TCRC) of Bangladesh Agricultural Research Institute (BARI) has released 77 high yielding potato varieties. These high yielding varieties cover about 85% of the total potato area in the country during 2014-15 (BBS, 2016). They produce bigger sized tuber and give higher yield and under optimum conditions yielded around 30-35 tons/ha.

1.12. POTATO RESEARCH IN BANGLADESH

Agronomic research on potato dates late 1950s when limited variety trials were started. Research expanded through 1960 to include fertilizer applications, seed degeneration, mulching, planting techniques and storage. In 1967-1968 Bangladesh Agricultural Development Corporation (BADC former EPADC) launched a project for the multiplication and distribution of high quality seed potatoes (Ahmad, 1977). Beginning in the 1970s potentially high yielding varieties have been introduced in Bangladesh. The improvement of potato has not given proper attention by the different research organization in Bangladesh. After the independence of Bangladesh, Tuber Crop Research Center (TCRC) of Bangladesh Agricultural Research Institute (BARI) mainly concerned with research for the improvement of potato. However, TCRC's work has been limited within optimization of different cultural practices for cultivation of potato and gives emphasis only on yield not on nutritional quality for the developed of new potato varieties. For the improvement of any crop, variation among the population is the most important requirements which seldom addressed. The problems of the present day are more complex due to modernization and specific needs (especially quantity not quality). So, it is necessary to give emphasis on nutritional quality for the improvement of new varieties. The main goal of potato breeding should be the development of potential varieties that are nutritionally enriched and ensures highest and stable production in a range of environments.

1.13. RATIONALE OF THE STUDY

The global population is estimated to reach nine billion by 2050, resulting in a growing demand for producing safe, sustainable and environment friendly food. Bangladesh is the 8th largest country in the world in terms of number of population. The population of Bangladesh is increasing day by day and agricultural land is decreasing gradually. According to the state of food security and nutrition in the world 2017, the number of undernourished people in the world has been raised since 2014, reaching an estimated 815 million in 2016 from which most of them were in developing countries (FAO, 2017). Extreme hunger and malnutrition are being a huge barrier to development in many countries. Generally in the developing countries including Bangladesh the demand of food is likely to rise significantly. Like other developing countries Bangladesh does not achieve food security in terms of

nutritional demand for the people. The Sustainable Development Goals (SDGs) aim to end all forms of hunger and malnutrition by 2030, making sure all people especially children have access to sufficient and nutritious food all the year round. This involves promoting sustainable agricultural practices. It is well recognized that to meet the demand for food for increasing population of Bangladesh, food habit has to be slightly diversified so as to reduce dependence on rice. To achieve this goal, production of maximum amount of nutrient per unit area and per unit time is to be emphasized. Because of its high yield potential and food value, compared to rice and wheat, potato is considered as a promising crop for feeding the hungry people of the world (Pushkarnath, 1976). So, to meet the ever increasing demand for food, nutritionally enriched and higher yielding potato varieties can play a major role in addressing this issue and feed millions of people.

Improvement programme for developing potato varieties, it requires information on nature of genetic variation in parental materials for different tuber yield contributing characters as well as nutritional quality characters and relationship between them. To meet the demands of diverse nature, plant breeding programme requires wider spectrum of genetic base than ever before. Variation is the basis of improvement and germplasm represents the sum total of variability or hereditary materials or genes available in particular genus or species (Dandin and Kumar, 1989). Germplasm is also considered as the basic foundation of crop improvement and its importance was realized as far as back as 1898 (Boraiah, 1986). With the advent of last decade, the major break-through in the genetic improvement in crops has come through in the utilization of germplasm resources. The value of germplasm is determined by its genetic diversity, availability and utility. In this sense, potato stands out among all other crops (Bamberg and del Rio, 2005). Primitive forms of cultivated potato and their wild relatives provide a rich, unique and diverse source of genetic variation, which could be a source of various traits for potato breeding. They are equally diversed in morphological traits (i.e. plant height, leaf and leaflet shape, flower color, stolon length, and size, color, and shape of tubers) (Hanneman, 1989) as well as nutritional quality. Many indigenous potato varieties cultivated in different ethnic pockets of Bangladesh are very tasty and nutritious especially rich in vitamin A and heme iron which can prevent VAD and IDA. However, these varieties have not been

explored because nutritional aspect of breeding new varieties of potato is mostly being ignored.

A logical way to start any breeding programme is to survey variation of characters if any in the available materials. Because, genetic variation is necessary for selecting the characters that improve crop yield as well as its nutritional quality. Moreover, correlation among the characters are helpful to determine the components of complex trait yield and nutrition, but they do not provide an exact picture of relative importance of direct and indirect influences of each of the component characters towards yield. Therefore, the correlations between characters can be further partitioned through path analysis. Further more, genetic diversity is used for discriminating divergent populations, which are reinstated by more scientific and advanced biometrical techniques, *viz*., multivariate analysis based on Mahalanobis D^2 statistics (Mahalanobis, 1936). Genetic diversity is essential to meet the diversified goals of plant breeding such as breeding for cultivation for increasing yield, nutritional quality, wider adaptation, desirable quality and pest and disease resistance. In addition, genetic divergence is studied to identify specific parents for wider genetic variation and heterosis when they are crossed. So far very limited research has been done for the improvement of potato apart from the improvement of agronomic practice in Bangladesh (Mondal, 2003). Wild potatoes have been used for disease resistance in breeding programme for over 100 years (Hawkes, 1958). Potato has many wild relatives and primitive cultivars and these genetic resources have proven to be valuable in breeding programme in addition to disease resistance, environmental tolerance, other agronomic traits and nutritional and processing qualities of interests (Bamberg and del Rio, 2005; Barker, 1996; D'hoop *et al.,* 2008; Hawkes, 1958, 1990; Hijmans *et al.,* 2003; Jansky, 2000; Ochoa, 1999; Spooner and Bamberg, 1994). Sources of resistance have been screened, identified and listed by several authors (Hanneman and Bamberg, 1986 cited in Hawkes, 1994a; Irikura, 1989). Hawkes and Hjerting (1989) discovered resistance to all pests and diseases known at that time in Bolivian potato species.

The development of potato varieties with improved horticultural characteristics and a wide adaptability is important to all segments of potato industries. The choice of

cultivars is probably the most critical decision in respect to match tuber quality with intended market. The present study was therefore conducted to investigate the yield and nutritional quality of different genotypes of potato at different maturity stages to identify the best genotypes which may be useful for designing future breeding efforts to improve potato varieties with enriched nutritional quality.

1.14. OBJECTIVES

Considering the above mentioned aspect and scope, the present study was undertaken with the following specific objectives:

1. Evaluation of important agronomic characters among the selected potato genotypes.
2. Identification of promising genotypes in terms of tuber yield suitable for early or late harvest.
3. Estimation of nutritional qualities and selection of nutritionally enriched potato genotypes suitable for early or late harvest.
4. Selection of genotypes with superior agronomic and nutritional quality characters for using in breeding programme to develop nutritionally enriched high yielding potato variety/varieties suitable for early or late harvest.

Chapter II

2. GENETIC DIVERSITY OF DIFFERENT AGRONOMIC CHARACTERS IN SELECTED POTATO GENOTYPES

2.1. INTRODUCTION

Potato (*Solanum* tubarosum L.) is a starchy, tuberous crop belongs to the Solanaceae family. It is a crop that grows mainly in climate with cool temperature, bright sunlight, moderate day temperature and cool night. It is one of the most important food crops of Bangladesh as well as of many countries of the world. In Bangladesh it is a popular and important vegetable. During the whole year, it is used as main vegetable. Potato is a prominent crop in consideration of production and its internal demands in Bangladesh. The increasing trend of global population results in a growing demand for producing safe, sustainable and environment friendly food. Potato is considered as a promising crop for feeding the hungry people of the world due to its high yield potential and food value, compared to rice and wheat. Bangladesh is a densely populated country in the world. The increasing trend of population would make the country food insecure in future. So, to meet the ever increasing demand of food for feeding millions of people it is necessary to increase food production vertically through higher yielding varieties as well as increase cropping intensity through short duration crops. Considering the trend of population growth and consequently the increased demand for food in the country and dwindling cultivable land area, the potato is likely to play a very important role in future due to its higher yield potential. Bangladesh is well recognized as a rice-eating nation; food habit has to be turned from rice to potato to meet the demand for food for increasing population. In many countries of the world potato is well known as the staple food of the people. Though potato is being eaten as an item of vegetables at present, it can be used as complementary food in Bangladesh.

The world average per hectare yield of potato is about 8 times than that of rice and wheat and it grows in a shorter period of time (Ahamed, 1982). The yield level of this crop in Bangladesh is low compared to other potato growing countries of the world (Anonymous, 1997) though the soil and climatic conditions of Bangladesh are congenial to the proper growth of potato crop. Yield in potato, as in other crops, is a

very complex character and is dependent on many other traits. Among the various factors responsible for low yield in Bangladesh, the performance of a variety 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, high in nutritional quality and resistant to pests and diseases. In Bangladesh there is a tendency of harvesting potatoes before its full maturity to catching high prices in the markets. Varieties 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). It is necessary to exploit the farmers' interest in the best possible manner, ways and means for rising the per hectare yield to a significantly higher level and selection of higher yielding short duration potato varieties.

Breeders should take the challenge to provide food at cheaper rate to the millions of hungry people in developing countries by increasing the production of potato per unit area and per unit time. To initiate any breeding programme to this direction, presence of enough genetic variability in the population for yield related traits should be considered as prerequisite element. In plant breeding selection has become a popular and useful technique and is being applied to solution of problem in many agricultural crops. As a result, in breeding programme selection method has become a useful technique for the improvement of many crops including potato. Moreover, application of perfect breeding method is dependent on estimation of genetic gain of the characters for successful selection as to develop desirable traits suggested (Johnson *et al.*, 1955). The estimation of correlation coefficient among the characters is necessary to carry out proper selection on the basis of simultaneous selection of correlated characters. However, knowledge of correlation alone is often misleading, because when more variables are included in a study, the indirect association becomes more complex. In such a situation the path-coefficient analysis provides an effective means of finding direct and indirect causes of association. The effect of harvesting at different dates on tuber yield of different genotypes can identify high yielding varieties which can be harvested even earlier with satisfactory yield so that farmers get benefit by selling

their product at higher premium value in off-season and at the same time land will be free for next crop.

An experiment was therefore, undertaken with thirty two diverse potato genotypes (local, released and exotic) with a view to finding out a variety or varieties which is suitable for early or late harvest having higher tuber yield.

2.1.1. **Objectives**

This part of the present research has following objectives:

i) To determine the nature and magnitude of variability for tuber yield and yield contributing traits of potato genotypes.

ii) To estimate the heritability and genetic advance on different traits concerned with yield.

iii) To study the association between tuber yield and its component traits.

iv) To understand the extent of direct and indirect influence of the components on yield.

v) To find out the effect of date of harvesting on yield and related traits.

2.2. MATERIALS AND METHODS

2.2.1. **Location and Season of the Experiment**

The field experiment was conducted at the research field of the Department of Botany, Rajshahi University, Rajshahi, Bangladesh during the winter season of 2014-2015. The location of the site is at 24.3636^0 N latitude and 88.6284^0 E longitude with an elevation of 23 meters from the sea level.

2.2.2. **Soil**

The soil of the experimental field was sandy loam in texture having a pH around 6.4 under AEZ no. 26. The field was medium high land above flood level. It is readily broken when pulverized, well drained soils and suitable for potato production.

2.2.3. **Climate**

Sub-tropical climatic zone and characterized by heavy rainfall, high temperature and humidity during summer and scarce rainfall, low temperature and humidity during winter. During the crop period the total rainfall was 28.20 mm, average minimum and maximum temperatures were 12.74^0 C and 25.63^0 C and mean minimum and maximum relative humidity were 62.46% and 82%, respectively. The weather data (air temperature, rainfall and humidity) during the study period are presented in **Appendix I**.

2.2.4. **Collection of Plant Materials**

The plant materials for the present study comprised of 32 potato (local, released and exotic) genotypes. The seed tubers were collected from Plant Breeding and Gene Engineering Laboratory, Department of Botany, Rajshahi University, Rajshahi, Akafuji Agro-technologies Ltd. Namo Vadra, Padma Residential Area, Rajshahi and different parts of Bangladesh. The potato genotypes used as experimental materials are presented in **Table 2.1.**

2.2.5. **Land Preparation**

The experimental plot was thoroughly prepared by ploughing and cross ploughing for several times with a power tiller followed by laddering until a good tilth was obtained up to a depth of 6-8 inches. All the weeds and stubbles were collected and removed from the land. The clods were broken into friable soil and the surface was leveled. The soil was treated with insecticides (Furadan 5G @ 25 kg/ha) at the time of final land preparation to protect young plants from the attack of soil insects such as cutworm and mole cricket. Finally, irrigation and drainage channels were prepared around the plot. The land was prepared 10 days before planting the tuber.

2.2.6. **Manure and Fertilizer Application**

Manure and fertilizers were applied in the experimental field as per Bangladesh Agricultural Research Council (BARC) fertilizer recommendation guide-2012 **(Table 2.2)**.

Table 2.2 Fertilizer dose and application time used in the present investigation

Sl. No.	Manure/Fertilizer	Dose (kg/ha)	Application
1.	Cow dung	10,000	Basal
2.	Urea	350	Basal and Top Dress
3.	TSP	180	Basal
4.	MOP	320	Basal and Top dress
5.	Gypsum	75	Basal
6.	Zinc Sulphate (Mono)	11	Basal
7.	Boric Acid	6	Basal

Source: Anonymous, 2012

Cow dung was applied before final land preparation. Half of urea, half of MOP and full dose of TSP, Gypsum, Zinc Sulphate (Mono) and Boric acid were applied at the time of seed planting in a furrows made on the both sides of the seed rows and properly mixed with soil. The remaining half of the urea and half of the MOP were applied as top dress at 30 days after planting of the seed tubers and mixed properly with soil followed by flood irrigation.

2.2.7. **Design of the Experiment**

The experiment was laid out following Randomize Complete Block Design (RCBD) with three replications.

2.2.8. **Experimental Layout**

The total area of the experiment is 112.50 m x 12 m. As the experiment comprised 32 genotypes and three replications, the number of total plots was 96. Each replication consists of 32 plots. The size of unit plot was 3 m x 3 m, Plot to plot distance 50 cm and block to block distance 1 m.

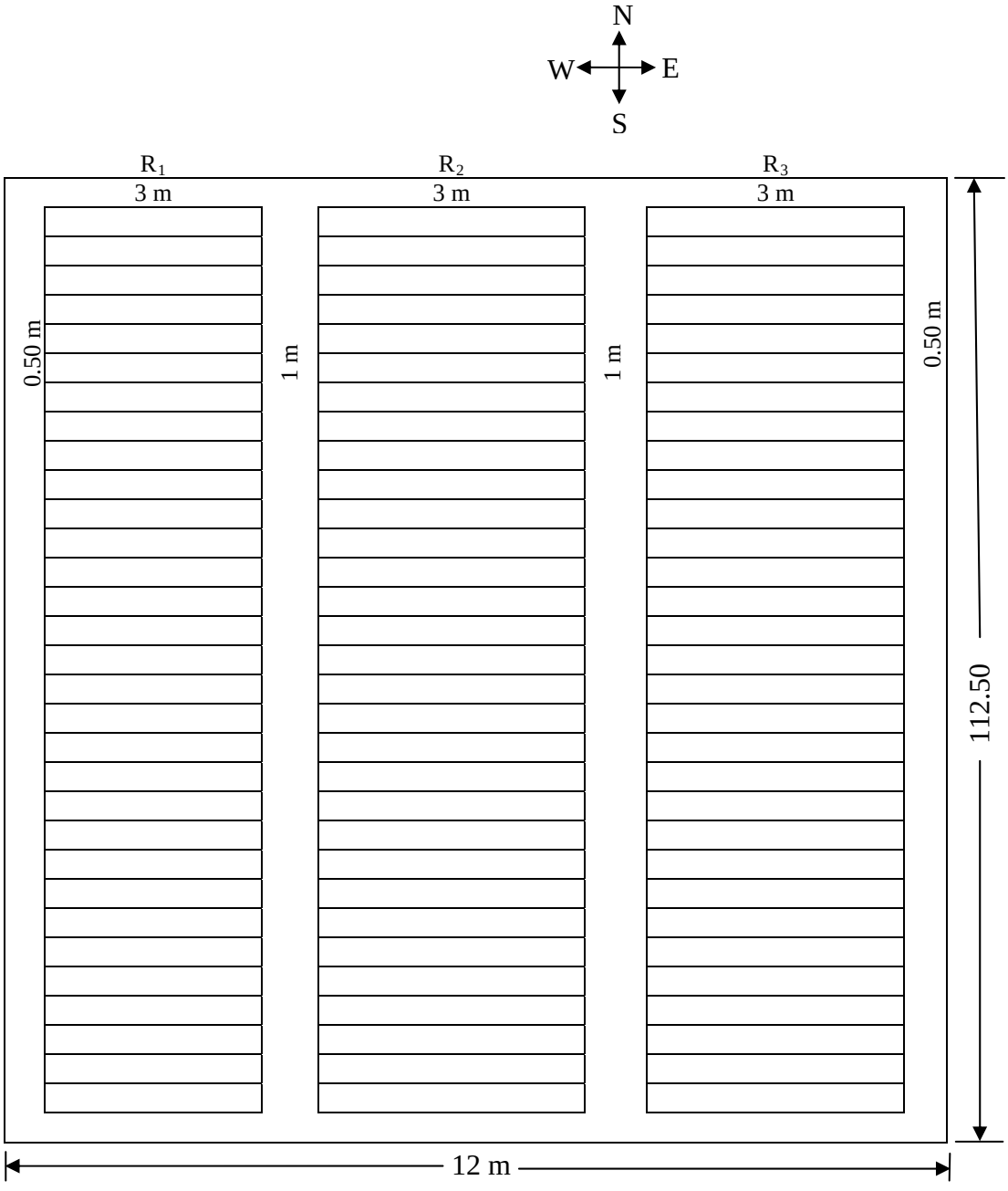

Figure 2.1 Layout of the experimental plot

2.2.9. **Planting of Seed Tubers**

Healthy and disease free seed tubers were planted in the experimental plots on 15th November, 2014 at a depth of 5 cm. A spacing of row to row 60 cm and plant to plant 25 cm was used (BARI, 2006). The soil along the rows of the seed tubers was ridged up immediately after planting.

2.2.10. **Intercultural Operation**

2.2.10.1. *Weeding*

Weeding was done manually as and when necessary to keep the plots free from weeds and the soil was mulched by breaking the upper crust of the soil for easy aeration and to conserve soil moisture.

2.2.10.2. *Irrigation and drainage*

Irrigation was given four times, first one was within one week of planting, second one was just after fertilizers top dressing followed by earthing up, third one was at 45 DAP and the last one was at 60 days after planting.

2.2.10.3. *Earthing up*

Earthing up was done three times during the growing period. First earthing up was done just after planting the seed tuber, the second one was done after fertilizers top dressing and last earthing up was done after 15 days of second earthing up.

2.2.10.4. *Plant protection*

Furadan 5G was applied during final land preparation @ 25 kg/ha against soil insects like cutworm. A general dose of 0.2 % Asataf (systemic insecticide) and 0.2% Ridomil MZ 72 WP was used at every 15 days interval, starting at 35 days after planting to prevent virus vectors and any late blight infection respectively.

A. Planting of potato seed tubers

B. Data collection on potato plant

C. Potato field at 60 DAP

D. Crop protection practice in research field

E. Prof. Dr. Md. Monzur Hossain, supervisor, inspecting research field

Plate 1 Different activities (A-E) in the potato research field

2.2.11. **Data Collection**

Data on different agronomic characters were recorded on 10 randomly selected plants for each genotype from each replication. Data were recorded on following parameters-

1. Days to first shoot emergence

Days to first shoot emergence was recorded with visual observation.

2. Foliage coverage (%)

Foliage coverage was measured at 40 and 60 days after planting for each plot by using meter scale and converted into percentage.

$$\text{Foliage coverage (\%)} = \frac{\text{Area coverd by plants}}{\text{Total area of the plot}} \times 100$$

3. Number of stems/plant

Number of stems/plant was calculated from the average of randomly selected 10 plants from each plot at 40 and 60 days after planting.

4. Number of leaves/plant

Number of leaves/plant was calculated from the average of randomly selected 10 plants from each plot at 40 and 60 days after planting.

5. Plant height (cm)

Plant height was measured from selected plants for each replication at 40 and 60 DAP with the help of a meter scale. It was measured from ground level to the tip of the tallest stem.

6. Chlorophyll content in leaf (mg/g)

Total chlorophyll, chlorophyll$_a$ and chlorophyll$_b$ contents were determined from fresh potato leaves without maceration using Dimethyl sulphoxide (DMSO) method described by Hiscox and Israelstam (1979) and Arnon (1949).

Equipments: i) Test tubes ii) Electric balance iii) Electric oven iv) Measuring cylinder v) Centrifuge machine and vi) Spectrophotometer.

Reagent: Dimethyl sulphoxide (DMSO)

Extraction of chlorophyll from potato leaf: About 50 mg of potato leaf was taken in a test tube. 7 ml of Dimethyl sulphoxide (DMSO) was added to the test tube and kept the mixture in an electric oven for 3 hours at 65^0 C. The mixture was then centrifuged and supernatant was transferred to a measuring cylinder. The volume made up to 10 ml with Dimethyl sulphoxide (DMSO). The extraction of chlorophyll sample was ready to measure.

Procedure: Total chlorophyll, $chlorophyll_a$ and $chlorophyll_b$ contents were measured by recording the optical density of the extract by a spectrophotometer. About 3 ml of the chlorophyll extract was transferred to a cuvette and optical density was recorded at 645 nm and 663 nm against Dimethyl sulphoxide (DMSO) blank.

Calculation: The amount of Total chlorophyll, $chlorophyll_a$ and $chlorophyll_b$ were calculated using the following equations-

$$\text{Amount of total chlorophyll (mg/g)} = \frac{20.2\times D645+8.02\times D663\times V}{1000\times \text{wt of sample (g)}}$$

$$\text{Amount chlorophyll}_a \text{ (mg/g)} = \frac{12.7\times D663-2.67\times D645\times V}{1000\times \text{wt of sample (g)}}$$

$$\text{Amount chlorophyll}_b \text{ (mg/g)} = \frac{22.9\times D645-4.68\times D663\times V}{1000\times \text{wt of sample (g)}}$$

Where, V= Volume of the extract, D= Optical density.

7. Number of tubers/plant at 70 and 90 DAP

Tubers were harvested from individual selected plant of each plot both at 70 and 90 DAP and counted.

8. Tuber weight/plant at 70 and 90 DAP (g)

Tuber harvested at 70 and 90 DAP from individual plant and total tubers were weighed in gram.

9. Single tuber weight at 70 and 90 DAP (g)

Single tuber weight at 70 and 90 DAP was calculated by dividing the weight of tubers/plant by the number of tubers/plant.

10. Tuber yield at 70 and 90 DAP (t/ha)

The tuber yield of the whole plot was converted into yield in tons/ha using the following formula:

$$\text{Yield (t/ha)} = \frac{\text{Tuber yield per plot (kg)}\times 10000}{\text{Area of plot (sqm)}\times 100}$$

2.2.12. **Data Analysis**

The statistical parameters like mean, range, variance, standard deviation, standard error and coefficient of variation were calculated using the method as described by Panse and Sukhatme (1967). Analysis of variance was done for each character by computer using statistical package programme MSTAT-C software. The test of significance was done by F test. The difference between any pair of means was performed by Duncan's Multiple Range Test (DMRT).

1. Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula as suggested by Johnson *et al.* (1955) using OPSTAT the online based software.

Genotypic variance ($\delta^2 g$) = (M_1-M_2)/r

Phenotypic variance, ($\delta^2 p$) = $\delta^2 g + r\delta^2 e$

Where,

r = Number of replication

M_1= Mean sum of square for the genotypes

M_2 = Mean sum of square for error

$\delta^2 e$ = Error variance

$\delta^2 g$= Genotypic variance

$\delta^2 p$ = Phenotypic variance

2. Estimation of genotypic and phenotypic coefficients of variation

The estimation of genotypic and phenotypic co-efficient of variation were done according to the formula given by Burton (1952) using OPSTAT the online based software.

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{(\text{Genotypic variance})}}{\text{Grand mean}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{(\text{Phenotypic variance})}}{\text{Grand mean}} \times 100$$

3. Estimation of broad sense heritability

Heritability in broad sense ($h^2b\%$) was calculated as suggested by Johnson *et al.* (1955) using OPSTAT the online based software.

h^2b (%) = ($\delta^2 g/\delta^2 p$) x 100

Where, $\delta^2 g$ = genotypic variance and $\delta^2 p$ = phenotypic variance

4. Estimation of genetic advance

The expected genetic advance (GA) for each individual character was obtained by following the formula as described by Johnson *et al.* (1955) using OPSTAT the online based software.

$GA = \delta p \times h^2 \times k$

Where,

δp = phenotypic standard deviation

$h^2 = (\delta^2 g / \delta^2 p) \times 100$

k = Selection differential value, which is 2.06 at 5% selection intensity.

$$\text{GA expressed as \% of mean} = \frac{\text{Genetic advance}}{\text{Grand mean}} \times 100$$

5. Estimation of genotypic and phenotypic correlations

Genotypic and phenotypic correlation coefficient was calculated using the formulae suggested by Miller *et al.* (1958) with the help of OPSTAT the online based software.

6. Estimation of path coefficient

Path coefficient analysis was done according to the method as suggested by Dewey and Lu (1959) with the help of OPSTAT the online based software.

Statistical analyses were done for the data expressed in percentage after angular transformation.

Table 2.1 List of potato genotypes used as experimental materials in the present study

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_1	Romana	Plant short; stem color green, very hairy; tuber small size, oval round; skin reddish color; eyes moderate in number, more red than other portion; tuber flesh color pale yellow.		
G_2	Bellini	Plant medium tall; 4-5 stems, green; leaf medium wavy, contains low anthocyanin; tuber small size, oval shape; skin smooth and light yellow in color; eyes shallow deep; tuber flesh color light cream.		
G_3	Tel Pakri	Plant short; stem green to medium pinkish, number many, very hairy; tuber small size, oval; skin red, yellow patches are present at the surrounding of eyes. Tuber flesh color yellowish.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_4	Shilbilati	Plant tall, open and spreading; stem few, semi hard, solid, moderately hairy, light green; leaf structure open, light green; tuber low in number, elongated and humped, smooth and shiny skin, reddish in color; eyes many, reddish, deep, more or less uniformly distributed; tuber flesh color white.		
G_5	Blondy	Plant medium tall, open and erect; stem moderate in number, solid, moderately hairy, green; leaf structure open, light green; tuber many, size small, round; smooth and shiny ski; eyes low in number, shallow deep, more or less uniformly distributed; tuber flesh color cream.		
G_6	Pahari Pakri	Plant medium tall; stem low in number, green color; leaf low in number, green; tuber round, skin reddish in color; eyes moderate in number, medium deep; tuber flesh color pale yellow.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_7	Lara	Plant tall, spreading; 4-5 stems, hard, blue violet in color; leaf and stem low hairy; tuber medium size, oval-elongated; skin smooth, reddish in color with whitish dot; eyes light and shallow deep; tuber flesh color deep yellow.		
G_8	Lady Rosetta	Plant tall, spreading type; stem color deep green; tuber medium size, round, skin reddish in color; eyes low in number and medium deep; tuber flesh color white.		
G_9	Granola	Plant medium tall, spreading type; stem moderate in number, green in color; tuber medium to large size, round-oval; skin rough, light yellowish in color; eyes moderate in number, shallow deep; tuber flesh color pale yellow.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{10}	Lal Pakri	Plant medium tall, spreading; stem many, hard, solid, very hairy, light green; leaf structure open, dark green; tuber no. high, size small to medium, round; rough skin, pinkish red with white patches; eyes low in number, pink, shallow to medium deep; tuber flesh color whitish yellow.		
G_{11}	Courage	Plant medium tall; stem green in color; leaf low in number, green; tuber low in number, large in size, round-oval; skin smooth, uniform red skin; eyes medium deep; tuber flesh color yellowish white.		
G_{12}	Hagrai	Plant short, open and erect; stem many, solid, very hairy, pinkish; leaf structure open, light green; tuber moderate in number, small, round and irregular; skin shiny, pinkish white; eyes low in number, deep, eyebrows are prominent more or less uniformly distributed; tuber flesh color whitish.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{13}	Indurkani	Plant medium tall; stem moderate in number, color reddish green; tuber small size, oval-elongated; skin color dark brown, eyes number medium, shallow deep; tuber flesh color is cream with red ring.		
G_{14}	Fata Pakri	Plant short; stem no. least, green to medium pinkish, very hairy; tuber small in size, round, skin rough, color reddish; eyes are pink and eyebrows are white; tuber flesh color pale yellow.		
G_{15}	Shada Guti	Plant medium tall, medium compact and erect; stems many, solid, moderately hairy, green; leaf structure open, green; tuber high in number, size small, round; skin smooth, creamy white; eyes moderate in number, medium deep, not uniformly distributed; tuber flesh color light yellow.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{16}	All Blue	Plant medium tall, spreading habit; stem blue-purple; leaf dark green; tubers medium size, oval to oblong; skin deep purple with netted texture; eyes large in number, moderately deep, evenly distributed; tuber flesh mottled purple streaked with white and its defining characteristic a white vascular ring.		
G_{17}	Barma Alu	Plant tall, spreading habit; stem many, whitish in color; leaf many, green in color; tuber moderate in number, medium size, round; skin smooth and shiny, white in color; eyes shallow deep; tuber flesh color cream.		
G_{18}	Asterix	Plant erect; 3-4 stems, green in color; leaf large size, green, spreading type; plant structure and leaf arrangement nice; tuber large size, oblong-oval, skin smooth, reddish in color, eyes medium deep; tuber flesh color pale yellow.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{19}	Atlas	Plant short; stems few, green; leaf medium wavy, green; tuber medium to large in size, long-oval; skin smooth, light yellowish; eyes fairly shallow deep; tuber flesh color pale yellow.		
G_{20}	Cardinal	Plant hard and rapid growth habit; stem few, long, slightly hairy, pinkish green; leaf edge slightly wavy, color green; tuber size large, elongated-oval; skin smooth, reddish in color; eyes number moderate, pinkish color; tuber flesh color light yellow.		
G_{21}	Vanderpur	Plant medium tall, open and erect; stem many, solid, very hairy, light pinkish green; leaf structure open, green; tuber high in number, small in size, round; skin smooth, whitish; eyes low in number, deep, prominent, more or less uniformly distributed; tuber flesh color light yellow.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{22}	Diamont	Plant vigorous, rapid growth habit; stem few, hard, long, green in color, moderately hairy; leaf large, deep green; tuber large size, oval-oblong shape, skin smooth, light yellowish in color; eyes moderate in number; shallow depth, eyes of distal end are pink color; tuber flesh color light yellow.		
G_{23}	JPR	Plant tall, spreading type; stem number many, pinkish color, hairy; leaf number many, light green; tuber moderate in number, medium size, round irregular, skin rough and reddish in color; eyes many, deep; tuber flesh color yellow.		
G_{24}	All Red	Plant tall, spreading type; stem high in number, pinkish, hairy; leaf number high, light green; tuber moderate in number, medium size, round-oval; skin orange red; eyes medium in number, deep; tuber flesh color yellowish with red surrounding.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{25}	Shepody	Plant medium tall, slightly upright; stem many, light green; leaf number large, pale green color; tuber large in size, long to slightly oblong; skin medium smooth, white to light buff color; eyes few, shallow to moderate deep, uneven distribution; tuber flesh color white.		
G_{26}	Baraka	Plant vigorous; stem many, thick, green; leaf many, green; tuber size small, round-oval; skin smooth, light yellow; eyes few, depth of eyes shallow; tuber flesh color light yellow.		
G_{27}	Akhira	Plant short, erect; stem few, solid, hard, yellowish green; leaf low in number, structure open, green; tuber moderate in number, small size, skin smooth, pale yellow color; eyes number low, shallow deep, uneven distributed; tuber flesh color deep yellow.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{28}	Ultra	Plant tall and erect; stem few, green; leaf large in size, deep green; tuber low in number, large in size, shape oval-oblong; skin smooth, pale yellow, eyes depth shallow; tuber flesh color white.		
G_{29}	Atlanta	Plant medium tall, slightly spreading type; stem few in number, green; tuber moderate in number, size medium, oval; skin medium smooth, white; depth of eyes shallow to medium; tuber flesh color whitish.		
G_{30}	Call White	Plant tall, slightly upright; stem few, green; leaf low in number, green; tuber low in number, medium size, oval; skin smooth, shiny, white; number of eyes low, shallow deep; tuber flesh color white.		

Table 2.1 Contd.

Accession No.	Genotype name	Brief description	Photograph (Plant, full and cut tuber)	
G_{31}	Blue Mountaion	Plant medium tall, erect; stem moderate in number, green; leaf structure open, moderate in number, light green; tuber number moderate, medium size, oval-oblong; skin smooth, yellowish, number of eyes few, shallow deep, tuber flesh color pale yellow.		
G_{32}	Martin	Plant medium tall, erect; stem few, solid, hard, green; leaf number low, structure open, green; tuber low in number, medium size, oval-oblong shape; skin rough, light yellow; number of eyes few, shallow deep, tuber flesh color pale yellow.		

2.3. RESULTS

Thirty two potato (*Solanum tuberosum* L.) genotypes (local/Indigenous, released and exotic) were collected and different yield contributing characters *viz*., days to first shoot emergence, foliage coverage at 40 and 60 DAP, number of stems/plant at 40 and 60 DAP, number of leaves/plant at 40 and 60 DAP, plant height (cm) at 40 and 60 DAP, chlorophyll content in leaf (mg/g) and number of tubers/plant, tuber weight/plant (g), single tuber weight (g) and tuber yield (t/ha) both at 70 and 90 DAP harvest were evaluated. Collected data were analyzed and results so far obtained from the experiment are presented under different heads. The brief analysis of variance of data in respect of various parameters studied are shown in **Appendix II**.

2.3.1. **Mean Performances of Tuber Yield and Yield Contributing Characters**

2.3.1.1. *Days to first shoot emergence*

Days to first emergence of 32 potato genotypes were observed visually from the date of planting the seed tuber and recorded. Days to first shoot emergence did not vary significantly among the genotypes and ranged from 15.33 to 18.00 **(Table 2.3)**.

2.3.1.2. *Foliage coverage (%)*

Foliage coverage was estimated at 40 and 60 DAP. Significant variation was observed for foliage coverage among the genotypes both the stages of growth. The variations ranged from 39.67 to 71.67 % at 40 DAP and 76.00 to 98.33% at 60 DAP. The highest foliage coverage was measured in G_{17} (71.67%) and G_{22} (98.33%) at 40 and 60 DAP respectively and was statistically similar to G_{16} (69.0%) and G_{25} (65.0%) at 40 DAP and G_{17} (97.67%), G_{20} (96%), G_7 (94.33), G_{16} (92.67%), G_3 (91.33%), G_9 (91%), G_8 (90.67%), G_{29} (89.67%), G_{25} (89.33%) and G_{11} (88.67%) at 60 DAP. The lowest foliage coverage was recorded in G_{13} (39.67%) which was statistically similar to G_{19} (40.33%), G_{27} (41.67%), G_{12} (45%), G_{30} (45%), G_1 (45.33%), G_5 (45.67%), G_4 (46.67%) and G_{11} (46.67%) at 40 DAP. At 60 DAP the lowest foliage coverage was obtained in G_{19} (76%) which was statistically similar to G_{13} (78.67%), G_2 (79%), G_5 (79%), G_{27} (79%) and G_{26} (79.67) **(Table 2.3)**.

2.3.1.3. *Number of stems/plant*

Significant variation was observed among the genotypes in case of number of stems/plant both at 40 and 60 DAP and ranged from 1.47 to 5.33 at 40 DAP with mean 3.28 and 1.93

to 5.33 at 60 DAP with mean 3.56. G_{10} showed the maximum number of stems/plant (5.33) both at 40 and 60 DAP and statistically similar to G_{15} (5.27) and G_{25} (4.93) at 40 DAP and G_{15} (5.27) and G_{25} (5.00) at 60 DAP. G_{11} produced the minimum number of stems/plant 1.47 and 1.93 for both the stages of growth respectively **(Table 2.3)**.

2.3.1.4. *Number of leaves/plant*

The number of leaves/plant differed significantly among the thirty two potato genotypes both the stages of growth (40 and 60 DAP) and ranged from 13.27 to 52.53 at 40 DAP with an average of 31.36 and 28.27 to 98.73 at 60 DAP with mean 61.07. The highest number of leaves/plant was found in G_{25} (52.53) at 40 DAP which was statistically similar to G_{24} (51.20). At 60 DAP the highest number of leaves/plant was recorded for G_{10} (98.73) which was statistically similar to G_4 (95.60), G_{15} (94.80) and G_{24} (94.40). The lowest number of leaves/plant was found in G_{19} (13.27) at 40 DAP while G_{20} (28.27) produced the lowest number of leaves/plant at 60 DAP and similar to G_{11} (33.47) (**Table 2.4**).

2.3.1.5. *Plant height (cm)*

Significant variation in plant height both at 40 and 60 DAP was observed among the genotypes ranging from 18.13 to 45.67 cm with an average of 27.53 cm at 40 DAP and 23.75 to 54.33 cm with an average of 37.59 cm at 60 DAP. The tallest plant was G_7 (45.67 cm) which was followed by G_{28} (40.53 cm) and G_{24} (35.40 cm) and the shortest plant was G_{26} (18.13 cm) which was statistically similar to G_1 (18.73 cm), G_{27} (19.33 cm), G_{19} (19.47 cm) and G_2 (20.07 cm) at 40 DAP. At 60 DAP the tallest plant was G_4 (54.33 cm) which was statistically similar to G_{28} (52.00 cm) and the shortest plant was G_1 (23.75 cm) which was statistically similar to G_{27} (26.20 cm), G_2 (26.73 cm), and G_{17} (27.00 cm) **(Table 2.4)**.

Table 2.3 Mean performances of days to first shoot emergence, foliage coverage and number of stems/plant of thirty two potato genotypes

Genotypes	DFSE	Foliage coverage (%)		No. of stems/plant	
		40 DAP	60 DAP	40 DAP	60 DAP
G_1	15.33	45.33 $^{i-l}$	85.67 $^{d-j}$	2.73 $^{j-l}$	2.93 $^{j-k}$
G_2	16.33	47.67^{g-k}	79.00 $^{h-j}$	2.80 $^{i-l}$	4.00 ^{d}
G_3	15.67	59.00 $^{b-d}$	91.33 $^{a-f}$	3.73 ^{d}	3.93 $^{d-e}$
G_4	16.00	46.67 $^{h-l}$	82.00 $^{f-j}$	3.00 $^{f-k}$	3.13 $^{g-k}$
G_5	15.67	45.67 $^{h-l}$	79.00 $^{h-j}$	2.80 $^{i-l}$	3.13 $^{g-k}$
G_6	16.67	50.33 $^{e-i}$	83.33 $^{e-j}$	2.93 $^{g-l}$	3.07 $^{h-k}$
G_7	18.00	58.33 $^{b-d}$	94.33 $^{a-d}$	3.13 $^{f-j}$	3.40 $^{f-i}$
G_8	16.67	61.67 ^{bc}	90.67 $^{a-f}$	3.40 $^{d-f}$	3.60 ^{ef}
G_9	15.67	60.67 $^{b-d}$	91.00 $^{a-f}$	3.67 ^{de}	3.93 ^{de}
G_{10}	17.00	60.33 $^{b-d}$	85.33 $^{d-j}$	5.33 ^{a}	5.33 ^{a}
G_{11}	16.67	46.67 $^{h-l}$	88.67 $^{a-i}$	1.47 ^{o}	1.93 ^{n}
G_{12}	17.67	45.00 $^{j-l}$	84.67 $^{d-j}$	2.67 $^{k-m}$	2.87 ^{k}
G_{13}	16.67	39.67 ^{l}	78.67 ^{ij}	3.33 $^{d-g}$	3.40 $^{f-i}$
G_{14}	16.00	56.00 $^{c-f}$	87.00 $^{c-i}$	3.20 $^{e-i}$	3.53 ^{fg}
G_{15}	18.00	53.33 $^{d-h}$	86.67 $^{c-i}$	5.27 ^{a}	5.27 ^{ab}
G_{16}	16.33	69.00 ^{a}	92.67 $^{a-e}$	3.27 $^{e-h}$	3.40 $^{f-i}$
G_{17}	15.33	71.67 ^{a}	97.67 ^{ab}	4.60 ^{bc}	4.73 ^{c}
G_{18}	18.00	55.67 $^{c-f}$	84.00 $^{d-j}$	4.20 ^{c}	4.20 ^{d}
G_{19}	16.00	40.33 ^{kl}	76.00 ^{j}	1.87 ^{n}	2.40 ^{m}
G_{20}	15.33	57.00 $^{c-e}$	96.00 $^{a-c}$	2.60 $^{k-m}$	2.80 ^{kl}
G_{21}	17.00	53.33 $^{d-h}$	84.67 $^{d-j}$	3.27 $^{e-h}$	3.47 $^{f-h}$
G_{22}	15.33	61.67 ^{bc}	98.33 ^{a}	3.00 $^{f-k}$	3.40 $^{f-i}$
G_{23}	17.00	56.67 $^{c-e}$	85.67 $^{c-j}$	3.67 ^{de}	4.13 ^{c}
G_{24}	16.00	58.33 $^{b-d}$	88.00 $^{b-i}$	4.53 ^{bc}	4.93 ^{bc}
G_{25}	16.00	65.00 ^{ab}	89.33 $^{a-h}$	4.93 ^{ab}	5.00 $^{a-c}$
G_{26}	16.67	49.33 $^{e-j}$	79.33 $^{g-j}$	3.33 $^{d-g}$	4.07 ^{d}
G_{27}	16.00	41.67 $^{j-l}$	79.00 $^{h-j}$	2.80 $^{i-l}$	3.07 $^{g-k}$
G_{28}	17.00	50.33 $^{e-i}$	86.00 $^{c-j}$	2.73 $^{j-l}$	3.00 $^{i-k}$
G_{29}	16.00	55.00 $^{c-g}$	89.67 $^{a-g}$	2.87 $^{h-l}$	3.33 $^{f-j}$
G_{30}	16.00	45.00 $^{i-l}$	85.33 $^{d-j}$	2.27 ^{m}	2.47 ^{lm}
G_{31}	16.00	49.33 $^{e-j}$	86.00 $^{c-j}$	3.00 $^{f-k}$	3.13 $^{g-k}$
G_{32}	16.33	48.33 $^{f-j}$	83.67 $^{e-j}$	2.53 ^{lm}	2.93 ^{jk}
Grand Mean±SE	16.39±0.61	53.25 ±2.23	86.52 ± 3.04	3.28 ±0.13	3.56 ±0.12
CV %	6.86	7.67	6.05	7.22	6.28
Level of significance		*	*	**	**

* and ** significant at 5% and 1% level of significance respectively

DAP= Days after planting, DFSE= Days to first shoot emergence

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

Table 2.4 Mean performances of number of leaves/plant and plant height of thirty two potato genotypes

Genotypes	Number of leaves/plant		Plant height (cm)	
	40 DAP	60 DAP	40 DAP	60 DAP
G_1	23.53 ^{n}	53.33 ^{hi}	18.73 ^{rs}	23.73 ^{l}
G_2	27.40 ^{kl}	55.87 $^{g-i}$	20.07 $^{p-s}$	26.73 ^{kl}
G_3	31.07 $^{h-j}$	73.00 ^{e}	21.87 $^{n-q}$	30.67 ^{ij}
G_4	40.20 ^{d}	95.60 ^{a}	33.67 ^{cd}	54.33 ^{a}
G_5	20.67 ^{o}	52.00 $^{h-j}$	24.67 $^{k-m}$	31.00 ^{ij}
G_6	22.20 ^{no}	44.00 ^{k}	23.67 $^{l-o}$	34.80 $^{f-h}$
G_7	35.80 ^{ef}	46.40 ^{jk}	45.67 ^{a}	49.53 ^{b}
G_8	33.00 ^{gh}	44.47 ^{k}	27.73 $^{h-j}$	44.07 ^{c}
G_9	31.80 ^{hi}	46.20 ^{jk}	27.53 $^{h-j}$	38.00 ^{ef}
G_{10}	48.87 ^{b}	98.73 ^{a}	26.73 $^{i-k}$	40.40 ^{de}
G_{11}	16.07 ^{p}	33.47 ^{l}	33.07 $^{c-e}$	42.47 ^{cd}
G_{12}	24.33 ^{mn}	53.47 ^{hi}	22.20 $^{m-p}$	33.07 $^{g-j}$
G_{13}	26.67 $^{k-m}$	86.20 ^{b}	23.87 $^{l-n}$	39.73 ^{de}
G_{14}	28.87 ^{jk}	52.40 $^{h-j}$	22.60 $^{m-p}$	35.07 $^{f-h}$
G_{15}	45.20 ^{c}	94.80 ^{a}	24.47 $^{k-m}$	36.00 ^{fg}
G_{16}	36.40 ^{e}	53.80 ^{hi}	21.20 $^{o-r}$	32.40 $^{h-j}$
G_{17}	43.93 ^{c}	83.13 ^{bc}	30.53 $^{e-g}$	41.47 $^{c-e}$
G_{18}	35.60 $^{e-g}$	54.40 ^{hi}	25.33 $^{j-l}$	40.13 ^{de}
G_{19}	13.27 ^{q}	62.20 ^{f}	19.47 $^{q-s}$	27.00 ^{kl}
G_{20}	24.87 $^{l-n}$	28.27 ^{l}	29.47 ^{gh}	40.27 ^{de}
G_{21}	24.47 ^{mn}	49.87 $^{i-k}$	24.60 $^{k-m}$	33.67 $^{g-i}$
G_{22}	32.93 ^{gh}	46.73 ^{jk}	32.13 $^{d-f}$	43.13 ^{cd}
G_{23}	36.00 ^{ef}	79.27 ^{cd}	34.13 ^{cd}	40.20 ^{de}
G_{24}	51.20 ^{ab}	94.40 ^{a}	35.60 ^{c}	49.20 ^{b}
G_{25}	52.53 ^{a}	60.67 ^{fg}	30.80 $^{e-g}$	34.93 $^{f-h}$
G_{26}	23.73 ^{n}	74.13 ^{de}	18.13 ^{s}	29.80 ^{jk}
G_{27}	23.40 ^{n}	45.53 ^{k}	19.33 $^{q-s}$	26.20 ^{l}
G_{28}	31.20 $^{h-j}$	72.60 ^{e}	40.53 ^{b}	52.00 ^{ab}
G_{29}	33.60 $^{f-h}$	58.53 $^{f-h}$	33.40 ^{cd}	38.20 ^{ef}
G_{30}	33.07 ^{gh}	43.47 ^{k}	30.67 $^{e-g}$	42.93 ^{cd}
G_{31}	29.27 $^{i-k}$	62.33 ^{f}	30.33 ^{fg}	35.40 $^{f-h}$
G_{32}	22.47 ^{no}	55.00 $^{g-i}$	28.87 $^{g-i}$	36.40 ^{fg}
Grand Mean±SE	31.36 ±0.81	61.07 ±1.73	27.53 ±0.77	37.59 ±0.98
CV %	4.85	5.63	5.11	5.00
Level of significance	**	**	**	**

** Significant at 1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

2.3.1.6. *Chlorophyll content in leaf (mg/g)*

Chlorophyll$_a$, chlorophyll$_b$ and total chlorophyll content in leaf varied significantly among the thirty two potato genotypes. Chlorophyll$_a$, chlorophyll$_b$ and total chlorophyll content in leaf ranged from 0.685 to 1.533 mg/g, 0.229 to 0.550 mg/g and 0.959 to 1.992 mg/g respectively. Maximum amount of Chlorophyll$_a$ was found in G_{22} (1.553 mg/g) which was followed by G_{18} (1.361 mg/g), G_{32} (1.293 mg/g) and G_{27} (1.287 mg/g). The lowest amount of Chlorophyll$_a$ was estimated from G_{17} (0.695 mg/g). G_{27} (0.550 mg/g) showed the maximum amount of chlorophyll$_b$ followed by G_{30} (0.506 mg/g) and G_{31} (0.478 mg/g) and were statistically dissimilar to each other. The lowest amount of chlorophyll$_b$ was found in G_{12} (0.229 mg/g). In case of total chlorophyll content G_{22} (1.992 mg/g) showed the maximum amount of total chlorophyll which was followed by G_{27} (1.836 mg/g), G_{18} (1.776 mg/g) and G_{20} (1.713 mg/g). The lowest amount of total chlorophyll content was estimated from G_{17} (0.959 mg/g) and statistically dissimilar with other genotypes **(Table 2.5)**.

2.3.1.7. *Number of tubers/plant*

Significant difference was observed among the potato genotypes in respect of number of tubers/plant harvested at 70 and 90 DAP. Number of tubers/plant slightly increased in late harvest. Number of tubers/plant ranged from 4.00 to 28.27 at 70 DAP and 4.47 to 29.13 at 90 DAP. The highest number of tubers/plant was observed in the genotype G_{26} (28.27) followed by G_5 (26.00), G_{13} (25.60), G_{15} (25.00) and G_{21} (23.13) at 70 DAP. G_{26} (29.13) had the highest number of tubers/plant when harvested at 90 DAP which was statistically similar to G_5 (27.73) and G_{13} (27.73). The lowest number of tubers/plant at 70 DAP was found in G_{11} (4.00) which was statistically similar to G_{28} (4.33), G_{30} (4.33), G_7 (5.00) and G_{32} (5.13). In case of 90 DAP, G_{11} (4.47) also showed the lowest number of tubers/plant which was statistically similar to G_{30} (4.53), G_{28} (4.67), G_{32} (5.33), G_7 (5.40) and G_{18} (6.47). It was revealed that local genotypes produced more tubers/plant than released or exotic variety **(Table 2.5)**.

Table 2.5 Chlorophyll content in leaf and number of tubers/plant of thirty two potato genotypes

Genotypes	Chlorophyll (mg/g)			No. of tubers/Plant	
	Chl_a	Chl_b	Total Chl	70 DAP	90 DAP
G_1	1.003 $^{i-l}$	0.286 ^{no}	1.289 $^{j-l}$	10.27 ^{e}	11.20 $^{e-g}$
G_2	1.038 $^{f-j}$	0.463 ^{cd}	1.501 ^{fg}	17.33 ^{d}	19.20 ^{d}
G_3	1.085 ^{fg}	0.309 $^{k-m}$	1.394 ^{hi}	11.27 ^{e}	12.93 ^{e}
G_4	0.997 $^{j-l}$	0.285 ^{no}	1.282 ^{kl}	17.87 ^{d}	18.53 ^{f}
G_5	1.032 $^{g-j}$	0.365 ^{h}	1.397 ^{hi}	26.00 ^{b}	27.73 ^{a}
G_6	0.961 ^{lm}	0.284 ^{no}	1.245 $^{k-m}$	9.47 $^{e-g}$	9.67 $^{f-j}$
G_7	1.094 ^{f}	0.337 ^{i}	1.431 ^{gh}	5.00 $^{k-m}$	5.40 ^{mn}
G_8	0.968 $^{k-m}$	0.293 $^{m-o}$	1.262 ^{kl}	7.80 $^{g-i}$	8.00 $^{i-l}$
G_9	1.072 $^{f-h}$	0.324 $^{i-k}$	1.396 ^{hi}	7.40 $^{g-i}$	7.60 $^{j-l}$
G_{10}	1.058 $^{f-j}$	0.340 ^{i}	1.398 ^{hi}	21.80 ^{c}	23.47 ^{d}
G_{11}	1.026 $^{g-k}$	0.294 $^{m-o}$	1.320 $^{i-k}$	4.00 ^{m}	4.47 ^{n}
G_{12}	1.060 $^{f-i}$	0.229 ^{r}	1.290 $^{j-l}$	10.47 ^{e}	11.67 ^{ef}
G_{13}	0.790 ^{o}	0.258 ^{q}	1.048 ^{n}	25.60 ^{b}	27.73 ^{a}
G_{14}	1.043 $^{f-j}$	0.323 $^{i-k}$	1.365 $^{h-j}$	17.33 ^{d}	17.60 ^{d}
G_{15}	1.218 ^{d}	0.336 ^{ij}	1.554 ^{ef}	25.00 ^{c}	24.60 ^{bc}
G_{16}	0.961 ^{lm}	0.276 ^{op}	1.237 $^{k-m}$	6.60 $^{i-k}$	7.20 ^{lm}
G_{17}	0.695 ^{p}	0.265 ^{pq}	0.959 ^{o}	9.60 $^{e-g}$	9.87 $^{f-i}$
G_{18}	1.361 ^{b}	0.416 ^{e}	1.776 ^{bc}	6.27 $^{i-l}$	6.47 $^{l-n}$
G_{19}	0.879 ^{n}	0.301 $^{l-n}$	1.180 ^{m}	6.73 $^{i-k}$	7.53 $^{j-l}$
G_{20}	1.256 ^{cd}	0.457 ^{d}	1.713 ^{cd}	7.53 $^{g-i}$	7.87 $^{i-l}$
G_{21}	1.161 ^{e}	0.391 ^{f}	1.552 ^{ef}	23.13 ^{c}	25.47 ^{b}
G_{22}	1.533 ^{a}	0.459 ^{d}	1.992 ^{a}	7.20 $^{h-j}$	7.47 ^{kl}
G_{23}	0.911 ^{mn}	0.318 $^{j-l}$	1.229 ^{lm}	7.53 $^{g-i}$	7.80 $^{i-l}$
G_{24}	1.216 ^{d}	0.374 ^{gh}	1.590 ^{e}	7.80 $^{g-i}$	8.20 $^{h-l}$
G_{25}	1.071 $^{f-h}$	0.336 ^{ij}	1.406 ^{h}	7.80 $^{g-i}$	8.40 $^{h-l}$
G_{26}	1.037 $^{f-j}$	0.393 ^{f}	1.430 ^{gh}	28.27 ^{a}	29.13 ^{a}
G_{27}	1.287 ^{c}	0.550 ^{a}	1.836 ^{b}	8.13 $^{f-i}$	9.67 $^{f-j}$
G_{28}	1.011 $^{h-l}$	0.413 ^{e}	1.423 ^{gh}	4.33 ^{lm}	4.67 ^{n}
G_{29}	0.937 ^{m}	0.468 ^{cd}	1.404 ^{h}	9.13 $^{e-h}$	9.40 $^{g-k}$
G_{30}	1.023 $^{h-l}$	0.506 ^{b}	1.528 ^{ef}	4.33 ^{lm}	4.53 ^{n}
G_{31}	1.069 $^{f-h}$	0.478 ^{c}	1.546 ^{ef}	10.13 ^{ef}	10.27 $^{f-h}$
G_{32}	1.293 ^{c}	0.387 ^{fg}	1.680 ^{d}	5.13 $^{j-m}$	5.33 ^{mn}
Grand Mean±SE	1.067±0.02	0.360±0.007	1.427±0.030	11.65±0.510	12.47±0.500
CV %	3.38	3.30	3.27	9.87	9.08
Level of significance	**	**	**	**	**

** Significant at 5% and 1% level of significance respectively

DAP= Days after planting, Chl= Chlorophyll

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

2.3.1.8. *Tuber weight/plant (g)*

The genotypes varied significantly for tuber weight/plant at 70 and 90 DAP. Tuber weight/plant increased from 182.37 g to 299.93 g when tuber was harvested at 70 and 90 DAP. At 70 DAP tuber weight/plant ranged from 114.87 to 312.53 g among the genotypes. The maximum tuber weight/plant was found in G_9 (312.53 g) followed by G_{20} (267.73 g), G_{22} (261.07 g), G_{11} (258.33 g) and G_{18} (256.60 g). The genotype G_{13} had the minimum tuber weight/plant (114.87 g) which was statistically similar to G_{14} (117.93 g), G_{21} (127.93 g), G_6 (128.73 g), G_3 (130.73 g), G_{10} (132.40) and G_5 (135.87 g) **(Table 2.6)**.

In case of tuber harvested at 90 DAP tuber weight/plant among the genotypes ranged from 208.50 to 442.50 g. The maximum tuber weight/plant was observed in G_{28} (442.50 g) which was statistically similar to G_{22} (436.50 g), G_{20} (432.00 g), G_9 (426.00 g) and G_{11} (421.50 g). The lowest tuber weight/plant (208.50 g) was found in genotype G_3 which was similar to other eleven genotypes and most of them were indigenous **(Table 2.6)**.

2.3.1.9. *Single tuber weight (g)*

Single tuber weight increased with maturity and significant differences were existed among the genotypes for single tuber weight both at 70 and 90 DAP. It ranged from 4.49 to 64.65 g at 70 DAP and 7.78 to 94.89 g at 90 DAP**.** At 70 DAP the highest single tuber weight was obtained from G_{11} (64.65 g) which was followed by G_{28} (55.48 g) and G_7 (46.15 g) but statistically differ each other. The lowest single tuber weight was found in G_{13} (4.49 g) which was similar to G_5 (5.23 g), G_{21} (5.54 g), G_{10} (6.08 g) and G_{15} (6.32 g). In case of tuber harvested at 90 DAP the range of single tuber weight was 7.78 to 94.89 g and the highest single tuber weight was obtained from G_{28} (94.89 g) which was statistically similar to G_{11} (94.69 g). Tubers of G_{13} had the lowest (7.78 g) single tuber weight and which was statistically similar to G_{21} (8.61 g), G_{15} (9.06 g), G_5 (9.49 g), G_{26} (9.49 g), G_{10} (10.61 g), G_2 (11.10 g) and G_{14} (12.28 g) **(Table 2.6)**. From **Table 2.6** it was observed that single tuber weight was minimum in all the indigenous genotypes.

2.3.1.10. *Tuber yield (t/ha)*

The genotypes exhibited wide range of variation in respect of tuber yield (t/ha). Significant variation was observed for tuber yield (t/ha) both at 70 and 90 DAP and yield was increased with delay of harvesting. The variation ranged from 7.63 to 20.15 t/ha at 70 DAP and 13.63 to 28.42 t/ha at 90 DAP. The highest tuber yield at 70 DAP was obtained from G_9 (20.15 t/ha) which was followed by G_{20} (17.17 t/ha), G_{11} (16.98t/ha), G_{22} (16.73 t/ha) and G_{18} (16.42 t/ha). The lowest tuber yield was found in G_{13} (7.63t/ha) which was statistically similar to G_{14} (7.83 t/ha), G_{21} (8.51 t/ha), G_6 (8.57 t/ha), G_3 (8.70t/ha), G_{10} (8.82 t/ha) and G_5 (9.03 t/ha). In case of 90 DAP the highest tuber yield was obtained from G_{28} (28.82 t/ha) which was statistically similar to G_{22} (27.97 t/ha), G_{20} (27.63 t/ha), G_9 (27.37 t/ha) and G_{11} (27.03 t/ha). The lowest tuber yield was found in G_{14} (13.63 t/ha) which was an indigenous genotypes and statistically similar to most of the indigenous genotypes **(Table 2.6)**.

Table 2.6 Mean performances of tuber weight/plant, single tuber weight and tuber yield of thirty two potato genotypes harvested at different maturity stages

Genotypes	Tuber weight/plant (g)		Single tuber weight (g)		Tuber yield (t/ha)	
	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
G_1	141.47 $^{h-k}$	222.00 $^{j-l}$	13.78 ^{k}	19.82 ^{gh}	9.41 $^{g-k}$	14.50 $^{j-m}$
G_2	138.33 $^{h-k}$	213.00 ^{kl}	7.981 ^{mn}	11.10 $^{j-l}$	9.19 $^{h-l}$	14.10 ^{lm}
G_3	130.73 $^{i-l}$	208.50 ^{l}	11.62 ^{l}	16.14 $^{h-j}$	8.70 $^{j-m}$	13.70 ^{m}
G_4	151.73 $^{g-j}$	252.00 $^{h-j}$	8.51 ^{m}	13.69 $^{i-k}$	10.10 $^{f-j}$	16.63 $^{g-j}$
G_5	135.87 $^{h-l}$	261.75 ^{hi}	5.23 ^{op}	9.49 ^{kl}	9.03 $^{i-m}$	17.42 $^{f-h}$
G_6	128.73 $^{j-l}$	212.25 ^{kl}	13.61 ^{k}	22.10 ^{g}	8.57 $^{k-m}$	14.15 ^{lm}
G_7	230.27 ^{d}	336.00 ^{e}	46.15 ^{c}	62.40 ^{c}	14.67 ^{d}	20.53 ^{e}
G_8	158.60 ^{gh}	386.25 ^{d}	20.37 ^{i}	48.44 ^{e}	10.55 $^{f-h}$	24.55 ^{d}
G_9	312.53 ^{a}	426.00 ^{ab}	42.36 ^{d}	56.43 ^{d}	20.15 ^{a}	27.37 ^{ab}
G_{10}	132.40 $^{i-l}$	249.00 $^{h-k}$	6.08 $^{n-p}$	10.61 $^{j-l}$	8.82 $^{i-m}$	16.50 $^{h-k}$
G_{11}	258.33 ^{bc}	421.50 $^{a-c}$	64.65 ^{a}	94.69 ^{a}	16.98 ^{b}	27.03 $^{a-c}$
G_{12}	153.80 $^{g-i}$	217.50 $^{j-l}$	14.69 ^{k}	18.62 $^{g-i}$	10.23 $^{f-i}$	14.50 $^{j-m}$
G_{13}	114.87 ^{l}	216.00 $^{j-l}$	4.49 ^{p}	7.78 ^{l}	7.63 ^{m}	14.27 $^{k-m}$
G_{14}	117.93 ^{kl}	214.50 ^{kl}	6.80 $^{m-o}$	12.28 $^{j-l}$	7.83 ^{lm}	13.63 ^{m}
G_{15}	139.00 $^{h-k}$	220.50 $^{j-l}$	6.32 $^{n-p}$	9.06 ^{kl}	9.25 $^{g-l}$	14.67 $^{j-m}$
G_{16}	181.80 ^{ef}	297.00 ^{fg}	27.53 ^{fg}	41.23 ^{f}	11.45 ^{ef}	18.77 $^{e-g}$
G_{17}	220.10 ^{d}	379.50 ^{d}	22.96 ^{h}	38.64 ^{f}	14.20 ^{d}	24.23 ^{d}
G_{18}	256.60 ^{bc}	406.50 $^{b-d}$	40.93 ^{d}	62.82 ^{c}	16.42 ^{bc}	26.05 $^{b-d}$
G_{19}	196.00 ^{e}	321.00 ^{ef}	29.09 ^{f}	42.63 ^{f}	12.38 ^{e}	20.30 ^{e}
G_{20}	267.73 ^{b}	432.00 ^{ab}	35.52 ^{e}	55.10 ^{d}	17.17 ^{b}	27.63 ^{ab}
G_{21}	127.93 $^{j-l}$	219.00 $^{j-l}$	5.54 ^{op}	8.61 ^{kl}	8.51 $^{k-m}$	14.50 $^{j-m}$
G_{22}	261.07 ^{bc}	436.50 ^{ab}	36.26 ^{e}	58.62 ^{cd}	16.73 ^{b}	27.97 ^{ab}
G_{23}	196.47 ^{e}	298.50 ^{fg}	26.07 ^{g}	38.27 ^{f}	12.42 ^{e}	18.73 $^{e-g}$
G_{24}	225.33 ^{d}	327.00 ^{ef}	28.85 ^{f}	39.87 ^{f}	14.12 ^{d}	20.70 ^{e}
G_{25}	224.20 ^{d}	307.50 ^{ef}	28.78 ^{f}	36.80 ^{f}	14.27 ^{d}	19.45 ^{ef}
G_{26}	195.87 ^{e}	273.75 ^{gh}	6.93 $^{m-o}$	9.49 ^{kl}	12.37 ^{e}	17.17 $^{g-i}$
G_{27}	141.53 $^{h-k}$	229.50 $^{i-l}$	17.40 ^{j}	23.78 ^{g}	9.42 $^{g-k}$	15.02 $^{i-m}$
G_{28}	240.07 ^{cd}	442.50 ^{a}	55.48 ^{b}	94.89 ^{a}	15.33 ^{cd}	28.42 ^{a}
G_{29}	170.20 ^{fg}	392.25 ^{cd}	18.63 ^{ij}	41.81 ^{f}	10.68 ^{fg}	25.08 ^{cd}
G_{30}	194.73 ^{e}	316.50 ^{ef}	44.94 ^{c}	69.83 ^{b}	12.28 ^{e}	20.03 ^{e}
G_{31}	151.67 $^{g-j}$	244.50 $^{h-l}$	14.96 ^{k}	23.81 ^{g}	10.08 $^{f-j}$	16.23 $^{h-l}$
G_{32}	140.07 $^{h-k}$	217.50 $^{j-l}$	27.28 ^{fg}	40.85 ^{f}	9.33 $^{g-k}$	14.47 $^{j-m}$
Grand Mean±SE	182.37±6.96	299.93±10.70	23.12±0.42	35.62±1.42	11.82±0.42	19.32 ± 0.68
CV %	6.77	6.32	4.63	8.66	6.37	6.20
Level of significance	**	**	***	**	**	**

** and *** significant at 1% and 0.1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

2.3.2. **Genetic Parameters**

Different genetic parameters *viz.*, genotypic variance (δ^2g), phenotypic variance (δ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2b), genetic advance (GA) and genetic advance as percentage of mean for different agronomic characters of thirty two potato genotypes were estimated to compare the variation among the genotypes. Results obtained on different genetic parameters are presented in T**able 2.7** and described separately.

2.3.2.1. *Genotypic (δ^2g) and phenotypic (δ^2p) variances*

The estimated genotypic variance among all the studied agronomic characters of thirty two potato genotypes revealed that the highest genotypic variance (δ^2g) at 70 DAP was recorded for tuber weight/plant (2764.71) which was followed by number of leaves/plant (348.46), single tuber weight (256.56) plant height (54.81) and number of tubers/plant(51.25). The lowest genotypic variance (0.05) was estimated for total chlorophyll content in leaf **(Table 2.7)**. In case of tuber harvested at 90 DAP the highest genotypic variance (δ^2g) was also estimated for tuber weight/plant (6625.90) and it was followed by single tuber weight (594.39), number of leaves/plant (348.46), number of tubers/plant (59.31) and plant height (54.81). The lowest genotypic variance (0.05) was estimated for total chlorophyll content in leaf **(Table 2.7).**

Phenotypic variances for all the characters studied among the genotypes were also estimated and the highest value of phenotypic variance (δ^2p) at 70 DAP was recorded for tuber weight/plant (2917.30) which was followed by number of leaves/plant (360.28), single tuber weight (257.71), plant height (58.34) and number of tubers/plant (52.58). The lowest phenotypic variance (0.05) was estimated for total chlorophyll content in leaf **(Table 2.7).** The highest phenotypic variance (δ^2p) was estimated for tuber weight/plant (6984.73) when harvested at 90 DAP and it was followed by single tuber weight (603.91), number of leaves/plant (360.28), number of tubers/plant (60.59) and plant height (58.34). The lowest phenotypic variance (0.05) was estimated for total chlorophyll content in leaf **(Table 2.7).**

2.3.2.2. *Genotypic (GCV) and phenotypic (PCV) coefficients of variation*

The values of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for thirty two potato genotypes are presented in **Table 2.7**. GCV

ranged from 2.60 for days to first shoot emergence to 69.29 and 68.45 for at 70 and 90 DAP respectively. The maximum GCV was estimated for single tuber weight (69.29) followed by number of tubers/plant (61.37), number of leaves/plant (30.57), tuber weight/plant (28.83) and tuber yield (t/ha) (27.47) when tuber was harvested at 70 DAP. In case of tuber was harvested at 90 DAP the maximum GCV was also estimated for single tuber weight (68.45) which was followed by number of tubers/plant (61.75), number of leaves/plant (30.57), tuber weight/plant (27.14) and tuber yield (t/ha) (25.98). The lowest GCV was for days to first emergence (2.60) **(Table 2.7)**.

PCV ranged from 7.34 for days to first shoot emergence to 69.44 and 69.00 for single tuber weight at 70 and 90 DAP respectively. High value for PCV was also estimated for single tuber weight (69.44) followed by number of tubers/plant (62.16) number of leaves/plant (31.08), tuber weight/plant (29.62) and tuber yield (t/ha) (28.20) at 70 DAP. In case of tuber harvested at 90 DAP maximum PCV was estimated for single tuber weight (69.00) which was followed number of tubers/plant (62.42) number of leaves/plant (31.08), tuber weight/plant (27.87) and tuber yield (t/ha) (26.72). The lowest PCV both at 70 and 90 DAP was estimated for days to first shoot emergence **(Table 2.7)**.

2.3.2.3. *Broad sense heritability (h^2b)*

In the present study estimated broad sense heritability was high for all the characters except days to first shoot emergence and foliage coverage. Days to first shoot emergence (6.26%) showed low heritability and foliage coverage exhibited moderate heritability (45.37%) **(Table 2.7).** The rest of the characters like number of stems/plant (93.09%), number of leaves/plant (96.72%), plant height (93.93%), total chlorophyll content in leaf (95.59%), number of tubers/plant (97.48% at 70 DAP and 97.88% at 90 DAP), tuber weight/plant (94.77% at 70 DAP and 94.86% at 90 DAP), single tuber weight (99.56% at 70 DAP and 98.42% at 90 DAP) and tuber yield/ha (94.90% at 70 DAP and 94.61% at 90 DAP) showed above 90% heritability.

2.3.2.4. *Genetic advance (GA) and genetic advance as percentage of mean*

The highest value of genetic advance was observed for tuber weight/plant (105.45) followed by number of leaves/plant (37.82), single tuber weight (32.92), plant height

(14.78) and number of tubers/plant (14.56) at 70 DAP. At 90 DAP tuber weight/plant (163.32) showed the highest value of genetic advance followed by single tuber (49.83), number of leaves/plant (37.82), number of tubers/plant (15.70) and plant height (14.78). The lowest genetic advance was (0.31) recorded in days to first shoot emergence **(Table 2.7).** The maximum genetic gain of 142.41% (expressed as %) was observed in single tuber weight at 70 DAP and 139.90% at 90 DAP followed by number of tubers/plant (124.83% at 70 DAP and 125.86% at 90 DAP), number of leaves/plant (61.93%), tuber weight/plant (57.82% at 70 DAP and 54.45% at 90 DAP), tuber yield (t/ha) (55.13% at 70 DAP and 52.07% at 90 DAP), number of stems/plant (45.82%), plant height (39.32%) and total chlorophyll content in leaf (30.63%) **(Table 2.7)**. The lowest genetic gain was found in days to first shoot emergence (1.90%) and foliage coverage (7.65%). Characters like single tuber weight, number of tubers/plant, number of leaves/plant, tuber weight/plant, tuber yield/ha and number of stems/plant showed high heritability value as well as high value of genetic advance as percentage of mean for tuber harvesting both at 70 and 90 DAP **(Table 2.7)**.

2.3.3. **Correlation Studies Among Tuber Yield and its Components**

Relationship between tuber yield and its component characters were studied at genotypic and phenotypic levels. Correlation coefficients between tuber yield and yield attributing characters and correlation coefficients among tuber yield attributing characters of the studied potato genotypes at genotypic and phenotypic levels were presented in T**able 2.8** and T**able 2.9.**

2.3.3.1. *Genotypic correlation coefficients among tuber yield and its components*

Genotypic correlation coefficients between tuber yield and yield contributing characters and among the yield contributing characters both at 70 and 90 DAP were presented in **Table 2.8. F**oliage coverage showed highly significant positive correlation with plant height (0.470), tuber yield/ha (0.610 at 70 DAP and 0.642 at 90 DAP), single tuber weight (0.486 at 70 DAP and 0.508 at 90 DAP). Foliage coverage exhibited positive but non-significant correlation with number of stems/plant (0.188) and total chlorophyll content in leaf (0.132). Foliage coverage had highly significant negative correlation with number of tubers/plant (-0.551 at 70 DAP and -0.350 at 90 DAP). In case of number of leaves/plant significant negative correlation (-0.251) with foliage coverage was observed.

Number of stems/plant showed highly significant positive correlation with number of leaves/plant (0.637), number of tubers/plant (0.326 at 70 DAP and 0.327 at 90 DAP). Number of stems/plant had positive but non-significant correlation with plant height (0.070). Total chlorophyll content in leaf exhibited non-significant negative correlation with number of stems/plant (-0.003). Single tuber weight both at 70 DAP (-0.330) and 90 DAP (-0.354) showed highly significant negative correlation with number of stems/plant. Number of stems/plant showed non-significant negative correlation with tuber yield/ha (-0.019 and-0.106) at 70 and 90 DAP respectively.

Highly significant positive correlation was observed between number of leaves/plant and number of tubers/plant (0.442 and 0.442) both at 70 and 90 DAP respectively. Number of leaves/plant had positive significant relationship with plant height (0.246). Number of leaves/plant exhibited significantly negative correlation with total chlorophyll content in leaf (-0.302), single tuber weight (-0.412 at 70 DAP and -0.411 at 90 DAP) and tuber yield/ha (-0.282 at 70 DAP and -0.283 at 90 DAP).

Plant height showed highly significant positive correlation with tuber yield/ha (0.423 and 0.527) and single tuber weight (0.471 and 0.524) at 70 and 90 DAP respectively. Plant height exhibits positive but non-significant correlation with total chlorophyll content in leaf (0.012). Number of tubers/plant at 90 DAP had high significant negative correlation with plant height (-0.280) and significantly negative correlation (-0.258) at 70 DAP.

Total chlorophyll content in leaf significant and positively correlated only with tuber yield/ha at 70 DAP (0.230). Total chlorophyll content in leaf had positive but non-significant correlation with single tuber weight (0.194 and 0.178) at 70 and 90 DAP respectively and also with tuber yield/ha at 90 DAP (0.169). Total chlorophyll content in leaf showed non-significant negative correlation with number of tubers/plant (-0.165 and -0.156) both at 70 and 90 DAP respectively.

Number of tubers/plant showed highly significant negative correlation with single tuber weight (-0.784 and -0.786) and tuber yield/ha (-0.566 and-0.555) both at 70 and 90 DAP respectively.

Single tuber weight exhibited highly significant positive correlation with tuber yield/ha (0.829 and 0.832) both at 70 DAP respectively.

2.3.3.2. *Phenotypic correlation coefficients among tuber yield and its components*

Phenotypic correlation coefficients between tuber yield and yield contributing characters and among the yield contributing characters both at 70 and 90 DAP were presented in **Table 2.9. F**oliage coverage showed highly significant positive correlation with plant height (0.314), tuber yield/ha (0.412 at 70 DAP and 0.441 at 90 DAP) and single tuber weight (0.328 at 70 DAP and 0.347 at 90 DAP). Foliage coverage exhibited positive but non-significant correlation with number of stems/plant (0.170) and total chlorophyll content in leaf (0.065). Foliage coverage had highly significant negative correlation with number of tubers/plant (-0.350 and -0.358) at 70 and 90 DAP respectively. Number of leaves/plant showed negative non-significant correlation with foliage coverage (-0.130).

Number of stems/plant showed highly significant positive correlation with number of leaves/plant (0.635) and number of tubers/plant (0.308 and 0.309) both at 70 DAP and

at 90 DAP respectively. Number of stems/plant had positive but non-significant correlation with plant height (0.074) and total chlorophyll content in leaf (0.002). Number of stems/plant exhibited highly significant negative correlation with single tuber weight (-0.317 and -0.333) both at 70 and 90 DAP respectively. Number of stems/plant showed non-significant negative correlation with tuber yield/ha both at 70 DAP (-0.025) and 90 DAP (-0.095).

Highly significant positive correlation was observed between number of leaves/plant and number of tubers/plant (0.426 and 0.427) both at 70 and 90 DAP respectively. Number of leaves/plant had significant positive relationship with plant height (0.241). Number of leaves/plant exhibited significantly negative correlation with total chlorophyll content in leaf (-0.293), single tuber weight (-0.405 at 70 DAP and -0.399 at 90 DAP) and tuber yield/ha (-0.276 at 70 DAP and -0.276 at 90 DAP).

Plant height showed highly significant positive correlation with tuber yield/ha (0.402 and 0.496) and single tuber weight (0.459 and 0.501) at 70 and 90 DAP respectively. Total chlorophyll content in leaf was positive but non-significantly correlated with plant height (0.004). Number of tubers/plant at 90 DAP showed highly significant negative correlation with plant height (-0.274). In case of 70 DAP number of tubers/plant showed significant negative correlation with plant height (-0.254).

Total chlorophyll content in leaf positive and significantly correlated with tuber yield/ha at 70 DAP (0.236). Total chlorophyll content in leaf had positive but non-significant correlation with tuber yield/ha at 90 DAP (0.168) and single tuber weight (0.189 at 70 DAP and 0.168 at 90 DAP). Number of tubers/plant both at 70 and 90 DAP had non-significant negative correlation with total chlorophyll content in leaf (-0.152 and -0.144) respectively.

Number of tubers/plant exhibited highly significant negative correlation with single tuber weight (-0.774 and -0.778) and tuber yield/ha (-0.521 and -0.534) both at 70 and 90 DAP respectively.

Single tuber weight showed highly significant positive correlation with tuber yield/ha (0.806 and 0.819) both at 70 and 90 DAP respectively.

2.3.4. **Path Coefficient Analysis**

Association of characters determined by correlation coefficient may not provide an exact picture of the relative importance of direct and indirect influence of each of the yield components on yield. As a matter of fact, the correlation coefficient between tuber yield and other yield components were partitioned into direct and indirect effects through path coefficient analysis in order to find out more realistic picture of relationship. This allows separation of direct influence of each component on total yield of potato from the indirect influence caused by the mutual relationship among them. Path coefficient analysis was performed using the values of genotypic and phenotypic correlation and the results are presented in **Table 2.10** and **Table 2.11.**

2.3.4.1. *Path coefficient at genotypic level*

The direct and indirect effects of yield component characters towards tuber yield/ha at genotypic level were calculated and the results are presented in **Table 2.10.** From the table it was revealed that the foliage coverage employed positive direct effect (0.416, 0.496) towards tuber yield/ha at 70 and 90 DAP respectively as well as positive indirect effect via single tuber weight and total chlorophyll content in leaf. It employed negative indirect effect of number of leaves/plant, plant height and number of tubers/plant. Foliage coverage employed positive indirect effect via number of stems/plant when tubers harvested at 70 DAP but had negative indirect effect at 90 DAP.

Number of stems/plant employed positive direct effect (0.068) on tuber yield/ha at 70 DAP but played negative direct effect (-0.070) towards yield/ha at 90 DAP. Number of stems/plant also had positive indirect effect via foliage coverage, number of leaves/plant and number of tubers/plant when tuber harvest both at 70 and 90 DAP. It had negative indirect effect of plant height, total chlorophyll content in leaf and single tuber weight both at 70 and 90 DAP on tuber yield.

Number of leaves/plant employed positive direct effect (0.144, 0.182) towards tuber yield/ha at 70 and 90 DAP respectively as well as positive indirect effect via number of tubers/plant. It played negative indirect effect via foliage coverage, plant height, total chlorophyll content in leaf and single tuber weight. Number of leaves/plant had

positive indirect effect via number of stems/plant when tubers harvested at 70 DAP but had negative indirect effect when harvested at 90 DAP.

It was observed that plant height employed negative direct effect (-0.241, -0.189) towards tuber yield/ha at 70 and 90 DAP respectively. It played negative indirect effect via number of tubers/plant both at 70 and 90 DAP. It had positive indirect effect of foliage coverage, number of leaves/plant, total chlorophyll content in leaf and single tuber weight towards tuber yield/ha both at 70 and 90 DAP. Plant height had positive indirect effects via number of stems/plant when harvested at 70 DAP but negative at 90 DAP.

Total chlorophyll content in leaf employed positive direct effect (0.070, 0.041) on tuber yield/ha at 70 and 90 DAP respectively as well as positive indirect effect via foliage coverage and single tuber weight. It played negative indirect effect of number of leaves/plant, plant height and number of tubers/plant both at 70 and 90 DAP. Total chlorophyll content in leaf had negative indirect effect via number of stems/plant on tuber yield at 70 DAP but positive at 90 DAP.

Number of tubers/plant employed positive direct effect (0.419, 0.489) towards tuber yield/ha both at 70 and 90 DAP respectively as well as positive indirect effect via number of leaves/plant and plant height. It also played positive indirect effect via number of stems/plant when tuber harvested at 70 DAP but negative at 90 DAP. Number of tubers/plant both at 70 and 90 DAP had negative indirect effect via foliage coverage, total chlorophyll content in leaf and single tuber weight.

Single tuber weight employed strongly positive direct effect (0.987, 0.986) towards tuber yield/ha both at 70 and 90 DAP respectively and it also played positive indirect effect via foliage coverage and total chlorophyll content in leaf. It had negative indirect effect of number of leaves/plant, plant height and number of tubers/plant (both at 70 and 90 DAP). Single tuber weight employed negative indirect effect through number of stems/plant when tuber harvested at 70 DAP but positive at 90 DAP.

2.3.4.2. *Path coefficient at phenotypic level*

The direct and indirect effects of yield component characters towards tuber yield/ha at phenotypic level were calculated and the results are presented in **Table 2.11**. From the table it was observed that the foliage coverage employed positive direct effect (0.118, 0.134) towards tuber yield/ha both at 70 and 90 DAP respectively as well as positive indirect effect via number of stems/plant, number of leaves/plant and single tuber weight (both at 70 and 90 DAP). It employed negative indirect effect of number tubers/plant both at 70 and 90 DAP. It also played negative indirect effect through total chlorophyll content in leaf at 90 DAP but positive at 70 DAP. On the other hand foliage coverage employed negative indirect effect via plant height when tuber harvested at 70 DAP but had positive indirect effect at 90 DAP.

Number of stems/plant employed positive direct effect (0.271, 0.199) on tuber yield/ha at 70 and 90 DAP respectively as well as positive indirect effect of foliage coverage and number of tubers/plant (both at 70 and 90 DAP). It had negative indirect effect via number of leaves/plant and single tuber weight on tuber yield/ha both of 70 or 90 DAP. Number of stems/plant also had negative indirect effect via plant height when tubers harvested at 70 DAP but had positive indirect effect at 90 DAP. It had no indirect effect of total chlorophyll content in leaf.

Number of leaves/plant employed negative direct effect (-0.118, -0.130) towards tuber yield/ha both at 70 and 90 DAP respectively as well as negative indirect effect via foliage coverage and single tuber weight (both at 70 and 90 DAP). It played positive indirect effect via number of stems/plant and number of tubers/plant (both 70 and 90 DAP). Number of leaves/plant had positive indirect effect via plant height and total chlorophyll content on tuber yield/ha when harvested at 90 DAP while slightly negative indirect effect at 70DAP.

It was observed that plant height employed negative direct effect (-0.027) towards tuber yield/ha at 70 DAP but played positive direct effect (0.057) at 90 DAP. It employed positive indirect effect via foliage coverage, number of stems/plant and single tuber weight both 70 and 90 DAP. It employed negative indirect effect of number of leaves/plant and number of tubers/plant when tubers harvested at 70 DAP

or 90 DAP. Plant height exhibited slight or no indirect effect via total chlorophyll content in leaf.

Total chlorophyll content in leaf employed positive direct effect (0.042) on tuber yield/ha when tuber harvested at 70 DAP. But this direct effect was little bit reduced by the negative indirect effect via plant height and number of tubers/plant. It showed low positive indirect effect through foliage coverage, number of leaves/plant and single tuber weight. Total chlorophyll content in leaf employed lower negative direct effect (-0.002) on tuber yield when harvested at 90 DAP. This negative direct effect was slightly reduced by positive indirect effect via foliage coverage, number of leaves/plant and single tuber weight. It also showed negative indirect effect through number of tubers/plant. Total chlorophyll content in leaf showed negligible indirect effect through plant height and had no indirect effect via number of stems/plant both at 70 or 90 DAP harvesting situation.

Number of tubers/plant employed positive direct effect (0.285, 0.289) towards tuber yield/ha both at 70 and 90 DAP respectively as well as positive indirect effect via number of stems/plant. Number of tubers/plant played negative indirect effect through foliage coverage, number of leaves/plant and single tuber weight both at 70 and 90 DAP. It also played positive and negative indirect effect via plant height when tuber harvested at 70 and 90 DAP respectively. It employed minimum indirect effect via total chlorophyll content in leaf.

Single tuber weight employed strongly positive direct effect (0.986, 0.984) towards tuber yield/ha both at 70 and 90 DAP respectively. But this direct effect little bit reduced by the negative indirect effect via number of stems/plant, plant height and number of tubers/plant when harvested at 70 DAP and number of stems/plant and number of tubers/plant at 90 DAP. It also played positive indirect effect via foliage coverage and number of leaves/plant both at 70 and 90 DAP. Single tuber weight also showed indirect positive effect through plant height when tuber harvested at 90 DAP. It employed little or no indirect effect via total chlorophyll content in leaf.

Table 2.7 Variability and genetic parameters for different yield parameters of thirty two potato genotypes harvested at different maturity stages

Characters	Range	Mean ± SE	Variance		GCV	PCV	h^2b (%)	GA	GA (%) of mean
			δ^2g	δ^2p					
Days to first shoot emergence	15.33-18.00	16.39±0.61	0.18	1.45	2.60	7.34	12.58	0.31	1.90
Foliage coverage (%)	76.00-98.33	86.52±3.05	22.75	50.14	5.51	8.18	45.37	6.62	7.65
Number of stems/plant	1.93-5.33	3.56±0.12	0.67	0.72	23.05	23.89	93.09	1.63	45.82
Number of leaves/plant	28.27-98.73	61.07±1.76	348.46	360.28	30.57	31.08	96.72	37.82	61.93
Plant height (cm)	23.73-54.33	37.59±0.98	54.81	58.34	19.69	20.32	93.94	14.78	39.32
Total chlorophyll content (mg/g)	0.959-1.992	1.43±0.03	0.05	0.05	15.21	15.56	95.59	0.44	30.63
Number of tubers/plant at 70 DAP	4.00-28.27	11.66±0.51	51.25	52.58	61.37	62.16	97.48	14.56	124.83
Number of tubers/plant at 90 DAP	4.47-29.13	12.47±0.50	59.31	60.59	61.75	62.42	97.88	15.70	125.86
Tuber weight/plant at 70 DAP (g)	114.87-312.53	182.37±6.96	2764.71	2917.30	28.83	29.62	94.77	105.45	57.82
Tuber weight/plant at 90 DAP (g)	208.50-442.50	299.93±10.70	6625.90	6984.73	27.14	27.87	94.86	163.32	54.45
Single tuber weight at 70 DAP (g)	4.49-64.65	23.12±0.42	256.56	257.71	69.29	69.44	99.56	32.92	142.42
Single tuber weight at 90 DAP (g)	7.78-94.89	35.62±1.41	594.39	603.90	68.45	69.00	98.42	49.83	139.90
Tuber yield at 70 DAP (t/ha)	7.63-20.15	11.82±0.43	10.55	11.11	27.47	28.20	94.90	6.52	55.13
Tuber yield at 90 DAP (t/ha)	13.63-28.42	19.32±0.68	25.21	26.64	25.98	26.71	94.62	10.06	52.07

DAP=Days after planting, SE=Standard error, δ^2g =Genotypic variance, δ^2p =Phenotypic variance, GCV=Genotypic coefficient of variation, PCV=Phenotypic coefficient of variation, h^2b=Heritability in broad sense and GA=Genetic advance

Table 2.8 Genotypic correlation coefficients among tuber yield and its components of thirty two potato genotypes harvested at different maturity stages

Characters	No. of stems/plant	No. of leaves/plant	Plant height (cm)	Total chlorophyll (mg/g)	No. of tubers/plant		Single tuber weight (g)		Tuber yield (t/ha)	
					70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
Foliage coverage (%)	0.188	-0.251*	0.470**	0.132	-0.551**	-0.560**	0.486**	0.508**	0.610**	0.642**
No. of stems/plant		0.637**	0.070	-0.003	0.326**	0.327**	-0.330**	-0.354**	-0.019	-0.106
No. of leaves/plant			0.246*	-0.302**	0.442**	0.442**	-0.412**	-0.411**	-0.282**	-0.283**
Plant height (cm)				0.012	-0.258*	-0.280**	0.471**	0.524**	0.423**	0.527**
Total chlorophyll (mg/g)					-0.165	-0.156	0.194	0.178	0.230*	0.169
No. of tubers/plant							-0.784**	-0.786**	-0.566**	-0.555**
Single tuber weight (g)									0.829**	0.832**

* and ** indicate significant at 5% and 1% level of significance respectively
DAP=Days after planting

Table 2.9 Phenotypic correlation coefficients among tuber yield and its components of thirty two potato genotypes harvested at different maturity stages

Characters	No. of stems/plant	No. of leaves/plant	Plant height (cm)	Total chlorophyll (mg/g)	No. of tubers/plant		Single tuber weight (g)		Tuber yield (t/ha)	
					70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
Foliage coverage (%)	0.170	-0.130	0.314**	0.065	-0.350**	-0.358**	0.328**	0.347**	0.412**	0.441**
No. of stems/plant		0.635**	0.074	0.002	0.308**	0.309**	-0.317**	-0.333**	-0.025	-0.095
No. of leaves/plant			0.241*	-0.293**	0.426**	0.427**	-0.405**	-0.399**	-0.276**	-0.276**
Plant height (cm)				0.004	-0.254*	-0.274**	0.459**	0.501**	0.402**	0.496**
Total chlorophyll (mg/g)					-0.152	-0.144	0.189	0.168	0.236*	0.168
No. of tubers/plant							-0.774**	-0.778**	-0.521**	-0.534**
Single tuber weight (g)									0.806**	0.819**

* and ** indicate significant at 5% and 1% level of significance respectively
DAP=Days after planting

Table 2.10 Path coefficient analysis showing genotypic direct (bold) and indirect effects of different yield components towards tuber yield of thirty two potato genotypes harvested at different maturity stages

Characters	DAP	Foliage coverage (%)	Stems/plant	Leaves/plant	Plant height (cm)	Total chlorophyll (mg/g)	No. of tubers/plant	Single tuber weight (g)	r_g with yield
Foliage coverage (%)	70	**0.416**	0.013	-0.036	-0.113	0.009	-0.231	0.553	0.610**
	90	**0.496**	-0.013	-0.046	-0.089	0.005	-0.274	0.562	0.642**
Stems/plant	70	0.078	**0.068**	0.092	-0.017	-0.0002	0.136	-0.375	-0.019
	90	0.093	**-0.070**	0.116	-0.013	-0.0001	0.160	-0.392	-0.106
Leaves/plant	70	-0.104	0.043	**0.144**	-0.059	-0.021	0.185	-0.469	-0.282**
	90	-0.124	-0.044	**0.182**	-0.046	-0.012	0.216	-0.454	-0.283**
Plant height (cm)	70	0.195	0.005	0.035	**-0.241**	0.001	-0.108	0.536	0.423**
	90	0.233	-0.005	0.045	**-0.189**	0.001	-0.137	0.579	0.527**
Total chlorophyll (mg/g)	70	0.055	-0.0002	-0.043	-0.003	**0.070**	-0.069	0.221	0.230*
	90	0.065	0.0002	-0.055	-0.002	**0.041**	-0.076	0.197	0.169
No. of tubers/plant	70	-0.229	0.022	0.063	0.062	-0.012	**0.419**	-0.892	-0.566**
	90	-0.278	-0.023	0.081	0.053	-0.006	**0.489**	-0.870	-0.555**
Single tuber weight (g)	70	0.202	-0.022	-0.059	-0.114	0.014	-0.328	**0.987**	0.829**
	90	0.252	0.025	-0.075	-0.099	0.007	-0.384	**0.986**	0.832**

* and ** indicate significant at 5% and 1% level of significance respectively
Residual effect at 70 DAP is **0.168** and at 90 DAP is **0.169**
DAP=Day after planting

Table 2.11 Path coefficient analysis showing phenotypic direct (bold) and indirect effects of different yield components towards tuber yield of thirty two potato genotypes harvested at different maturity stages

Characters	DAP	Foliage coverage (%)	Stems/plant	Leaves/plant	Plant height (cm)	Total chlorophyll (mg/g)	No. of tubers/plant	Single tuber weight (g)	r_p with yield
Foliage coverage (%)	70	**0.118**	0.046	0.015	-0.009	0.003	-0.100	0.338	0.412**
	90	**0.134**	0.034	0.017	0.018	-0.0001	-0.103	0.342	0.441**
Stems/plant	70	0.020	**0.271**	-0.075	-0.002	0.000	0.088	-0.327	-0.025
	90	0.023	**0.199**	-0.082	0.004	-0.000	0.089	-0.328	-0.095
Leaves/plant	70	-0.015	0.172	**-0.118**	-0.007	-0.012	0.121	-0.417	-0.276**
	90	-0.017	0.126	**-0.130**	0.014	0.001	0.123	-0.393	-0.276**
Plant height (cm)	70	0.037	0.020	-0.028	**-0.027**	0.0001	-0.072	0.473	0.402**
	90	0.042	0.015	-0.031	**0.057**	-0.0001	-0.079	0.493	0.496**
Total chlorophyll (mg/g)	70	0.008	0.000	0.035	-0.0001	**0.042**	-0.043	0.195	0.236*
	90	0.009	0.000	0.038	0.0002	**-0.002**	-0.042	0.165	0.168
No. of tubers/plant	70	-0.041	0.083	-0.050	0.007	-0.006	**0.285**	-0.798	-0.521**
	90	-0.048	0.062	-0.055	-0.016	0.001	**0.289**	-0.765	-0.534**
Single tuber weight (g)	70	0.039	-0.086	0.048	-0.012	0.008	-0.220	**0.986**	0.806**
	90	0.047	-0.066	0.052	0.028	-0.001	-0.225	**0.984**	0.819**

* and ** indicate significant at 5% and 1% level of significance respectively
Residual effect for 70 DAP is **0.24348** & 90 DAP is **0.24496**
DAP=Day after planting

2.4. DISCUSSION

The present study had emphasized the determination of the nature and magnitude of variability, heritability and genetic advance on different traits concerned with yield and effect of date of harvesting on yield and related traits of 32 potato genotypes. Data on different yield contributing characters *viz*., days to first shoot emergence, foliage coverage at 40 and 60 DAP, number of stems/plant at 40 and 60 DAP, number of leaves/plant at 40 and 60 DAP, plant height (cm) at 40 and 60 DAP, chlorophyll content in leaf (mg/g), number of tubers/plant, tuber weight/plant (g) and tuber yield (t/ha) harvested at 70 and 90 DAP were collected. The results obtained from different statistical analyses are discussed with an endeavor to justify them.

The means for all the genotypes for different characters were calculated and the difference between any pair of means was performed by Duncan's Multiple Range Test (DMRT).

Days to first shoot emergence did not vary significantly among the genotypes. Emergence of potato seedling depends on both biological properties of seed tuber as well as environmental condition especially on soil temperature (Kuil, 2002; Christiansen *et al.*, 2006). Among the biological properties, dormancy and physiological age of seed tuber dominate in seedling emergence. Physiological aged seed tuber can produce sprout earlier to quick emergence while younger seed tuber needs more time to sprouting and hence slow down seedling emergence. Bashir (2012) conducted an experiment and reported non-significant result for days to first emergence and it varied from 16 to 21 days which is in agreement with the present study. Khayatnezhad *et al*. (2011) obtained the range 18-31 for days to emergence. The result was contradictory with present finding may be due to plant the sprouted seed tuber of all the genotypes in the present experiment.

Vegetative growth is an important factor that determines the ultimate plant production. Good foliage of a plant indicates its good growth which contributes to high yield through photosynthesis. Significant variation was observed for foliage coverage among the genotypes both the stages of growth (40 and 60 DAP). The highest foliage coverage was measured in G_{17} and G_{22} at 40 and 60 DAP respectively. Sattar (2006) evaluated 28 potato genotypes and obtained foliage coverage 30.00 to

86.7% at 40 DAP while Rahman and Hossain (1982) reported 50.13% to 65.28% foliage coverage at 40 DAP. These results are in agreement with present finding. Foliage coverage increased from 53.25% at 40 DAP to 86.52%% at 60 DAP. Vegetative growth in potato slows down after reproductive structures (tubers and flowers) are initiated (Malik, 1995). Rahman and Hossain (1982) recorded maximum 93.7% foliage coverage in 23 exotic potato varieties, while it was 98.3% in Patrones. Sattar (2006) reported 50 to 98.30% of foliage coverage at 60 DAP. The range of foliage coverage obtained in the present investigation was almost similar to the results of Rahman and Hossain (1982) and Sattar (2006).

The number of leaves/plant differed significantly among the thirty two potato genotypes both the stages of growth (40 and 60 DAP). The highest number of leaves/plant was recorded in G_{25} at 40 DAP and G_{10} at 60 DAP and lowest in G_{19} at 40 DAP while G_{20} at 60 DAP. Hossain (1997) recorded 19 to 22 leaves/plant in potato (single stem plant), while Hossain and Rashid (1991) conducted an experiment on development of potato plant and recorded 46.85 to 106.38 leaves/plant. According to Seema (2011) potato plant produced 3.87 to 74.00 leaves/hill. The number of leaves/plant in the present study is in agreement with the findings of Hossain and Rashid (1991) and Seema (2011).

Significant variation was observed among the genotypes in case of number of stems/plant both at 40 and 60 DAP. G_{10} showed the maximum number of stems/plant both at 40 and 60 DAP and G_{11} produced the minimum number of stems/plant for both the stages of growth. The number of stems/plant was influenced by genetic composition, size of tubers as well as environmental factors (Pushkarnath, 1969; Sharma *et al.,* 1990). According to Beukema and Zaag (1990), 18 to 20 main stems/sq. meter is optimum for obtaining maximum yield of potato. In the present investigation, the number of stems/plant ranged from 1.93 to 5.33, which was equivalent to 13 to 35 stems/sq. meter. Hossain and Rashid (1991) recorded 1.7 to 4.1 stems/plant in an evaluation with 26 high yielding potato varieties which supported the present findings. Comparable results on variability in number of shoots/plant were also reported by Nandekar and Sharma (1998), Sandhu and Kang (1998) and Mishra (2002).

Plant height is a good indicator of plant vigor and genetic potentiality of the genotype, which may contribute towards higher productivity. Significant variation in plant height both at 40 and 60 DAP was observed among the genotypes. The tallest plant was G_7 and G_4 and shortest plant was G_{26} and G_1 at 40 and 60 DAP respectively. Hossain *et al.* (1984) evaluated a large number of Dutch potato varieties and obtained a plant height which ranged from 39.5 to 59.6 cm, while Rahman and Hossain (1982) obtained plant height ranging from 23.5 to 58.3 cm for Dutch potato varieties in Bangladesh. These values support the results of the present investigation. The differences among the genotypes for plant height had also been reported by Rajani (2015), Khan *et al*. (2013), Khayatnezhad *et al.* (2011), Mondal *et al.* (2007), Kumar (2003), Mishra (2002), Nandekar and Sharma (1998) and Sandhu and Kang, (1998) in potato.

$Chlorophyll_a$, $chlorophyll_b$ and total chlorophyll content in leaf varied significantly among the thirty two potato genotypes. Güler (2009) observed that leaf chlorophyll content was significantly influenced by potato cultivar. There were significant correlations between chlorophyll and yield and yield related characters.

The number of tubers/plant is a varietal character which is largely governed by environmental factors. Significant difference was observed among the potato genotypes in respect of number of tubers/plant harvested both at 70 and 90 DAP. G_{26} produced the highest number of tuber and G_{11} the lowest number of tubers/plant both at 70 and 90 DAP. Number of tubers/plant increased slightly at 90 DAP compared to 70 DAP. This result is in agreement with the results of Sogut and Ozturk (2011) who also reported an increase in number of tubers/plant from 3.8 to 6.3 and 4.2 to 6.4. Khayatnezhad *et al*. (2011) obtained 5.4- to 38.2 tubers/plant in their experiment. In an experiment Salam (2011) found a range of 7.33 to 37.33 tubers/plant. Chaudhary and Sharma (1984) also reported a range of 3.4 to 25.7 for number tubers/plant. The present findings are in agreement of with these results. This result is partially similar with another report Anonymous (1987a), Bhuiya *et al.* (1984) and Khan (1995).

The genotypes varied significantly for tuber weight/plant both at 70 and 90 DAP harvest. Tuber weight/plant is purely a varietal character which is largely governed by interaction of nutrient supplied and environment. Highest tuber weight/plant was

recorded in G_9 and G_{28} and lowest in G_{13} and G_3 at 70 and 90 DAP respectively. Sikka and Hossain (1982) evaluated 52 CIP cultivars at the Potato Research Centre and obtained a yield range of 362 to 558 g/plant while they (1984) evaluated 20 genotypes and obtained a yield range of 333 to 400 g/plant. Sattar (2006) evaluated 28 potato germplasm and found yield range 132.00 to 481.70 g/plant. At 90 DAP tuber weight/plant in present investigation ranged from 208.50 to 442.50 g. The lower value of tuber weight/plant in the present investigation compared to Sikha and Hossain (1982 and 1984) was might be due to the presence of some indigenous genotypes. Though there was some lower value of the present investigation it was in agreement to the results reported by Sikka and Hossain (1982 and 1984).

Significant differences existed among the genotypes for single tuber weight or average weight of a tuber both at 70 and 90 DAP harvesting situations and it increased with maturity. At 70 DAP the highest single tuber weight was obtained from G_{11} which was followed by G_{28} and G_7 and lowest single tuber weight was found in G_{13} which was similar to G_5, G_{21}, G_{10} and G_{15}. In case of tuber harvested at 90 DAP the highest single tuber weight was obtained from G_{28} which was statistically similar to G_{11}. Tubers of G_{13} had the lowest single tuber weight and which was statistically similar to G_{21}, G_{15}, G_5, G_{26}, G_{10}, G_2 and G_{14}. Uniformity in tubers of potato is a varietal character. Most of the varieties cultivated in Bangladesh produced 60 to 70% uniform sized tubers while only Granola had >80% uniform sized tubers. In an experiment Chaudhary and Sharma (1984) found 11.2 to 98.2 g for average weight a tuber which is in agreement with the present findings. The average weight of a tuber in the present study is also in agreement with the findings of Salam (2011) and also reported Anonymous. (1999).

Significant variation was observed for tuber yield (t/ha) both at 70 and 90 DAP and yield was increase with delay harvesting. The highest tuber yield (t/ha) at 70 DAP was obtained from G_9 and lowest from G_{13}. In case of tuber harvested at 90 DAP G_{28} produced the highest tuber yield (t/ha) and G_{14} the lowest. Different cultivars as well as harvesting time significantly affected the tuber yield and yield increased with maturity (Solaiman *et al.*, 2015). Wider range of variation in yield among the potato genotypes was observed by Das *et at.* (2014). Sogut and Ozturk (2011) reported that

tuber yield was increased from 8.90 to 17.20 t/ha and 9.20 to 18.80 t/ha in two locations when harvesting was delayed from 75 to 120 DAP. Randhawa and Kooner (1994) observed significantly higher yield when harvested late. Panigrahi *et al.* (2017) also reported that yield was increased when harvesting was delay from 75 to 90 days after plantation. Tuber yield increased with the progress of growth and maturing of tuber. This may be explained with a progressive increase of day-length and sunlight intensity and starch accumulation during crop cycle (Ierna, 2009). Cultivars, planting time and locations had significant effects on yield and quality of potato tuber. Sikka and Hossain (1982) evaluated 52 CIP cultivars and they obtained tuber yield ranged from 20.11 to 30.99 t/ha. Sikka and Hossain (1984) also evaluated 20 CIP cultivars at the experimental plot of TCRC and obtained 17.30 to 36.40 tons tuber yield/ha. Salam (2011) conducted an experiment with 24 potato genotypes in Sher-e-Bangla Agricultural University, Dhaka and obtained 13.00 to 30.30 tons tuber yield/ha. In the present investigation tuber yield at 90 DAP ranged from 13.63 to 28.42 t/ha, which is more or less similar with these findings.

Genetic variability is a prerequisite for a successful breeding programme of any crop species and a critical survey of genetic variability is essential before initiating an improvement programme. Studies on the variability, heritability, phenotypic and genotypic coefficient of variation would help in identification of effective yield relating characters for the improvement of crops. Identification of genotypes with high variability and heritability for desirable characters are pre-requisite in the development of new varieties with increased yield potential. Information on the nature and magnitude of variation in the populations, the extent of environmental influence on the expression of characters is necessary for fruitful gain in breeding programme. The genetic parameters also help in the prediction of possible genetic advance through selection based on phenotypic value. However, reports on the inheritance of qualitative and quantitative characters of potato (*Solanum tuberosum* L.) are limited. Different genetic parameters *viz.,* genotypic variance (δ^2g), phenotypic variance (δ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2b), genetic advance (GA), genetic advance as percentage of mean for different agronomical characters of thirty two potato genotypes were estimated to compare the variation among the genotypes. In the present study estimated genetic

parameters revealed that the genotypic variance followed the same trend of phenotypic variance for all the characters studied, indicating that phenotypic variability may be considered as a reliable measure of genetic variability. The differences between genotypic variance (δ^2p) and phenotypic variance (δ^2g) were low in most of the characters indicating less environmental influence on these characters. Mondal (2003) reported that genotypic variance ranged from 0.65 to 5111.23 and phenotypic variance from 1.36 to 5188.20 for number of stems/plant and tuber weight/plant respectively.

The value of genotypic coefficient of variation (GCV) was lower than corresponding value of phenotypic coefficient of variation (PCV) for most the studied characters indicating the influence of environment in the expression of these characters. It was revealed that the observed variation for the trait were due to genetic and environmental factors. High genotypic coefficient of variation (GCV) as well as phenotypic coefficient of variation (PCV) percentage was observed for most of the characters studied. These results suggest that the greater variability for these characters among the studied genotypes were due to genetic causes which are less affected by the environment and hence could be improved through selection. High phenotypic variation composed of high genotypic variations and on contrary less environmental variation indicates the presence of high genetic variability for different traits and less influence of environment. In the present investigation the difference between GCV and PCV were lowest in the characters single tuber weight and chlorophyll content indicating less environmental influence on these characters. On the other hand highest difference between PCV and GCV was observed in days to first shoot emergence. Highest magnitude of difference between PCV and GCV implied environment effect predominantly acting upon the expression of phenotypic behaviour of the character. The characters having high GCV indicate high potential for effective selection (Burton, 1957). According to Sattar *et al.* (2007) high GCV and PCV were estimated for tuber weight/plant, number of tubers/plant, plant vigor and days to maturity trait had low GCV. Barik *et al.* (2009) evaluated forty four genotypes and observed that marketable yield, total tuber yield and number of tubers/plant showed higher genotypic and phenotypic coefficient of variation, whereas the moderate magnitude of variation was observed for percentage of emergence, fresh

weight of shoots/plant and plant height. Rahman (2015) conducted an experiment at Sher-e-Bangla Agricultural University with 21 potato genotypes and reported high GCV and PCV for number of tubers/plant, number of leaves/plant, average weight/tuber, weight of tubers/plant and lowest for chlorophyll content in leaf. Mishra *et al.* (2006) reported high GCV and PCV for plant height and tuber yield/plant. Similar result was also reported by Biswas *et al*. (2005). Regassa and Basavaraja (2005a) recorded a higher PCV and GCV for number of tubers/plant, total tuber yield, number of small size tubers/plant and number of large size tubers/plant. Fekadu *et al.* (2013) reported that number of stems/plant, number of tubers/plant and total tuber yield showed high GCV and PCV on potato germplasm. High GCV and PCV percentage for tuber numbers/plant, average tuber weight and tuber weight/plant was also observed by Luthra *et al.* (2005), Mondal (2003), Chaudhary (1985), Chaudhary and Sharma (1984), Garg and Bhutani (1991), Pandita *et al.* (1981), Sidhu and Pandita (1979) and Desai and Jaimini (1997a).

The genotypic coefficient of variation alone is not sufficient to assess the heritable variation hence estimation of heritability becomes necessary. For more reliable conclusion, estimation of heritability and genetic gain should be considered together (Johnson *et al.* 1955). Heritability estimates are useful in selection on the basis of phenotypic performance of the quantitative characters. The characters with high heritability value could be improved straight way through selection since they are less affected by the environment. The degree of success of a selection programme also depends upon the magnitude of heritable variation. According to Robinson *et al.* (1949) heritability between 0-30% categorized as low, 30-60% as moderate and 60% or above as high heritability traits. The characters having lowest heritability was the least suggesting for selection because this trait was greatly influenced by environment. Panchal *et al.* (1979) stated that the low heritability largely might be due to environment, which could reduce the degree of correspondence below phenotypic and breeding values. In the present research most of the characters except days to first shoot emergence and foliage coverage showed heritability above 90 percentage suggesting that greater effectiveness of selection and improvement to be expected from these characters in future breeding programme. Sattar *et al.* (2007) reported high heritability for tuber yield/plant, number of tubers/plant and plant height.

Barik *et al* (2009) reported high heritability for fresh weight of shoots/plant, percentage of emergence, fresh weight of tubers/plant, total tuber yield/plot and plant height. Ahmad *et al.* (2005) also observed high heritability for plant height, tubers/plant and tuber weight/plant. Similarly Regassa and Basavaraja (2005a) reported moderate to high heritability for plant height and total yield of tuber for 100 genotypes. The present findings are also in agreement with the earlier findings of Chaudhary and Sharma (1984), Dayal *et al.* (1972), Metin (1985), Pandita *et al.* (1981) and Desai and Jaimini (1997a). They have also observed high heritability for tuber yield, average tuber weight, tuber numbers/plant and plant height.

Though the estimation of GCV percentage and heritability are useful to plant breeder as they provide basis of selection, more reliable conclusion can be made when heritability is considered in conjunction with genetic advance and genetic advance as percentage of mean. Johnson *et al.* (1955) suggested that heritability and genetic advance when calculated together were more useful for predicting the resultant effect of selection the best individual than heritability and genetic advance calculated alone. High heritability value along with high value of genetic advance as percentage of mean is most effective condition for selection (Gandhi *et al.,* 1964). Panse (1957) suggested that effective selection may be done for the characters having high heritability accompanied by high genetic advance which is due to the additive gene effect. He also reported that low heritability accompanied with low genetic advance is due to non-additive gene effects for the particular character and would offer less scope for selection, because that was under the influence of environment. It was suggested that selection of these characters could be more straightforward and effective (Masud *et al.* 1998). Therefore, in the present study number of leaves/plant, number of tubers/plant, tuber weight/plant, single tuber weight and tuber yield/ha would be more fruitful to consider in selection for further improvement both at 70 and 90 DAP harvesting since these characters showed high heritability along with high genetic advance as percentage of mean. The estimated heritability was also more than 90% for number of stems/plant, plant height and total chlorophyll content. But the genetic advance as percentage of mean was not equally high as compared to heritability for these three characters. So, all the characters with high heritability are not equally effective for selection. On the other hand characters had low genetic

advance values coupled with low heritability considered less effective for selection. Bhagyalakshimi *et al.* (1990) found genetic advance in chili was more than 100% (i.e. 142.99) which is in agreement with the present findings. Desai and Jaimini (1997a) reported high heritability along with high genetic advance as percentage of mean for tuber yield, number of stems/plant, number of leaves/plant, number of tubers/plant and average weight/tuber which is in agreement with the result of the present study. High heritability coupled with high genetic advance was recorded for the traits *viz.*, dry weight of tubers and total tuber yield/plot (Barik *et al.*, 2009). Sattar *et al.* (2007), Pandita *et al.* (1981) and Chaudhary and Sharma (1984) reported high genetic advance as well as high heritability in number of tubers/plant, tuber yield/plant and number of stems/plant which is in agreement with the result of the present study. The findings reported by Chaudhary (1985), Sidhu and Pandita (1979) and Metin (1985) were also in agreement with the present results.

Thus the results of the present study indicated that number of leaves/plant, number of tubers/plant, tuber weight/plant, single tuber weight and tuber yield/ha exhibited high GCV %, high heritability as well as high GA (% of mean). Alternate systems like random mating, intermating, biparental mating, crossing of selected sibs in early generation and dialel selective mating system may therefore, be advocated to improve the tuber yield by effective selection.

As yield together with good quality is the main object of a breeder, so it is important to know the relationship among various characters that have effect on yield. Yield is a complex character associated with many interrelated components (Murat & Vahdettin, 2004). Previous reports by Birhman and Kang (1993), Amadi (2005) and Amadi and Ene-Obong (2007) showed that simple correlation coefficients were useful to study the interrelationships between tuber yield and other characters. In the present investigation the results of correlation coefficient between tuber yield/ha and its component characters and among the various components themselves revealed that in most of the cases, the values of genotypic correlation coefficient (r_g) were higher than the corresponding phenotypic correlation coefficient (r_p) indicating less pronounced environmental effect. Higher genotypic correlations than phenotypic ones might be due to modifying or masking effect of environment in the expression of these characters

under study as explained by Nandpuri *et al*. (1973). Johnson *et al.* (1955) also reported that higher genotypic correlation than phenotypic correlation indicated an inherent association between various characters. Higher and wider genotypic correlation than phenotypic correlations have been reported by Sattar *et al.* (2007) in potato, Sarkar *et al.* (1999) in pointed gourd and Sharma and Swarup (1964) in cabbage. Tyagi (1987) and Dhanda *et al.* (1984) also reported higher magnitude of genotypic correlation coefficient over phenotypic ones between yield and yield contributing characters.

Among different characters studied, tuber yield/ha both at 70 and 90 DAP was found to be positively and significantly associated with foliage coverage, plant height and single tuber weight at genotypic and phenotypic levels. Total chlorophyll content in leaf was also found to be positively and significantly associated with tuber yield/ha at 70 DAP but non-significant positive association was observed with tuber yield/ha at 90 DAP. As tuber yield/ha is the ultimate goal, the positive association of these characters will help breeder for selecting best genotypes. Significant and positive correlation of number of tubers/plants with number of shoots/plant were recorded by Lemaga and Caesar (1990), while Sharma (1990) observed that weight of tuber was positively correlated with plant height which is in agreement with the present findings. The results of present findings are also in agreement with the findings of Luthra (2001) who reported weight of tubers was significant and negatively correlated with number of tubers/plant but significantly and positively correlated with plant height. Similar results have also been reported by Sattar *et al.* (2007), Mondal (2003), Desai and Jaimini (1998), Garg and Bhutani (1991) and Patel *et al.* (1973). Significant positive relationship of tuber yield/ha with the characters both at genotypic and phenotypic levels indicated that increase in positively associated characters contributes to increase tuber yield/ha. Abraham *et al.* (2014) reported that the positive and significant correlation existed between tuber yield and biological yield, tuber yield and plant height, stems/plant and tubers/plant which are in agreement with present findings. Güler (2009) observed significant correlation between total tuber yield and leaf chlorophyll content. Gusain (2010) calculated correlation studies in 168 genotypes and 4 checks. The results indicated that tuber yield was positive and significantly correlated with tuber weight/plant, plant height and tuber size. Weight of tubers was significant and negatively correlated with number of tubers/plant but

significantly and positively correlated with plant height (Luthra, 2001). Regassa and Basavaraja (2005b) noticed that tuber yield was highly and positively correlated both at phenotypic and genotypic levels with plant height, weight of medium size tubers, weight of large size tubers, total tuber weight and total number of tubers/plant. Fekadu *et al.* (2013), Khayatnezhad *et al.* (2011), Galarreta *et al.* (2006), Roy and Singh (2006b) and Yildirim *et al.* (1997) also reported that there was a significant positive correlation between tuber yield and tuber weight/plant as well as plant height and single tuber weight. Therefore, improvement of tuber yield in potato is possible by using appropriate breeding strategy through selection for those positively correlated traits.

Significant negative association was observed between tuber yield/ha both at 70 and 90 DAP with number of tubers/plant (at 70 and 90 DAP) and number of leaves/plant; single tuber weight (at 70 and 90 DAP) with number of tubers/plant (at 70 and 90 DAP), number of leaves/plant and number of stems/plant; number of tubers/plant (at 70 and 90 DAP) with foliage coverage and plant height; number of leaves/plant with total chlorophyll content in leaf and number of leaves/plant with foliage coverage both at genotypic and phenotypic level. This particularly indicates the increase in one of the characters may lead to decrease in the other. The findings were in agreement with the previous findings of Nasiruddin *et al.* (2014), Rahman (2015), Patel *et al*. (2003), Pandita and Sidhu (1980), Verma *et al.* (1975) and Patel *et al.* (1973).

Association of characters determined by correlation coefficient may not provide an exact picture of the relative importance of direct and indirect influence of each of the yield components on yield. As a matter of fact, the correlation coefficient between tuber yield/ha and other yield components were partitioned into direct and indirect effects through path coefficient analysis in order to find out more realistic picture of relationship. This allows separation of direct influence of each component on total yield of potato from the indirect influence caused by the mutual relationship among them.

In the present study path coefficient analysis at genotypic level based on tuber yield as a dependent variable showed the highest positive direct effect for single tuber weight both at 70 and 90 DAP and followed by number of tubers/plant (both at 70 and 90 DAP) and foliage coverage. The lowest positive direct effect was found for number of

stems/plant when tuber harvested at 70 DAP and total chlorophyll content in leaf at 90 DAP. Single tuber weight had the highest significant positive genotypic correlation with yield, which was obtained merely because of a considerably high direct effect of single tuber weight on yield. Plant height had highest direct negative effect towards tuber yield/ha both at 70 and 90 DAP. Similar findings were obtained by Sattar *et al.* (2007) and reported that number of tubers/plant, average weight of tuber, number of leaves/plant had high positive direct effect on tuber yield. Ozkaynak *et al*. (2003) reported that tuber number and average tuber weight were the most important components for tuber yield in potato. The current findings are in congruence with the reports of Rasool *et al.* (2006) and Amadi *et al.* (2008). Saha *et al*. (1992) and Kalloo and Sidhu (1982) obtained similar results in pumpkin and musk melon respectively. Gopalakrishnan *et al.* (1980) also noticed high positive direct effect of fruit weight on yield in pumpkin. It appeared that fruits/plant and fruit weight were major component traits for fruit yield in pumpkin.

Foliage coverage had positive direct effect on tuber yield/ha both at 70 and 90 DAP as well as significant positive genotypic correlation with tuber yield at 70 and 90 DAP. Total chlorophyll content in leaf also had positive direct effect on tuber yield/ha both at 70 and 90 DAP as well as significant positive genotypic correlation with tuber yield at 70 DAP and positive but non-significant genotypic correlation with tuber yield/ha at 90 DAP. Number of tubers/plant had high positive direct effect on tuber yield both at 70 and 90 DAP respectively, but the genotypic correlation between them was significantly negative. This direct effect of number of tubers/plant on yield was diluted mainly due to negative indirect effect via foliage coverage, total chlorophyll content in leaf and single tuber weight both at 70 and 90 DAP. Direct effect of number of tubers/plant at 90 DAP was also diluted to negative indirect effect via number of stems/plant. This character showed no remarkable positive indirect effect via remaining characters on yield. In case of number of leaves/plant also showed the same situation as like number of tubers/plant. Again plant height showed negative direct effect on tuber yield both at 70 and 90 DAP respectively but the genotypic correlation between them was significantly positive. This genotypic correlation between plant height and yield was mainly the accumulation of positive indirect effect via foliage coverage and single tuber weight both at 70 and 90 DAP. Consequently,

such anomalous situation suggested that a restricted simultaneous selection model could be followed to nullify the undesirable indirect effects to make proper use of the direct effect (Saha *et al.*,1992).

Path coefficient values based on phenotypic correlation revealed that foliage coverage, total chlorophyll content in leaf and single tuber weight had direct positive effect towards tuber yield/ha at 70 DAP also having positive correlation with tuber yield. In case of tuber harvested at 90 DAP foliage coverage, plant height and single tuber weight had direct positive effect towards tuber yield/ha. Single tuber weight had the highest direct positive effect towards tuber yield/ha both at 70 and 90 DAP which was followed by number of tubers/plant. The lowest direct positive effect was found for total chlorophyll content in leaf and plant height at 70 and 90 DAP respectively. The highest direct negative effect was found for number of leaves/plant towards tuber yield/ha both at 70 and 90 DAP.

Path analysis showed slightly different patterns between early and late harvesting situation for characters affecting tuber yields which are in agreement with Kim *et al*., 1993. Similar result was also reported by Panigrahi *et al.* (2017). Khayatnezhad *et al.* (2011) reported plant height, medium tuber weight and big tuber weight evolved the direct influence. The present findings are in agreement with the findings of Yildirim *et al.* (1997). They reported that average weight/tuber (single tuber weight), tubers/plant and plant height had positive and direct effects on tuber yield. Pradhan *et al*. (2011) conducted an experiment on genetic parameters and association of traits related to yield in potato and reported that plant height at 60 DAP had the greatest direct effect on yield, resulting in positive correlation coefficients at the phenotypic and genetic levels. Fekadu *et al.* (2013) also reported that plant height had positive direct effect on potato yield, whereas number of stems/plant showed negative direct effect on potato germplasm. The components which have high significant positive and direct contribution towards total tuber yield could be considered as selection criteria in potato breeding programme (Ara *et al.* 2009). Abraham *et al.* (2014) reported that path analysis of tuber yield and its components shows positive direct influence indicating their importance as selection index for yield improvement. Present investigation is in agreement with this statement. Gusain (2010) calculated correlation

studies in 168 genotypes and 4 checks. The results indicated that maximum positive direct effect on tuber yield was imposed by plant height. However, negative direct effects on tuber yield were observed for tuber weight/plant and number of tubers/plant. Therefore, proper attention should be taken on above characters for the improvement of tuber yield.

The genotypic residual effect of the genotypic path analysis was 0.1681 at 70 DAP and 0.1686 at 90 DAP indicated that about 83.19 % and 83.14% of the variability in tuber yield was contributed by the studied characters. The residual effect towards yield might be due to many reasons such as other characters which were not studied, environmental factors and sampling errors as stated by Sengupta & Karatia (1971). Within the scope of the path analysis carried out in the present investigation it is therefore, suggested that foliage coverage, total chlorophyll content in leaf, plant height and single tuber weight which are the main components of yield should be given high priority in the selection programme.

In the present study, correlation and path coefficient analysis suggests that during selection more emphasis should be given on foliage coverage, plant height, total chlorophyll content in leaf and single tuber weight. Since these characters, have high correlation and high direct effect on tuber yield. Generally, high yield with good quality is the most important objective in potato breeding. So, by considering the traits that have a strong positive association and correlation with tuber yield and the characters that show highest positive direct effect on tuber yield could be further used in the breeding programme.

2.5. SUMMARY

A field experiment was carried out with thirty two potato (local, released and exotic) genotypes following Randomized Complete Block Design (RCBD) with three replications to determine the extent of genetic variation for agronomic characters. Means, genotypic and phenotypic variances, genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance as percentage of mean, correlation coefficients and path coefficients were estimated for tuber yield and yield attributing characters both at 70 and 90 DAP harvesting situations. Analysis of variance revealed significant differences for all the characters except days to first shoot emergence both at 70 and 90 DAP indicating the presence of considerable variations among the studied genotypes. The values of genotypic coefficient of variation (% GCV) were quite close to the estimated values of phenotypic coefficient of variation (% PCV) and high GCV as well as PCV percentages was observed for majority of the traits under studied suggested that the greater variability among the genotypes were due to genetic causes, had negligible environmental role and the genotypes performance appeared to be well adapted to the environment for the fullest phenotypic expression of the traits. Foliage coverage, number of stems/plant, number of leaves/plant, plant height, chlorophyll content in leaf, number of tubers/plant, tuber weight/plant, single tuber weight and tuber yield/ha both at 70 DAP and 90 DAP showed moderate to high heritability along with high genetic advance as percentage of means were normally more helpful in predicting the genetic gain under selection. Foliage coverage, plant height and single tuber weight showed highly significant positive correlation with tuber yield/ha both at 70 and 90 DAP at genotypic and phenotypic level. Chlorophyll content in leaf had significant and positive correlation with tuber yield/ha at 70 DAP while at 90 DAP the relationship was positive but non-significant. So, the improving of these positively associated characters would contributed to increase tuber yield/ha. On the other hand number of stems/plant, number of leaves/plant and number of tubers/plant were negatively correlated with yield/ha both at 70 and 90 DAP *i.e.* with the increase of these traits yield reduced. Path coefficient analysis showed positive direct effect of foliage coverage, number of

stems/plant, chlorophyll content in leaf, number of tubers/plant and single tuber weight on tuber yield/ha at 70 DAP both at genotypic and phenotypic level. On the other hand foliage coverage, number of tubers/plant and single tuber weight had positive direct effect on tuber yield at 90 DAP both at genotypic and phenotypic level. So these traits would be helpful to select higher yielding genotypes for harvesting at 70 and 90 DAP. Correlation and path coefficient analysis suggest that during selection more emphasis should be given on foliage coverage, plant height, total chlorophyll content in leaf and single tuber weight.

Chapter III

3. GENETIC DIVERSITY OF DIFFERENT NUTRITIONAL CHARACTERS IN SELECTED POTATO GENOTYPES

3.1. INTRODUCTION

Potato is a good source of human nutrition. It is the staple food in many countries of the world. It is an excellent low fat source of carbohydrate with one-fourth the calories of bread. Potato tubers are one of the richest sources of antioxidants in the human diet. Potatoes are also a good source of some minerals, at least 12 essential vitamins and extremely high content of vitamin C in potato compare to other food crops (Struik and Wiersema, 1999). It is superior to rice or wheat particularly in terms of supplying carbohydrates, minerals specially potassium, calcium and iron, vitamin A or β-carotene and vitamin C (Ahmed and Kamal, 1984). The protein content of potato is high in that the protein produced is made of a high proportion of essential amino acid. Per hectare nutrient yield of potato is higher than that of wheat and rice. Such nutritional values of tuber are the key driver for growth and development of potato all over the world (Buono *et al*. 2009). However, there is considerable genetic variation in concentration of nutritional components of tuber both between and within *Solanum* species. The nutritional quality varies due to the varietal difference, maturity of tuber, temperature, storage stress and handling which have an important effect on food value especially processed food. Several other factors, including environmental conditions and cultivation practices during growth are also important for the concentrations of nutritional components (Kumar *et al.*, 2004).

The chemical compositions of potatoes are greatly affected by variety (Cargill *et al.,* 1986; Forbush 1989). Starch is a major nutritional component of the tuber. Starch percentage in potato tubers varied both with variety and environment (Gall *et al.*, 1965). On the other hand quality or kind of sugars and dry matter is a heritable character, but is also affected by a number of environmental factors (Ezekiel *et al.*, 1999). Sugar level in potato during tuberization and at harvest largely depends on cultivar (Sinha *et al.*, 1992). The genetic component; however, has the strongest

influence since the reducing sugars content is a heritable trait that can be screened for tubers (Stephenson *et al.*, 1964).

The most important factor that may influence quality of potatoes for processing is the variety. Varieties for potato fries must have a tuber dry matter content of 21-24% for high fry recovery, less oil uptake, crispy texture and light yellow or light brown in color (Balaoing, 2006). The quality of potato chip has been reported to be influenced by pre harvest factors mainly the growing condition and also influenced by variety (Salunkhe *et al.,*1989), inherent characteristics of potatoes like dry matter and specific gravity (Smith, 1968). Every factor that is a part of the environment has the potential to cause differential performance that is associated with genotype environment interaction in potatoes (Feher, 1987). Processors and other potato user would be benefited from a more uniform product if varieties produce the same specific gravity when grown in different environments (Johanson *et al.,* 1967). According to Kabira and Berga (2003) some varieties are not suitable for the production of processed product due to low dry matter content. It is important for researchers to recommend the growers to use only those varieties that make good quality products both at harvest and after storage for various periods of time.

β-carotene (pro-vitamin A) a common carotenoid in many other plants and also presents in the aerial parts of the potato plant is absent or present in only trace amounts in the tubers (Burton, 1989). There is a direct correlation between yellow flesh color and total carotenoid content, which is a heritable characteristic.

Tuber Ca, Fe and Zn concentrations have been shown to vary significantly between *Solanum* species grown under identical conditions (Andre *et al.*, 2007a; Bamberg *et al.*, 1993, 1998). Among the *Solanum* species, *S. gourlayi* and *S. microdontum* had the highest tuber Ca concentration, whereas *S. kurtzinum* and *S. tuberosum* had the lowest Ca concentrations when supplied with ample Ca (Bamberg *et al.*, 1993). Although the skin generally has a greater Ca concentration than the flesh (Ereifej *et al.*, 1998; McGuire and Kelman, 1984, 1986; Wszelaki *et al.*, 2005), differences in tuber Ca concentration between *Solanum* species do not appear to be associated

simply with differences in skin to flesh ratios (Bamberg *et al.*, 1993). Andre *et al.* (2007a) observed a strong relationship between tuber Ca and Fe concentrations and a weak but significant correlation between Zn and Fe concentration among 74 Andean landraces. They observed that some genotype from the Ajanhuiri group had exceptionally high tuber Ca and Fe concentration and that tuber size explained 13% of the variability in tuber Fe concentrations. When grown under identical conditions, *S. tuberosum* genotypes have been shown to differ in tuber N (Augustin, 1975; Fitzpatrick *et al.*, 1969; Rexen, 1976), K (Brown *et al.*, 2005; Ereifej *et al.*, 1998; Tekalign and Hammes 2005; Van Marle *et al.*, 1994; Workman and Holm, 1984), P (Dampney *et al.*, 2002; Ereifej *et al.*, 1998; Randhawa *et al.*, 1984; Tekalign and Hammes, 2005; Trehan and Sharma, 2003), S (Tekalign and Hammes, 2005), Ca (Ereifej *et al.*, 1998; Karlsson *et al.*, 2006; Mcguire and Kelman, 1986; Randhawa *et al.*, 1984; Tekalign and Hammes, 2005; Tzeng *et al.*, 1990; Van Marle *et al.*, 1994), Mg (Allison *et al.*, 2001a; Ereifej *et al.*, 1998; Randhawa *et al.*, 1984; Tekalign and Hammes, 2005), Fe (Brown *et al.*, 2005; Ereifej *et al.*, 1998; Randhawa *et al.*, 1984), Zn (Brown *et al.*, 2005; Ereifej *et al.*, 1998; Randhawa *et al.*, 1984; Tekalign and Hammes, 2005), Cu (Ereifej *et al.*, 1998; Randhawa *et al.*, 1984; Tekalign and Hammes, 2005) and Mn concentration (Brown *et al.*, 2005). Systematic differences in tuber K, Mg, Fe, Zn, Cu, and Mn concentrations have also been observed between potato varieties obtained commercially (Casanas *et al.*, 2003; Di Giacomo *et al.*, 2007). It is likely, therefore, that tuber mineral concentrations can be manipulated genetically through commercial breeding programmes. It has been hypothesized that higher yielding genotype have lower concentration of mineral elements than those of lower yielding genotypes when grown in the same environment because of a dilution effect caused by plant growth rate exceeding the ability of plants to acquire the elements (Jarrell and Beverly, 1981) that is impacted by both environment and genetic factors (Davis, 2005; Davis *et al.*, 2004).

In Bangladesh there is a tendency of harvesting potatoes before its full maturity to catching high prices in the markets. Potato processors are mainly concerned with the color and yield of processed products. The most important factor affecting the color of

fried processed products such as chips and French fries is the content of reducing sugars (Rao *et al.,* 1990), while the yield recovery of the processed products is directly related to the tuber yield and high specific gravity or dry matter content of tubers (Santerre *et al.,*1986). Potato tubers usually have high sugar content early in their development because the rate of transport from the leaves exceeds the rate of conversion to starch. As the tubers grow and mature, the sugar content decreases, reaching the lowest point when the vines are nearing complete senescence. Early harvesting of tubers resulted in significantly higher levels of reducing sugar than harvesting at maturity. Tubers from early planting were lower in glucose and sucrose than those from later planting. Freshly harvested potatoes contain very little amount of sugar. Small tubers are higher in sugar than that of big tubers. A series of experiments in the 1940s (Leichsenring, 1951) showed that the reduced ascorbic acid content of potatoes varies with variety, locality, crop year and maturity at time of harvest (values were highest when plants were at their maximum vigor and declined thereafter as vines began to die off).

Therefore, there is a need for conducting trial with different potato varieties to find out nutritionally enriched variety/varieties most suitable for harvesting early or late under the existing conditions of Bangladesh. The progress of breeding is conditioned by the magnitude, nature and interrelationship of genotypic and environmental variation in different characters. Genetic variability with respect to genetic diversity has been considered as an important factor which is also essential prerequisite for crop improvement programme. The quantification of genetic diversity through biometrical procedure made it possible to choose genetically diverse parents for a successful hybridization programme. Evaluation of genetic diversity is important to know the source of genes for a particular trait within the available genotype. Moreover, genetic diversity among the segregating population also helps to select suitable types for commercial cultivation. Despite of the commercial importance crop genetic data on nutritional aspect of potato in Bangladesh are relatively scarce. Knowledge of germplasm diversity among breeding materials and varieties is important for the genetic improvement of plants.

Therefore, in this part of research, nutritional quality of potato tuber at two different maturity stages were determined to find out the genetic divergence exists for nutritional quality characters among the different potato genotypes.

3.1.1. **Objectives**

The objectives of this part of research are as follows:

i) To assess the different nutritional quality characters of tubers among the 32 selected potato genotypes.

ii) To estimate the nature and magnitude of genetic variability in nutritional quality traits of potato tubers at early and late harvesting stages.

iii) To find the nature of the phenotypic and genotypic correlations between tuber yield and nutritional quality characters.

iv) To assess the genetic divergence exists in nutritional quality characters of tubers among the different potato genotypes.

v) To select genotypes with desirable nutritional quality characters to use in breeding programme for developing nutritionally enriched potato varieties.

3.2. MATERIALS AND METHODS

3.2.1. **Materials**

Freshly harvested tubers of 32 potato genotypes were brought to Bangladesh Council of Scientific and Industrial Research (BCSIR) Laboratories, Rajshahi and were subjected to biochemical analysis for the quantitative estimation of the following nutritional quality characters *viz*., moisture (M), dry matter (DM), specific gravity (SG), ash, pH, total soluble solids (TSS), titratable acidity (TA), total phenolic content (TPC), beta carotene (β-Car.), vitamin C (VC), starch content (SC), soluble protein (SP), total sugar (TS), reducing sugar (RS), non-reducing sugar (NRS), iron (Fe), phosphorous (P), calcium (Ca), potassium (K) and zinc (Zn) content.

3.2.2. **Methods**

Different methods used for quantitative determination of different nutritional quality of the tubers of all the genotypes are mentioned here under separate heads.

3.2.2.1. *Moisture content*

Moisture content was determined by the conventional procedure (Karmas, 1980).

Equipments: i) Porcelain crucible, ii) Electric Balance, iii) Electric oven and iv) Desiccators.

Procedure: About 50 g of potato tuber was weighed in a porcelain crucible which was previously cleaned, heated to 70^0 C, cooled and weighed. The crucible with the sample was heated in an electric oven for about 48 hours at 70^0 C or until total moisture removed. It was then cooled in desiccators and weight was taken again.

Calculation: Percentage of moisture content = $\frac{\text{Amount of moisture}}{\text{Weight of potato tuber}} \times 100$

3.2.2.2. *Dry matter content*

Dry matter content was determined from the data obtained for percentage of moisture content.

3.2.2.3. *Specific gravity*

Specific gravity was calculated using the following equation (Nissen, 1955).

$Y = 214 \times (V - 0.988)$

Where, Y= Dry matter content in 100 g of potato tuber and V= Specific gravity.

3.2.2.4. A*sh content*

Ash content was determined following the method of A. O. A. C. (1980)

Equipments: i) Porcelain crucible, ii) Balance, iii) Muffle furnace and iv) Desiccators.

Procedure: About 10 g of potato tuber was weighed in a porcelain crucible which was previously cleaned, heated to 100^0 C, cooled and weighed. The crucible was placed in a muffle furnace for about 4 hours at 600^0 C. It was then cooled in desiccators and weighed. To ensure completion of ashing, the crucible was again heated in the muffle furnace for half an hour then cooled and weight was taken again. This was repeated till two consecutive weights were the same and ash was almost white in color.

Calculation: Percentage of ash content = $\frac{\text{Amount of ash obtained}}{\text{Weight of potato tuber}} \times 100$

3.2.2.5. *pH content*

Preparation of standard buffer solution

pH 4 and pH 7 buffer tablets (BDH chemicals Ltd., Poole, England) were dissolved in distilled water and made up to mark of 100 ml with distilled water.

Equipments: i) Knife, ii) Electric balance, iii) Mortar and pestle and v) Centrifuge machine

Extraction of potato juice

For pH determination 20 g of potato was taken and cut into small pieces. The small pieces of potato were crushed thoroughly with mortar and pestle. The extract was filtered through double layer of muslin cloths. Then it was centrifuged and supernatant was used for pH determination.

Procedure: The electrode assembly of pH meter was dipped into the standard buffer solution of pH 7 taken in a clean and dry beaker. The temperature correction knob was set to 28^0 c and the fine adjustment was made by asymmetry potentially knob to 7. After washing with distilled water the electrode assembly was dipped into a solution of standard pH 4 and adjusted to the required pH by the asymmetry potential knob. The electrode assembly was raised, washed twice with distilled water, and then rinsed with potato juice and finally it was dipped into the potato extract for recording the pH of the extract.

3.2.2.6. *Total soluble solids content*

Total soluble solids (TSS) content in potato tuber was estimated by using abbe Refractometer. A drop of potato extract squeezed from the extract prepared for pH estimation on the prism of the refractometer. Percentage of total soluble solids (TSS) was obtained from the direct reading of the instrument. Temperature correction was done using the methods as described by Ranganna (1979).

3.2.2.7. *Titratable acidity content*

Titratable acidity content in potato tuber was determined by the method of Ranganna (1979).

Equipments: i) Knife, ii) Beaker, iii) Electric balance, iv) Mortar and pestle, v) Volumetric flask, vi) Conical flask, vii) Pipette viii) Burette ix) Whatman No-41 filter paper

Reagents: i) Standard NaOH solution (0.1 N) ii) 1% Phenolphthalein solution

Extraction of Potato juice : Ten g of potato tuber was taken in a 100 ml beaker and then it was homogenize with distilled water in blender. The blended materials were then filtered and transferred to a 100 ml volumetric flask. The volumetric flask was made up to the mark with distilled water.

Titration procedure: Ten ml of the extract solution was taken in a conical flask. Two to three drops of phenolphthalein indicator was added and then the conical flask was shaken vigorously. It was then titrated immediately with 0.1N NaOH solutions from a burette till a permanent pink color appeared. The volume of NaOH solution required

for titration was recorded. Percentage of titratable acidity was calculated by using the following formula:

$$\% \text{ Titratable acidity} = \frac{T \times N \times V1 \times E}{V2 \times W \times 1000} \times 100$$

Where,

T= Amount of titer (ml)

N= Normality of NaOH

V1= Volume made up (ml)

E= Equivalent weight of citric acid

V2= Volume of extract taken (ml) and

W= Weight of sample (g)

3.2.2.8. *Total phenolic content*

Phenolic compounds or total phenol content in potato tuber was determined spectrophotometrically by Follin-Ciocalteu's method (Bray and Thorpe, 1954).

Equipments: i) Knife, ii) Beaker, iii) Water bath, iv) Mortar and pestle, v) Muslin cloth, vi) Whatman No-41 filter paper, vii) Pipette, viii) Volumetric flask, ix) Test tube and x) Spectrophotometer.

Reagents:

i) 20% Na_2CO_3 solution: Approximately 20 g of Na_2CO_3 was dissolved in 100 ml of distilled water.

ii) Folin-Ciocalteu's Reagent (FCR): Diluted 10 times with distilled water.

iv) Caffeic acid standard: Approximately 10 mg of caffeic acid was dissolved in 100 ml distilled water (Contain 0.1 mg/ml Caffeicc acid).

Extraction of phenols from potato tuber: About 5 g of potato tuber was cut into small pieces and homogenized with 20 ml distilled water with the help of mortar and pestle. Homogenate was centrifuged at 3000 rpm for 20 minutes. Supernatant was collect into a 100 ml volumetric flask and made up to the mark. This extract was used for the estimation of total phenol.

Procedure: Aliquot of 1 ml of the extract of each sample was pipette into a test tube. 1 ml of Folin-Ciocalteu's reagent (FCR) was added followed by 2 ml of 20% sodium

carbonate (Na_2CO_3) solution. The mixture was shacked vigorously and placed on boiling water bath for 1 minute then cooled under running water. The blue solution was transferred to a 25 ml volumetric flask and made up to the mark with distilled water. A reagent blank was prepared by taking 1 ml of distilled water and 1 ml of FCR in a test tube and treated similarly. For preparing a standard curve of caffeic acid 0.0, 0.1, 0.2, 0.4, 0.6 and 0.8 ml of standard solution was taken in different test tube and made up to 1 ml with distilled water which contained 0.0, 10, 20, 40, 60 and 80 µg caffeic acid respectably. Then 1 ml of FCR was added to each test tube followed by addition of 2 ml 20% sodium carbonate (Na_2CO_3) solution and mixed well. Then it was treated as before. The absorbance of the solution was measured at 650 nm in a spectrophotometer using the blank.

Calculation: The amount of total phenol content was calculated from the standard curve of caffeic acid. Finally, the percentage of total phenol present in the potato tuber was determined using the following formula:

$$\text{Percentage of total phenol (mg/100 g of tuber)} = \frac{\text{Weight of total phenol obtained}}{\text{Weight of tuber}} \times 100$$

3.2.2.9. *β-carotene content*

β-carotene content in the potato tuber was determined according to the procedure reported in the Methods of Vitamin Assay (Anonymous, 1960) and Methods of Biochemical Analysis (Glick, 1957).

Equipments: i) Mortar and pestle, ii) pipette, iii) Conical flask, iv) Separating funnel, v) Column and vi) Spectrophotometer.

Reagents:

i) Ammonium sulphate

Ii) Acetone

iii) n-hexane

iv) Petroleum ether

v) 5.6% potassium hydroxide solution: Approximately 5.6 g of KOH was dissolved in 100 ml distilled water.

vi) Column preparation: A column (40×2.5 cm) was prepared by using activated alumina as a packing material 10% acetone in petroleum ether was used as eluant buffer.

vii) 10% acetone in petroleum ether: Aliquot of 10 ml acetone was taken in 100 ml volumetric flask made up to the volume with petroleum ether.

viii) Standard β-carotene solution: Standard solution of β-carotene was prepared by dissolving 2 mg of β-carotene in 100 ml of petroleum ether.

Procedure: About 10 g of potato tuber and 8 g of ammonium sulphate were taken in a mortar and rubbed to an even paste with pestle. The extraction was carried out with acetone (12 ml) and small amount of n-hexane (8 ml). Extraction was continued until the acetone extract becomes colorless. Then the extraction was filtered by double layer of muslin cloth. Aliquot of 10 ml potassium hydroxide solution (5.6%) was added to the filtrate extract and mixed well. Then it was kept in a dark place for half an hour. The mixture was then transferred to a separating funnel. 20 ml of petroleum ether, a few (3-5) ml of n-hexane and 10 ml of water were added to the separating funnel and shacked gently. The ether layer (Upper layer) was collected and the process was repeated until the petroleum ether layer became colorless. After the ether layer collection, its volume was measured. The extract was equal volume before applied onto the top of the column with ether. The concentrated extract (2 ml) was applied onto the top of the alumina column and eluted with 10% acetone in petroleum ether. The absorbance of the eluant was taken at 440 nm in a spectrophotometer.

Construction of standard curve of β-carotene: A standard curve was prepared by taking 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of standard solution of β-carotene and the volume was made up to 2 ml with petroleum ether and mixed well. The absorbance of the solutions was taken at 440 nm in a spectrophotometer and a standard curve of β-carotene was prepared by plotting the data. The amount of β-carotene content in each genotype of potato was calculated by using the standard curve of β-carotene.

Calculation: Amount of β-carotene in the potato tuber (µg/100 g potato tuber)

$$= \frac{\text{Amount of β-carontene obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.10. *Vitamin C content*

Vitamin C content in potato tuber was determined by the titrimetric method (Bessey and King, 1933).

Equipment: i) Beaker, ii) Mortar and pestle, iii) Volumetric flask, iv) Double layer of muslin cloths, v) Burette, vi) Pipette, vii) Conical flask and viii) Centrifuge machine.

Reagents:

i) Dye solution: Approximately 200 mg of 2, 6-dichlorophenol indophenols was dissolving in water and then 210 mg of sodium bicarbonate was dissolved in it and made up to the volume 1000 ml with distilled water. The solution was then filtered.

ii) 3% metaphosphoric acid (HPO_3): Approximately 3 g of metaphosphoric acid was dissolved in 20 ml distilled water and then made up to 100 ml with acetic acid.

iii) Standard vitamin C solution (0.1 mg/ml): A standard vitamin C solution was prepared by dissolving 10 mg of ascorbic acid in 3% metaphosphoric acid and made up to 100 ml with 3% metaphosphoric acid.

Extraction of vitamin C from potato tubers: About 5 g of the potato tuber was cut into small pieces and homogenized well with 20 ml of 3% metaphosphoric acid. Then it was filtered through double layer of muslin cloth. The filtrate was centrifuged at 6000 rpm for 10 minutes and clear supernatant was collected. The volume of this supernatant was measured.

Procedure: About 10 ml of standard ascorbic acid solution was taken in conical flask and titrate with dye solution from a burette. The titration was terminated by the appearance of a permanent pink color in the titration medium. The operation was repeated for two times and burette readings were recorded each time. 10 ml solution of each genotype was taken into different conical flask and titrated with dye solution. The operation was repeated for two times and burette readings were recorded each time. The amount of vitamin C present in the extract was determined by comparing with the titration result of standard vitamin C solution.

Calculation: The amount of vitamin C content was calculated using the following formula:

$$\text{Vitamin C content (mg/100 g of potato tuber)} = \frac{I \times S \times D}{A \times W} \times 100$$

Where, I= Amount of 2, 6-dichlorophenol indophenols used in the titration (ml); S=Amount of ascorbic acid reacting with 1 ml of the dye reagent (mg); D=Total volume of the extract (ml); A=Amount of sample solution used in titration (ml) and W= Weight of the sample (g).

3.2.2.11. *Starch content*

The starch content in potato tuber was determined by the Anthrone method as described in Laboratory Manual in Biochemistry (Jayaraman, 1981).

Equipment: i) Volumetric flask, ii) Mortar and pestle, iii) Beaker, iv) Pipette, v) Double layer of muslin cloths, vi) Water bath, vii) Glass marbles, viii) Test tubes, ix) Centrifuge machine and x) Spectrophotometer.

Reagents:

i) 1M HCl

ii) Ethanol

iii) Anthrone reagent: The anthrone reagent was prepared by dissolving 200 mg of anthrone in 100 ml of concentrated sulfuric acid (H_2SO_4).

iv) Standard glucose solution: A standard glucose solution was prepared by dissolving glucose in distilled water. 10 mg of glucose was taken in 100 ml volumetric flask and distilled water was added up to the mark.

Extraction of starch from potato tubers: About 5 g of the potato tuber was cut into small pieces and homogenized well with 20 ml distilled water. It was then filtered through double layer of muslin cloth. To the filtrate, twice the volume of ethanol was added to precipitate the polysaccharide, mainly starch. After keeping it over night in cold, the precipitate was collected by centrifugation at 3000 rpm for 15 minutes. The precipitate was then dried over a steam bath. Then 40 ml of 1M HCl was added to the dried precipitate and heated to about 70^0 C. Then it was transferred to a 100 ml volumetric flask and diluted up to 100 ml with 1M HCl. Then 1 ml of the diluted solution was taken in another 100 ml volumetric flask and made up to the mark with 1M HCl (working standard).

Procedure: Aliquot of 1 ml of the extract from each genotype was pipette into different test tubes and 4 ml of anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each tube to prevent loss of water by evaporation. The test tubes were placed in a boiling water bath for 10 minutes, then removed and cooled. A reagent blank was prepared by taking 1 ml of 1M HCl and 4 ml of anthrone reagent in a test tube and treated similarly. The absorbance of the blue-green solution was measured at 680 nm in a spectrophotometer.

A standard curve of glucose was prepared by taking 0.0, 0.05, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of standard glucose solution in different test tubes and made up to the volume 1 ml with 1M HCl which contained 0.0, 10, 20, 40, 60, 80 and 100 µg of starch respectively. Then 4 ml of anthrone reagent was added to each test tube and mixed well. All the solutions were treated similarly as described for the sample. The absorbance was measured at 680 nm using the blank containing 1 ml of 1M HCl and 4 ml of anthrone reagent.

Calculation: The amount of starch content was calculated from the standard curve of glucose. Finally, the percentage of starch present in the potato tuber was determined using the formula given below:

$$\text{Percentage of starch (g/100 g of potato tuber)} = \frac{\text{Weight of starch obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.12. *Total sugar content*

Total sugar content in potato tuber was determined by the anthrone method, as described in Laboratory Manual in Biochemistry (Jayaraman, 1981).

Equipments: i) Volumetric flask, ii) Mortar and pestle, iii) Pipette, iv) Conical flask, v) Double layer of muslin cloths, vi) Steam bath, vii) Glass marbles, viii) Test tubes, ix) Whatman filter paper no. 41 and x) Spectrophotometer.

Reagents:

i) 80% Ethanol: 80 ml of pure (analytical grade) ethanol was taken in a 100 ml volumetric flask and made up to the mark with distilled water.

ii) Anthrone reagent: The anthrone reagent was prepared by dissolving 200 mg of anthrone in 100 ml of concentrated sulfuric acid (H_2SO_4).

ii) Standard glucose solution: A standard glucose solution was prepared by dissolving glucose in distilled water. 10 mg of glucose was taken in 100 ml volumetric flask and distilled water was added up to the mark.

Extraction of sugar from potato tubers: Extraction of sugar from potato tuber was done following the method described by Loomis and Shull (1937). Approximately 5 g of potato tuber were plunged into boiling ethyl alcohol and allowed to boil for 5-10 minutes (5 to 10 ml of 80 percent ethyl alcohol was used per gram tuber). The extract

was cooled and pasted thoroughly in a mortar with a pestle. Then the extract was filtered through double layer of muslin cloth and re-extracted the pasted tissue for three minutes in hot 80 percent alcohol, using 2 to 3 ml of alcohol/g of sample. Then, it treated as before. This second extraction ensured complete removal of alcohol soluble substances. The extract was cooled and passed through the muslin cloth. Then both the extracts were mixed and filtered through Whatman No. 41 filter paper. The volume of the extract was evaporated to about $1/4^{th}$ the volume over steam bath and cooled. This reduced volume of the extract was then transferred to a 100 ml volumetric flask and made up to the mark with distilled water. Then 1 ml of the diluted solution was taken into another 100 ml volumetric flask and again made up to the mark with distilled water (Working solution).

Procedure: Aliquot of 1 ml of the extract from each genotype was pipette into different test tube and 4 ml of anthrone reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each tube to prevent loss of water by evaporation. The test tubes were placed in a boiling water bath for 10 minutes, then removed and cooled. A reagent blank was prepared by taking 1 ml of distilled water and 4 ml of anthrone reagent in test tube and treated similarly. The absorbance of the blue green solution was measured at 680 nm in a spectrophotometer.

The standard curve of glucose was prepared by taking 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1 ml of standard glucose solution in different test tubes and made up to the volume 1 ml with distilled water which contained 0.0, 10, 20, 40, 60, 80 and 100 µg of glucose respectively. Then 4 ml of anthrone reagent was added to each test tube and mixed well. All the solutions were treated similarly as described for the sample. The absorbance was measured at 680 nm using the blank containing 1 ml water and 4 ml of anthrone reagent.

Calculation: The amount of total sugar content was calculated from the standard curve of glucose. Finally, the percentage of total sugar present in the potato tuber was determined using the formula given below:

$$\text{Percentage of total sugar (g/100 g of potato tuber)} = \frac{\text{Weight of total sugar obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.13. *Reducing sugar content*

Reducing sugar content in potato tuber was determined by the dinitrosalicylic acid method (Miller, 1959).

Equipments: i) Beaker, ii) Test tube, iii) Pipette and iv) Spectrophotometer.

Reagents:

i) Dinitrosalicylic acid (DNS) reagent: Simultaneously 1 g of DNS, 200 mg of crystalline phenol and 50 mg of sodium sulfite were placed in a beaker and mixed with 100 ml of 1% sodium hydroxide (NaOH) solution by stirring (If it is to store then sodium sulfite must be added just before use).

ii) 40% Rochelle salt solution: 40 g of Rochelle salt (Na-K Tartarate) was dissolved in 100 ml distilled water.

iii) Standard glucose solution: A standard glucose solution was prepared by dissolving glucose in distilled water. 10 mg of glucose was taken in 100 ml volumetric flask and distilled water was added up to the mark.

Extraction of reducing sugar from potato tubers: Extraction of reducing sugar from tuber was done by the procedure as described in the determination of total sugar.

Procedure: Aliquot of 3 ml of the extract from each genotype was pipetted into different test tube and 3 ml of DNS reagent was added to each of this solution and mixed well. Glass marbles were placed on top of each tube to prevent loss of water by evaporation. The test tubes were placed in a boiling water bath for 5 minutes. After developing the color, 1 ml of 40% Rochelle salt solution was added when the solution of the test tubes was still warm. The test tubes were then cooled under a running tap water. A reagent blank was prepared by taking 3 ml of distilled water and 3 ml of DNS reagent in a test tube and treated similarly. The absorbance of the solution was measured at 575 nm in a spectrophotometer.

A standard curve of glucose was prepared by taking 0.0, 0.3, 0.6, 1.2, 1.8, 2.4 and 3.0 ml of standard glucose solution in different test tubes and made up to the volume 3 ml with distilled water which contained 0.0, 10, 20, 40, 60, 80 and 100 µg of glucose respectively. Then 3 ml of DNS reagent was added to each test tube and mixed well.

All the solutions were treated similarly as described for the sample. The absorbance was measured at 575 nm using the blank containing 3 ml water, 3 ml of DNS reagent and 1 ml of 40% Rochelle salt.

Calculation: The amount of reducing sugar content was calculated from the standard curve of glucose. Finally, the percentage of reducing sugar present in the potato tuber was determined using the formula given below:

Percentage of reducing sugar (g/100 g of potato tuber)

$$= \frac{\text{Weight of reducing sugar obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.14. *Non-reducing sugar content*

Non-reducing sugar content or sucrose content was determined by the following formula (Golder, 2000).

Percentage of non-reducing sugar = (% Total sugar - % Reducing sugar) × 0.95.

3.2.2.15. *Soluble protein content*

Soluble protein content in potato tuber was determined following the method of Lowry *et al.* (1951).

Equipments: i) Whatman # 41 filter paper, ii) Spectrophotometer, iii) Centrifuge tubes, iv) Pipette, v) Mortar and pestle, vi) Centrifuge machine and vii) muslin cloth.

Reagents:

i) 2% Na_2CO_3 solution in 0.1 N NaOH (0.4 g of NaOH was dissolved in 100 ml of distilled water and then 2 g of Na_2CO_3 was dissolved it.).

ii) 0.5% $CuSO_4.5H_2O$ in 1% Na-K tartarate (1 g of Na-K tartarate was dissolved in 100 ml of distilled water and then 0.5 g of $CuSO_4.5H_2O$ was dissolved it).

iii) Folin-Ciocalteu's Reagent (FCR) (Diluted with equal volume of distilled water, just before use) and

iv) Protein standard (10 mg of bovine serum albumin dissolved in 100 ml distilled water).

Extraction of potato tubers: About 5 g potato tuber was cut into small pieces and homogenized well with 5 ml distilled water. It was then filtered through double layer

of muslin cloth. The filtrate was centrifuged at 3000 rpm for 15 minutes and the clear supernatant was transferred in 50 ml volumetric flask and made up to the mark with distilled water. Then 10 ml of this diluted solution was taken in another 100 ml volumetric flask and made up to the mark with distilled water (working standard). Water was added carefully to avoid foam.

Procedure: Reagent (i) and (ii) were mixed in the ratio of 50:1 and the reagent (iii) was diluted just before use. In 6 glass test tubes, 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1 ml of the standard protein solution were taken and the volume made up to 1 ml with distilled water. 1 ml (one) of the sample was taken in a test tube and a duplicate was made. To each of tubes (standard and sample) 5.0 ml of (i : ii) mixture was added and after 10 minutes 0.5 ml of FCR solution was added. A reagent blank was made with distilled water. Absorbance of the solution was recorded after 30 minutes at 650 nm. A graph was drawn with the data obtained from the standards and the amount of protein in the sample was calculated from the graph.

Calculation: Percentage of soluble protein content (g/100 g of the potato tuber)

$$= \frac{\text{Amount of protein obtained}}{\text{Weightof potato tuber}} \times 100$$

3.2.2.16. *Iron (Fe) content*

Iron content of potato tuber was determined by colorimetric method following Wong, (1928).

Stock solution preparation for mineral estimation: The stock solution of potato tuber for mineral estimation was prepared from dry matter. The dry matter of potato tuber was grinded into powder form with mortar and pestle. Approximately 0.5 g of each sample in duplicate was taken into digestion tubes and to each of the tubes 5 ml of nitric acid and 2.5 ml of perchloric acid (followed by 2:1 ratio) was added and mixed well. The test tubes were heated to about 100^0 C for 10-12 hours in boiling water bath and cooled. Then 2.5 ml of nitric acid was further added to each of the tubes and heated to about 90^0 C for 3-4 hours in boiling water bath till the solution become transparent (water color). The solutions were cooled and filtered through Whatmann No.41 filter paper and made up to 100 ml with de-ionized distilled water (working solution). The stock solution was then ready for the estimation of iron,

phosphorous, calcium, potassium and zinc. All the glassware including digestion tubes were soaked with 30% nitric acid (HNO_3) for 8 hours and finally washed with de-ionizes distilled water.

Equipments: i) Volumetric flask, ii) Pipette, iii) Electric balance and iv) Spectrophotometer.

Reagents:

i) Hydroxylamine solution: 10 g of Hydroxylamine was dissolved in 100 ml of distilled water and mixed well.

ii) Ammonium acetate buffer solution: About 250 gm of ammonium acetate was dissolved in 150 ml distilled water. Then 700 ml of glacial acetic acid was added.

iii) Phenanthroline solution: 100 mg of 1, 10-phenenthroline monohydrate was dissolved in 100 ml distilled water by stirring and heating to 80^0C but not to boil.

iv) Standard iron (II) solution: 100 ppm iron (II) solution was used as standard. The solution contains 100 mg of Fe (II) per liter. From this solution 2.5 ml was taken in 50 ml volumetric flask and then made up to the mark with distilled water for preparing 5 ppm standard Fe (II) solution.

Procedure: 5 ml of the stock solution from each genotype was pipette into 25 ml volumetric flask and 1 ml of hydroxylamine solution was added and mixed well. 10 ml of ammonium acetate buffer solution was added to it and was shaking well. Then 4 ml of 1, 10-phenanthroline solution was added and made up to the mark with distilled water. The absorbance of the solution was measured at 510 nm in a spectrophotometer.

A standard curve of iron (Fe^{++}) was prepared by taking 0.0, 0.125, 0.25, 0.50, 1.00, 2.00, 3.00, 4.00 and 5.00 ml of standard iron solution in 25 ml volumetric flask. 1 ml of hydroxylamine solution was added and mixed well. 10 ml of ammonium acetate buffer solution was added to it and was shaking well. Then 4 ml of 1, 10-phenanthroline solution was added and made up to the mark with distilled water. The solution contains 0.00, 0.025, 0.05, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 mg/liter iron respectively. A reagent blank was prepared by taking 5 ml of distilled water and treated as before. The absorbance was measured at 510 nm.

Calculation: The amount of iron content in the solution was calculated from the standard curve of iron. Finally, the amount of iron present in the potato tuber was determined using the formula given below:

$$\text{Amount of iron (mg/100 g of potato tuber)} = \frac{\text{Weight of iron obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.17. *Phosphorous (P) content*

Phosphorous content of potato tuber was determined following the method as described by Chapman and Parker (1961).

Equipments: i) Volumetric flask, ii) Pipette, iii) Electric balance and iv) Spectrophotometer.

Reagents:

i) 5% Ammonium molybdate solution: 5 g of ammonium molybdate was dissolved in 100 ml of distilled water and mixed well.

ii) 0.25% Ammonium vanadate solution: 0.25 g of ammonium vanadate was dissolved in 100 ml distilled water and mixed well.

iii) 5% Sulfuric acid solution: 5% Sulfuric acid was prepared from concentrate sulfuric acid with distilled water.

iv) Standard phosphorous solution: 100 ppm phosphorous solution was used as standard. This solution contains 100 mg/liter phosphorous.

Procedure: 5 ml of the stock solution from each genotype was pipetted into 25 ml volumetric flask and added 5 ml of 5% ammonium molybdate solution and mixed well. 5 ml of 0.25% ammonium vanadate solution was added to it and was shaking well. Then 5 ml of 5% sulfuric acid solution was added and made up to the mark with distilled water. The absorbance of the solution was measured at 420 nm in a spectrophotometer.

A standard curve of phosphorous was prepared by taking 0.00, 0.125, 0.250, 0.500, 1.00, 1.50 and 2.00 ml of 100 ppm standard phosphorous solution in 25 ml volumetric flask. 5 ml of 5% ammonium molybdate solution was added and mixed well. 5 ml of 0.25% ammonium vanadate solution was added to it and was shaking well. Then 5 ml of 5% sulfuric acid solution was added and made up to the mark with distilled water.

The solution contains 0.00, 0.50, 1.00, 2.00, 4.00, 6.00 and 8.00 mg/liter phosphorous respectively. A reagent blank was prepared by taking 5 ml of distilled water and treated as before. The absorbance was measured at 420 nm.

Calculation: The amount of phosphorous in the stock solution of potato tuber was calculated from the standard curve of phosphorous. Finally, the amount of phosphorous present in the potato tuber was determined using the formula given below:

Amount of phosphorous (mg/100 g of potato tuber)

$$= \frac{\text{Weight of phosphorous obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.18. *Calcium (Ca) content*

Calcium content of potato tuber was determined by colorimetric method following Stern and Lewis (1957).

Equipments: i) Spectrophotometer, ii) Volumetric flask, iii) Pipette, iv) Electric balance and iv) Test tube.

Reagents:

1. Buffer solution (pH=10): i) 20 g of ammonium chloride was dissolved in 200 ml of distilled water and mixed well.

ii) 150 ml of ammonium hydroxide (NH_4OH) solution was prepared. Then solution (i) and (ii) mixed in 1 (one) liter volumetric flask and made up to the mark with distilled water maintaining the pH 10.

2. Color reagent: 187.5 mg of O-cresolphthalein complexon (OCPC) was dissolved in 150 ml distilled water in 500 ml volumetric flask. 4.20 g of 8-hydroxyquinolein was added to it and mixed well. Then 10 ml of hydrochloric acid (HCl) was added. 250 ml distilled water was added and mixed well. Finally the volume was made up to the mark with distilled water.

3. Standard Calcium solution: 100 ppm calcium solution was used as standard. The solution contains 100 mg/liter calcium.

Procedure: 1 ml of the stock solution from each genotype of potato tuber was pipette into different test tube. 0.250 ml of color reagent was added and mixed well. Then 3

ml of buffer solution was added and was shaking very well. The absorbance of the solution was measured at 570 nm in a spectrophotometer.

A standard curve of calcium was prepared. 10 ml of 100 ppm standard solution was taken in a 100 ml volumetric flask and made up to the mark with distilled water. Then the concentration of the solution was 10 ppm i.e. 10 mg Ca/liter. From this 10 ppm solution 0.00, 0.05, 0.10, 0.20, 0.40, 0.60 and 0.80 ml solution was taken in different test tubes and distilled water was added to make the volume 1 ml. The solution contains 0.00, 0.50, 1.00, 2.00, 4.00, 6.00 and 8.00 mg Ca/liter respectively. A reagent blank was prepared by taking 1 ml of distilled water and treated as before. The absorbance was measured at 570 nm.

Calculation: The amount of calcium in the stock solution of potato tuber was calculated from the standard curve of calcium. Finally, the amount of calcium present in the potato tuber was determined using the formula given below:

$$\text{Amount of calcium (mg/100 g of potato tuber)} = \frac{\text{Weight of calcium obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.19. *Potassium (K) content*

Potassium content in potato tuber was measured by flame emission spectroscopy (FES) following the method of Jackson (1973).

Equipments: i) Beaker, ii) Volumetric flask, iii) Pipette, iii) Electric balance and iv) Atomic absorption spectrophotometer.

Standard potassium solution: 100 ppm potassium solution was used as standard. This solution contains the equivalent of 0.1 mg K/ml.

Procedure: The intensity of emission (read out) of each of the potato tuber sample is measured for potassium with the help of a flam photometer using potassium filter at 766.5 nm. 2.5 ml of each stock solution was taken in different 25 ml volumetric flask. The volume was made up to the mark with distilled water. Then the stock solution was diluted for ten times.

Calibration curve of emission vs concentration of potassium was constructed by taking 0.00, 2.50, 5.00, 7.50 and 10.00 ml of standard solution in 25 ml volumetric

flask and made up to the mark with distilled water. This standard potassium solution contains 0.00, 10, 20, 30 and 40 ppm of the potassium ions. A reagent blank was prepared by taking 25 ml distilled water.

Calculation: The amount of potassium in the stock solution of potato tuber was calculated from the standard curve of potassium. Finally, the amount of potassium present in the potato tuber was determined using the formula given below:

Amount of potassium (mg/100 g of potato tuber)

$$= \frac{\text{Weight of potassium obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.2.20. *Zinc (Zn) content*

Zinc content in potato tuber was determined using atomic absorption spectrophotometer following the method of Jackson (1973).

Equipments: i) Beaker, ii) Volumetric flask, iii) Pipette, iii) Electric balance and iv) Atomic absorption spectrophotometer.

Standard zinc solution: 100 ppm zinc solution was used as standard. The solution contains 0.1 mg Zn/ml.

Procedure: The atomic absorbance of each of the potato tuber solutions was taken for zinc with the help of an atomic absorption Spectrophotometer using hollow cathode at 213.9 nm.

A standard curve of zinc was prepared by taking 0.0, 1.0, 2.0, 3.0 and 4.0 ml of standard (0.1 mg zn/ml) zinc solution in 100 ml volumetric flask separately and made up to the mark with deionized water. The concentration of the standard solutions was 0.0, 1.0, 2.0, 3.0 and 4.0 ppm of zinc respectively. A reagent blank was taken with distilled water. The atomic absorbance of the solutions was taken at 213.9 nm and standard curve was prepared by plotting the data.

Calculation: The amount of zinc in the stock solution of potato tuber was calculated from the standard curve of zinc. Finally, the amount of zinc present in the potato tuber was determined using the formula given below:

$$\text{Amount of zinc (mg/100 g of potato tuber)} = \frac{\text{Weight of zinc obtained}}{\text{Weight of potato tuber}} \times 100$$

3.2.3. **Statistical Analysis**

3.2.3.1. *Univariate analysis*

Same as describe in 2.2.12. under chapter II.

3.2.3.2. *Multivariate analysis*

The genetic divergence for nutritional quality characters of thirty two potato genotypes was estimated following Mahalanobis (1936) generalized distance (D^2) extended by Rao (1952). Non-hierarchical cluster analysis by Beale (1969) was followed for determining the group constellations. Canonical analysis was also done according to Rao (1986) to confirm the result of cluster and D^2 analysis. Mean data of the characters were subjected to multivariate analysis techniques for principal component analysis (PCA), principal coordinate analysis (PCO), cluster analysis (CLSA) and canonical variate analysis (CVA) were done by computer using GENSTAT 5.13 software programme.

1. Principal component analysis (PCA)

Principal component analysis is one of the multivariate techniques to know the interrelationship among several characters and can be done from the sum of squares and product matrix of 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 the unity (Jeger *et al.,* 1983). The latent roots are called “Eigen values”. The first component has the property of accounting for maximum variance. The PCA displays most of the original variability in a smaller number of dimensions, since it finds linear combinations of a set of variate that maximize the variation contained within them. Contribution of different characters towards divergence is discussed from the latent vectors of the two principal components.

2. Principal coordinate analysis (PCO)

Principal coordinate analysis is equivalent to PCA but is used to calculate inter-unit distances. Through the use of all dimensions of P it gives the minimum distance

between each pair of the N points using similarity matrix (Digby *et al.,* 1989). Inter-distances between genotypes were studied by PCO.

3. Cluster analysis (CLSA)

Genotypes 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 optimal 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 transfers genotypes from one group to another so long as such transfer improved the value of the criterion. No further transfer can be found to improve the criterion. The algorithm switches to the second stages that examine the effect swopping two genotypes of different classes, and so on.

4. Canonical variate analysis (CVA)

Canonical variate analysis (CVA), complementary to D^2-statistic, is a sort of multivariate analysis where canonical vectors and roots representing different axes of differentiation and the amount of variation accounted for by each of such axes, respectively are derived. Canonical variate analysis finds linear combination of original variability that maximize the ratio of between groups to within group variation, thereby giving functions of the original variables that can be used to discriminate between the groups. Thus in this analysis, a series of orthogonal transformations sequentially maximize the ratio among groups to within group variations.

5. Computation of average intra-cluster distance

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 $\Sigma D^2/n$ (Singh and Chaudhury (1985), where ΣD^2 is the sum of distances between all possible combinations (n) of the genotypes included in a cluster. The square roots of the average D^2 values represent the distance (D) within cluster.

6. Computation of average inter-cluster distance

Average inter-cluster distance between different clusters was calculated by taking possible D^2 values within the members of two different clusters obtained from the PCO after the clusters are formed. The formula utilized was $\Sigma D_{ij}^2/(n_i \times n_j)$ (Singh and Chaudhary (1985), where ΣD_{ij}^2 is the sum of distances for all possible combinations between the genotypes in cluster i and cluster j and n_i and n_j is the number of genotypes in cluster i and cluster j respectively.

7. Cluster diagram

A cluster diagram was drawn using the values between and within cluster distances as suggested by Singh and Chaudhary (1985). It presents a momentary idea of the pattern of diversity among the genotypes include in a cluster.

3.3. RESULTS

In the present investigation potato tubers from 32 selected genotypes were harvested at two maturity stages (70 and 90 DAP) and chemically analyzed for estimating different nutritional quality characters *viz.,* moisture (M), dry matter (DM), specific gravity (SG), ash, pH, total soluble solids (TSS), titratable acidity (TA), total phenolic content (TPC), beta carotene (β-Car), vitamin C (VC), starch content (SC), total sugar (TS), reducing sugar (RS), non-reducing sugar (NRS), soluble protein (SP), iron (Fe), phosphorous (P), calcium (Ca), potassium (K) and zinc (Zn) content. The data recorded on different nutritional characters were analyzed using different statistical procedure and the results are presented below under separate heads. The brief analysis of variance of data in respect of various parameters studied are shown in **Appendix III**

3.3.1. **Mean Performances of Nutritional Quality characters**

3.3.1.1. *Moisture content (%)*

Moisture content in tuber significantly varied among the genotypes and decreased with maturity. Moisture content ranged from 74.59 to 83.36 % in tubers harvested at 70 DAP and 73.04 to 82.48% at 90 DAP. The highest moisture content was measured in G_{31} (83.36%) which was statistically similar to G_{19} (83.24%), G_9 (82.25%), G_1 (82.03%) and G_7 (81.91%) when tuber harvested at 70 DAP. The lowest was recorded in G_{12} (74.59%) which was statistically similar to G_{23} (75.45%). In case of tuber harvested at 90 DAP the highest moisture content was found in G_{31} (82.48%) and it was statistically similar to G_{19} (82.37%) and G_9 (81.45%). Lowest moisture content in tuber was observed in G_{12} (73.04%) and was statistically similar to G_{23} (74.16%) and G_{15} (74.18%) **(Table 3.1)**.

3.3.1.2. *Dry matter content (%)*

Significant variation was observed among the thirty two potato genotypes for percentage of dry matter both in tuber harvested at 70 and 90 DAP and increased with the maturity of tuber. Percentages of dry matter ranged from 16.64 to 25.41 in tuber harvested at 70 DAP and 17.52 to 26.96 at 90 DAP. The highest dry matter content in tuber at 70 DAP was measured in G_{12} (25.41%) which was statistically similar to G_{23} (24.55%). The lowest was determined in G_{31} (16.64%) which was statistically similar

to G_{19} (16.76%), G_9 (17.75%), G_7 (18.09) and G_1 (17.97). G_{12} also showed the highest dry matter (26.96%) content when tuber harvested at 90 DAP and statistically similar to G_{23} (25.84%) and G_{15} (25.82%). The lowest dry matter content was estimated in G_{31} (17.52%) and similar to G_9 (18.55%) and G_{19} (17.63%) **(Table 3.1).**

3.3.1.3. *Specific gravity*

Specific gravity of tuber significantly varied among the genotypes and increased with the maturity of tuber. Specific gravity ranged from 1.066 to 1.107 in tuber harvested at 70 DAP and 1.070 to 1.114 at 90 DAP. The highest specific gravity was measured in G_{12} (1.107) which was followed by G_{23} (1.103), G_8 (1.098) and G_{22} (1.098) and was statistically similar to each other when tuber harvested at 70 DAP. The lowest was recorded in G_{19} (1.066) and G_{31} (1.066) which were followed by G_9 (1.071), G_1 (1.072), G_7 (1.073) and G_{27} (1.075). In case of tuber harvested at 90 DAP the highest specific gravity was found in G_{12} (1.114) and it was statistically similar to G_{23} (1.109), G_{15} (1.108), G_{24} (1.104), G_{29} (1.104), G_{13} (1.103) and G_{22} (1.103). Lowest moisture content in tuber was observed in G_{19} (1.070) and G_{31} (1.070) and was statistically similar to G_9 (1.075), G_1 (1.079), G_7 (1.079) and G_{27} (1.079) **(Table 3.2)**.

3.3.1.4. *Ash content (%)*

Significant variation was observed among the thirty two potato genotypes for ash content in tuber both at 70 and 90 DAP harvest and increased with maturity. Ash content ranged from 0.809 to 1.004 in tuber harvested at 70 DAP and 0.895 to 1.198 at 90 DAP. The highest ash content in tuber at 70 DAP was measured in G_{15} (1.004) which was statistically similar to G_5 (1.002), G_{12} (1.002), G_{16} (0.995) and G_{29} (0.998). The lowest ash content in tuber harvested at 70 DAP was determined from G_9 (0.809). G_{12} showed the highest ash (1.198) content when tuber harvested at 90 DAP and followed by G_{15} (1.102), G_5 (1.086) and G_{23} (1.064). The lowest ash content was estimated in G_9 (0.895) which was statistically similar to G_3 (0.907) and G_{19} (0.902) **(Table 3.2)**.

Table 3.1 Mean performances of moisture and dry matter content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Moisture (%)		Dry matter (%)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	82.03 $^{a-c}$	80.62 $^{b-c}$	17.97 $^{l-n}$	19.38 $^{k-m}$
G_2	80.10 $^{d-f}$	79.05 $^{d-f}$	19.90 $^{i-k}$	20.95 $^{i-k}$
G_3	77.74 $^{g-k}$	76.56 $^{i-l}$	22.26 $^{c-h}$	23.44 $^{c-f}$
G_4	79.22 $^{e-h}$	78.12 $^{f-i}$	20.78 $^{g-j}$	21.88 $^{f-i}$
G_5	77.92 $^{g-k}$	76.76 $^{h-l}$	22.08 $^{c-h}$	23.24 $^{c-g}$
G_6	77.87 $^{g-k}$	76.46 $^{i-l}$	22.13 $^{c-h}$	23.54 $^{c-f}$
G_7	81.91 $^{a-c}$	80.45 $^{c-e}$	18.09 $^{l-n}$	19.55 $^{j-l}$
G_8	76.56 ^{kl}	75.97 $^{k-m}$	23.44 ^{bc}	24.03 $^{b-d}$
G_9	82.25 $^{a-c}$	81.45 $^{a-c}$	17.75 $^{l-n}$	18.55 $^{l-n}$
G_{10}	78.35 $^{f-k}$	76.99 $^{g-l}$	21.65 $^{c-i}$	23.01 $^{c-h}$
G_{11}	79.10 $^{e-i}$	78.19 $^{f-i}$	20.90 $^{e-j}$	21.81 $^{f-i}$
G_{12}	74.59 ^{m}	73.04 ^{n}	25.41 ^{a}	26.96 ^{a}
G_{13}	77.02 $^{j-l}$	75.49 ^{lm}	22.98 $^{b-d}$	24.51 ^{bc}
G_{14}	77.33 $^{h-l}$	76.01 $^{j-m}$	22.67 $^{b-g}$	23.99 $^{b-e}$
G_{15}	77.29 $^{h-l}$	74.18 ^{mn}	22.71 $^{b-f}$	25.82 ^{ab}
G_{16}	79.02 $^{e-i}$	77.92 $^{f-k}$	20.98 $^{e-j}$	22.08 $^{d-i}$
G_{17}	80.69 $^{c-e}$	78.66 $^{e-h}$	19.31 $^{j-l}$	21.34 $^{g-j}$
G_{18}	79.36 $^{e-g}$	77.99 $^{f-j}$	20.64 $^{h-j}$	22.01 $^{e-i}$
G_{19}	83.24 ^{ab}	82.37 ^{ab}	16.76 ^{mn}	17.63 ^{mn}
G_{20}	79.10 $^{e-i}$	78.04 $^{f-i}$	20.90 $^{e-j}$	21.96 $^{f-i}$
G_{21}	76.88 ^{kl}	75.67 ^{lm}	23.12 ^{bc}	24.33 ^{bc}
G_{22}	76.55 ^{kl}	75.32 ^{lm}	23.45 ^{bc}	24.68 ^{bc}
G_{23}	75.45 ^{lm}	74.16 ^{mn}	24.55 ^{ab}	25.84 ^{ab}
G_{24}	77.23 $^{i-l}$	75.22 ^{lm}	22.77 $^{b-e}$	24.78 ^{bc}
G_{25}	79.22 $^{e-h}$	78.13 $^{f-i}$	20.78 $^{f-j}$	21.87 $^{f-i}$
G_{26}	78.91 $^{e-j}$	77.80 $^{f-k}$	21.09 $^{d-j}$	22.20 $^{d-i}$
G_{27}	81.49 $^{b-d}$	80.55 $^{b-e}$	18.51 $^{k-m}$	19.45 $^{j-m}$
G_{28}	78.86 $^{e-j}$	77.75 $^{f-k}$	21.14 $^{d-j}$	22.25 $^{d-i}$
G_{29}	76.78 ^{kl}	75.22 ^{lm}	23.22 ^{bc}	24.78 ^{bc}
G_{30}	80.44 $^{c-e}$	79.41 $^{d-f}$	19.56 $^{j-l}$	20.59 $^{i-k}$
G_{31}	83.36 ^{a}	82.48 ^{a}	16.64 ^{n}	17.52 ^{n}
G_{32}	79.98 $^{d-f}$	78.93 $^{d-g}$	20.02 $^{i-k}$	21.07 $^{h-k}$
Grand Mean±SE	78.93 ± 0.560	77.65 ± 0.605	21.07 ± 0.560	22.35 ± 0.605
CV %	1.25	1.33	4.68	4.63
Level of significance	**	**	**	**

** indicate significant at 1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

Table 3.2 Mean performances of specific gravity and ash content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Specific Gravity		Ash (%)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	1.072 $^{f-i}$	1.079 $^{d-f}$	0.976 $^{b-d}$	1.007 $^{h-k}$
G_2	1.081 $^{c-i}$	1.086 $^{c-f}$	0.986 $^{a-c}$	1.018 $^{f-i}$
G_3	1.092 $^{a-e}$	1.097 $^{a-d}$	0.882 ^{j}	0.907 ^{q}
G_4	1.085 $^{b-i}$	1.090 $^{b-e}$	0.953 ^{fg}	1.011 $^{g-k}$
G_5	1.091 $^{a-f}$	1.097 $^{a-d}$	1.002 ^{a}	1.086 ^{c}
G_6	1.091 $^{a-f}$	1.098 $^{a-d}$	0.988 $^{a-c}$	1.021 $^{f-i}$
G_7	1.073 $^{e-i}$	1.079 $^{d-f}$	0.880 ^{j}	0.945 ^{p}
G_8	1.098 $^{a-c}$	1.100 $^{a-c}$	0.988 $^{a-c}$	1.010 $^{h-k}$
G_9	1.071 $^{g-i}$	1.075 ^{ef}	0.809 ^{l}	0.895 ^{q}
G_{10}	1.089 $^{a-g}$	1.096 $^{a-d}$	0.946 ^{gh}	1.025 $^{f-h}$
G_{11}	1.086 $^{b-h}$	1.090 $^{b-e}$	0.938 ^{gh}	1.018 $^{f-i}$
G_{12}	1.107 ^{a}	1.114 ^{a}	1.002 ^{a}	1.198 ^{a}
G_{13}	1.095 $^{a-c}$	1.103 $^{a-c}$	0.929 ^{h}	0.965 ^{o}
G_{14}	1.094 $^{a-d}$	1.100 $^{a-c}$	0.897 ^{ij}	0.966 ^{o}
G_{15}	1.094 $^{a-d}$	1.108 ^{ab}	1.004 ^{a}	1.102 ^{b}
G_{16}	1.086 $^{b-h}$	1.091 $^{b-e}$	0.995 ^{ab}	1.032 ^{ef}
G_{17}	1.078 $^{c-i}$	1.088 $^{c-f}$	0.930 $^{d-f}$	0.996 $^{j-l}$
G_{18}	1.084 $^{b-i}$	1.091 $^{b-e}$	0.966 $^{d-f}$	1.008 $^{h-k}$
G_{19}	1.066 ^{hi}	1.070 ^{f}	0.862 ^{k}	0.902 ^{q}
G_{20}	1.086 $^{b-h}$	1.090 $^{b-e}$	0.978 $^{b-d}$	0.994 $^{j-l}$
G_{21}	1.096 $^{a-c}$	1.101 $^{a-c}$	0.988 $^{a-c}$	1.022 $^{f-i}$
G_{22}	1.098 $^{a-c}$	1.103 $^{a-c}$	0.986 $^{a-c}$	1.012 $^{g-j}$
G_{23}	1.103 ^{ab}	1.109 ^{ab}	0.986 $^{a-c}$	1.064 ^{d}
G_{24}	1.094 $^{a-d}$	1.104 $^{a-c}$	0.973 $^{c-e}$	1.029 ^{fg}
G_{25}	1.085 $^{b-h}$	1.090 $^{b-e}$	0.889 ^{j}	0.972 ^{no}
G_{26}	1.087 $^{b-g}$	1.092 $^{b-e}$	0.956 $^{e-g}$	1.004 $^{i-l}$
G_{27}	1.075 $^{d-i}$	1.079 $^{d-f}$	0.946 ^{gh}	0.996 $^{j-l}$
G_{28}	1.087 $^{a-g}$	1.092 $^{b-e}$	0.894 ^{ij}	0.986 $^{l-n}$
G_{29}	1.097 $^{a-c}$	1.104 $^{a-c}$	0.998 ^{a}	1.048 ^{de}
G_{30}	1.080 $^{c-i}$	1.084 $^{c-f}$	0.897 ^{ij}	0.945 ^{p}
G_{31}	1.066 ^{i}	1.070 ^{f}	0.892 ^{ij}	0.976 $^{m-o}$
G_{32}	1.082 $^{c-i}$	1.086 $^{c-f}$	0.908 ^{i}	0.992 $^{k-m}$
Grand Mean±SE	1.086 ± 0.003	1.092 ± 0.003	0.944 ± 0.003	1.005 ± 0.003
CV %	0.43	0.44	0.60	0.49
Level of significance	*	*	**	**

* and ** indicate significant at 5% and 1% level of significance respectively

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.5. *pH content*

Significant variation was observed among the genotypes for pH of tuber juice both at 70 and 90 DAP harvested tuber and ranged from 5.95 to 6.44 and 6.18 to 6.54 respectively. The values of pH in the present investigation slightly increased with the maturity of tuber. The maximum pH in tuber of 70 DAP was observed in G_{22} (6.44) which was statistically similar to G_5 (6.42), G_{28} (6.42) and G_{16} (6.38). The minimum pH was observed in G_{10} (5.95). In case of tuber harvested at 90 DAP highest pH was found in G_{16} (6.54) which was statistically similar to G_{22} (6.51) and G_5 (6.50). The lowest pH content was measured from G_{10} (6.18) which was followed by G_{14} (6.20), G_{12} (6.22) and G_2 (6.24) and statistically similar to each other **(Table 3.3)**.

3.3.1.6. *Total soluble solids content (%)*

Significant variation was observed among the genotypes in case of total soluble solids (TSS) content in tuber harvested both at 70 and 90 DAP and ranged from 5.80 to 7.00 and 6.20 to 7.50 respectively. The total soluble solids (TSS) content in tuber increased with delay harvesting. The highest total soluble solids (TSS) content in tuber at 70 DAP was found in G_{12}, G_{13} and G_{24} (7.00) which were statistically similar to G_{23} (6.80), G_1 (6.75), G_8 (6.75) and G_{18} (6.75). The lowest amount of TSS was measured in three genotypes like G_7, G_{19} and G_{28} and it was 5.80. When tuber harvested at 90 DAP TSS was more than that of 70 DAP and highest TSS content was estimated from G_{13} (7.50) which was followed by G_4 (7.40) and G_{12} (7.40). The lowest amount of TSS was found in G_{28} (6.20) and it was similar to G_{30} (6.30), G_7 (6.40), G_{19} (6.40), G_{16} (6.50), G_{20} (6.50), G_{22} (6.50), G_{25} (6.50), G_{27} (6.50) **(Table 3.3)**.

Table 3.3 Mean performances of pH and total soluble solids content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	pH		Total soluble solids (%)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	6.21 $^{a-f}$	6.26 $^{b-e}$	6.75 $^{a-c}$	7.25 $^{a-c}$
G_2	6.13 $^{d-g}$	6.24 $^{b-e}$	6.40 $^{d-g}$	7.00 ^{cd}
G_3	6.34 $^{a-e}$	6.35 $^{a-e}$	6.60 $^{b-e}$	7.20 $^{a-c}$
G_4	6.15 $^{d-g}$	6.29 $^{a-e}$	6.70 $^{b-d}$	7.40 ^{ab}
G_5	6.42 $^{a-c}$	6.50 ^{ab}	6.10 ^{hi}	6.80 ^{de}
G_6	6.17 $^{b-g}$	6.25 $^{b-e}$	6.70 $^{b-d}$	7.10 $^{b-d}$
G_7	6.26 $^{a-f}$	6.30 $^{a-e}$	5.80 ^{i}	6.40 $^{f-h}$
G_8	6.29 $^{a-f}$	6.30 $^{a-e}$	6.75 $^{a-c}$	7.00 ^{cd}
G_9	6.16 $^{c-g}$	6.27 $^{a-e}$	6.70 $^{b-d}$	7.00 ^{cd}
G_{10}	5.95 ^{g}	6.18 ^{e}	6.50 $^{c-f}$	7.10 $^{b-d}$
G_{11}	6.32 $^{a-f}$	6.43 $^{a-e}$	6.60 $^{b-e}$	7.00 ^{cd}
G_{12}	6.07 ^{fg}	6.22 $^{c-e}$	7.00 ^{a}	7.40 ^{ab}
G_{13}	6.21 $^{a-f}$	6.35 $^{a-e}$	7.00 ^{a}	7.50 ^{a}
G_{14}	6.09 $^{e-g}$	6.20 ^{de}	6.40 $^{e-g}$	7.00 ^{cd}
G_{15}	6.33 $^{a-f}$	6.44 $^{a-e}$	6.50 $^{b-f}$	7.25 $^{a-c}$
G_{16}	6.38 $^{a-d}$	6.54 ^{a}	5.90 ^{i}	6.50 $^{e-h}$
G_{17}	6.29 $^{a-f}$	6.40 $^{a-e}$	6.10 ^{hi}	6.80 ^{de}
G_{18}	6.33 $^{a-f}$	6.48 $^{a-c}$	6.75 $^{a-c}$	7.00 ^{cd}
G_{19}	6.31 $^{a-f}$	6.39 $^{a-e}$	5.80 ^{i}	6.40 $^{f-h}$
G_{20}	6.28 $^{a-f}$	6.40 $^{a-e}$	5.85 ^{i}	6.50 $^{e-h}$
G_{21}	6.21 $^{a-f}$	6.31 $^{a-e}$	6.50 $^{c-f}$	7.00 ^{cd}
G_{22}	6.44 ^{a}	6.51 ^{ab}	6.00 ^{hi}	6.50 $^{e-h}$
G_{23}	6.37 $^{a-d}$	6.46 $^{a-d}$	6.80 ^{ab}	7.00 ^{cd}
G_{24}	6.36 $^{a-d}$	6.46 $^{a-d}$	7.00 ^{a}	7.25 $^{a-c}$
G_{25}	6.35 $^{a-e}$	6.49 $^{a-c}$	6.25 $^{f-h}$	6.50 $^{e-h}$
G_{26}	6.12 $^{d-g}$	6.29 $^{a-e}$	6.00 ^{hi}	6.60 $^{e-g}$
G_{27}	6.28 $^{a-f}$	6.32 $^{a-e}$	6.20 ^{gh}	6.50 $^{e-h}$
G_{28}	6.42 ^{ab}	6.48 $^{a-c}$	5.80 ^{i}	6.20 ^{h}
G_{29}	6.35 $^{a-d}$	6.49 $^{a-c}$	6.40 $^{e-g}$	6.80 ^{de}
G_{30}	6.07 ^{fg}	6.26 $^{b-e}$	5.90 ^{i}	6.30 ^{gh}
G_{31}	6.18 $^{a-g}$	6.40 $^{a-e}$	6.10 ^{hi}	6.60 $^{e-g}$
G_{32}	6.14 $^{d-g}$	6.38 $^{a-e}$	6.20 ^{gh}	6.65 ^{ef}
Grand Mean±SE	6.25±0.07	6.36±0.08	6.38±0.09	6.86±0.09
CV %	2.09	2.17	2.43	2.34
Level of significance	*	*	*	*

* indicate significant at 5% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.7. *Titratable acidity content (% as citric acid)*

Acidity content in tuber differed significantly among the genotypes and decreased with the maturity of tuber. Acidity content ranged from 0.211 to 0.475 and 0.177 to 0.339 when tuber harvested at 70 and 90 DAP respectively. Acidity content measured highest in G_{10} (0.475) which was followed by G_{18} (0.441), G_{14} (0.425), G_{30} (0.418), G_{25} (0.416), and G_{22} (0.414) at 70 DAP. The lowest acidity content was found in G_8 (0.211) which was statistically similar to G_3 (0.213), G_{28} (0.225) and G_{12} (0.226). In case of tuber harvested at 90 DAP, G_{10} (0.339) showed the highest acidity content which was statistically similar to G_{22} (0.327) and G_{25} (0.337). The lowest acidity content was found in G_3 (0.177) which was statistically similar to G_5 (0.188) and dissimilar from other genotypes **(Table 3.4)**.

3.3.1.8. *Total phenolic content (mg/100 g)*

Significant variation was noticed for total phenolic content in tuber among the different potato genotypes. Total phenolic content varied from 28.750 mg to 86.189 mg when tuber harvested at 70 DAP. In this stage of growth the highest amount of total phenolic content was found in G_{13} (86.189 mg) which was followed by G_{21} (76.010 mg), G_4 (62.705 mg) and G_{14} (59.368 mg). The lowest amount of total phenolic content was observed in genotype G_{30} (28.750 mg) and it was statistically similar to the genotypes G_{29} (29.326 mg). Total phenolic content in potato tuber decreased with maturity of tuber and it decreased from 45.543 mg at 70 DAP to 33.798 mg at 90 DAP. The highest amount of total phenolic content in tuber at 90 DAP was in genotype G_{13} (63.045 mg) which was followed by G_{21} (49.930 mg), G_{16} (47.506 mg) and G_{23} (43.895 mg). Genotype G_{30} (21.968 mg) showed the lowest amount of total phenolic content in tuber at 90 DAP **(Table 3.4)**.

Table 3.4 Mean performances of acidity and total phenolic content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Acidity (% as citric acid)		Total phenolic content (mg/100 g)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	0.283 ^{j}	0.216 ^{kl}	42.910 ^{i}	33.269 ^{jk}
G_2	0.245 ^{k}	0.203 $^{l-n}$	36.380 ^{kl}	26.568 $^{r-t}$
G_3	0.213 ^{l}	0.177 ^{o}	43.450 ^{i}	28.052 $^{p-r}$
G_4	0.375 ^{f}	0.270 $^{h-i}$	62.705 ^{c}	38.721 ^{f}
G_5	0.296 ^{ij}	0.188 ^{no}	38.236 ^{jk}	28.890 $^{o-q}$
G_6	0.310 ^{hi}	0.232 ^{jk}	35.034 ^{lm}	28.526 ^{pq}
G_7	0.281 ^{j}	0.201 $^{l-n}$	49.599 ^{gh}	36.472 ^{gh}
G_8	0.211 ^{l}	0.196 ^{mn}	49.138 ^{gh}	41.579 ^{e}
G_9	0.316 ^{h}	0.290 $^{e-g}$	43.228 ^{i}	31.530 ^{lm}
G_{10}	0.475 ^{a}	0.339 ^{a}	50.465 ^{fg}	37.264 ^{fg}
G_{11}	0.396 $^{d-e}$	0.316 $^{b-d}$	39.480 ^{j}	30.986 ^{mn}
G_{12}	0.226 ^{l}	0.196 ^{mn}	34.140 $^{l-n}$	29.320 $^{n-p}$
G_{13}	0.380 ^{ef}	0.237 ^{j}	86.189 ^{a}	63.045 ^{a}
G_{14}	0.425 ^{c}	0.264 ^{i}	59.368 ^{d}	35.682 $^{g-i}$
G_{15}	0.346 ^{g}	0.196 ^{mn}	52.424 ^{ef}	37.322 ^{fg}
G_{16}	0.378 ^{f}	0.261 ^{i}	54.056 ^{e}	47.506 ^{c}
G_{17}	0.352 ^{g}	0.288 $^{e-h}$	47.498 ^{h}	33.160 $^{j-l}$
G_{18}	0.441 ^{b}	0.318 ^{bc}	47.940 ^{h}	30.352 $^{m-o}$
G_{19}	0.290 ^{j}	0.208 ^{lm}	35.726 ^{l}	28.428 ^{pq}
G_{20}	0.290 ^{j}	0.199 $^{l-n}$	42.359 ^{i}	36.229 ^{gh}
G_{21}	0.315 ^{h}	0.286 $^{f-h}$	76.010 ^{b}	49.930 ^{b}
G_{22}	0.414 ^{c}	0.327 ^{ab}	35.478 ^{lm}	28.028 $^{p-r}$
G_{23}	0.353 ^{g}	0.274 $^{g-i}$	58.173 ^{d}	43.895 ^{d}
G_{24}	0.350 ^{g}	0.267 ^{i}	51.787 ^{f}	35.434 ^{hi}
G_{25}	0.416 ^{c}	0.337 ^{a}	33.321 ^{mn}	25.216 ^{tu}
G_{26}	0.408 ^{cd}	0.304 $^{c-f}$	39.325 ^{j}	31.756 $^{k-m}$
G_{27}	0.378 ^{f}	0.272 $^{g-i}$	47.850 ^{h}	34.182 ^{ij}
G_{28}	0.225 ^{l}	0.206 $^{l-n}$	35.518 ^{lm}	27.216 $^{q-s}$
G_{29}	0.292 ^{j}	0.196 ^{mn}	29.326 ^{o}	24.215 ^{u}
G_{30}	0.418 ^{c}	0.308 $^{c-e}$	28.750 ^{o}	21.968 ^{v}
G_{31}	0.318 ^{h}	0.216 ^{kl}	32.418 ^{n}	26.235 st
G_{32}	0.364 ^{fg}	0.298 $^{d-f}$	39.086 ^{j}	30.568 $^{m-o}$
Grand Mean±SE	0.337±0.003	0.253±0.003	45.543±0.66	33.798±0.56
CV %	1.40	1.92	2.64	2.82
Level of significance	**	**	***	***

** and *** indicate significant at 1% and 0.1% level of significance respectively

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.9. *β-carotene content (µg/100 g)*

Significant variation was existed in β-carotene content among the different potato genotypes. Among the thirty two potato genotypes only six genotypes exhibited remarkable β-carotene content and rest of the potato genotypes showed either no or negligible (trace) amount of β-carotene. The highest amount of β-carotene in tuber harvested at 70 DAP was found in G_{23} (47.565 µg) and was followed by G_{27} (43.342 µg) and G_{24} (41.678 µg), G_7 (38.297 µg), G_1 (18.070 µg) and G_3 (14.490 µg). When tuber harvested at 90 DAP the amount of β-carotene content slightly reduced from 47.565 µg to 45.786 µg in G_{23}. The other genotypes also exhibited the same trend **(Table 3.5)**.

3.3.1.10. *Vitamin C content (mg/100 g)*

Wide range of variation was observed among the genotypes in respect of vitamin C content. It was also observed that the amount of vitamin C content increased with the maturity of tuber. Vitamin C content in tuber ranged from 10.21 mg to 17.42 mg at 70 DAP and 11.62 mg to 21.10 mg at 90 DAP. The highest amount of vitamin C was obtained from G_{24} (17.42 mg) followed by G_7 (16.68 mg) and G_{23} (16.37 mg) and the lowest amount of vitamin C was recorded from G_{19} (10.21 mg) which was statistically similar to G_{32} (10.34 mg) at 70 DAP. The average amount of vitamin C was 13.09 mg at 70 DAP. In case of tuber harvested at 90 DAP the highest amount of vitamin C was estimated from G_{24} (19.70 mg) which was statistically similar to G_7 (19.34 mg). The lowest amount of vitamin C was measured from G_{19} (12.68 mg) which was statistically similar to G_{32} (13.02 mg) and G_{31} (13.18 mg). The average amount of vitamin C was 15.85 mg at 90 DAP **(Table 3.5)**.

Table 3.5 Mean performances of β-carotene and vitamin C content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	β-carotene (µg/100 g)		Vitamin C (mg/100 g)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	18.07	17.137	13.485 ^{de}	15.760 $^{e-g}$
G_2	Trace	Trace	12.327 $^{i-k}$	14.260 ^{kl}
G_3	14.49	13.056	15.480 ^{c}	17.800 ^{c}
G_4	0.000	0.000	15.173 ^{c}	18.420 ^{b}
G_5	0.000	0.000	12.440 $^{i-k}$	15.520 $^{f-h}$
G_6	Trace	Trace	11.658 $^{l-n}$	14.857 $^{i-k}$
G_7	38.30	36.437	16.677 ^{b}	19.340 ^{a}
G_8	0.000	0.000	11.857 $^{k-m}$	14.976 $^{h-j}$
G_9	Trace	Trace	11.687 $^{l-n}$	14.288 ^{kl}
G_{10}	0.000	0.000	11.186 ^{n}	15.647 $^{e-g}$
G_{11}	Trace	Trace	12.753 $^{g-j}$	13.637 ^{m}
G_{12}	0.000	0.000	13.397 $^{d-f}$	15.153 $^{g-j}$
G_{13}	0.000	0.000	13.200 $^{e-h}$	16.500 ^{d}
G_{14}	0.000	0.000	13.360 $^{d-g}$	16.259 ^{de}
G_{15}	0.000	0.000	12.658 $^{h-j}$	15.650 ^{fg}
G_{16}	0.000	0.000	12.333 $^{i-k}$	13.376 ^{mn}
G_{17}	0.000	0.000	11.897 $^{k-m}$	15.279 $^{g-i}$
G_{18}	0.000	0.000	12.517 ^{mn}	14.224 ^{l}
G_{19}	Trace	Trace	10.207 ^{o}	12.678 ^{o}
G_{20}	0.000	0.000	13.923 ^{d}	18.415 ^{b}
G_{21}	Trace	Trace	13.090 $^{e-h}$	16.119 $^{d-e}$
G_{22}	0.000	0.000	15.447 ^{c}	17.478 ^{c}
G_{23}	47.56	45.786	16.373 ^{b}	18.669 ^{b}
G_{24}	41.68	40.548	17.423 ^{a}	19.700 ^{a}
G_{25}	0.000	0.000	15.270 ^{c}	17.670 ^{c}
G_{26}	0.000	0.000	12.653 $^{h-j}$	15.314 $^{g-i}$
G_{27}	43.34	41.478	12.443 $^{i-k}$	14.551 $^{j-l}$
G_{28}	0.000	0.000	14.160 $^{j-l}$	15.204 $^{g-i}$
G_{29}	0.000	0.000	12.833 $^{f-i}$	14.879 $^{h-k}$
G_{30}	0.000	0.000	12.320 $^{i-k}$	15.217 $^{g-i}$
G_{31}	Trace	Trace	11.220 ^{n}	13.177 $^{m-o}$
G_{32}	0.000	0.000	10.337 ^{o}	13.017 ^{no}
Grand Mean±SE	-	-	13.09±0.20	15.85±0.20
CV %	-	-	2.61	2.16
Level of significance	-	-	**	**

** indicate significant at 1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.11. *Starch content (%)*

Potato genotypes under investigation were significantly different in total content of starch. The starch content in tuber increased with the maturity of tuber and it increased from 14.73% at 70 DAP to 15.84% at 90 DAP. Among the studied genotypes starch content ranged from 11.12 to 17.94% at 70 DAP and 11.75 to 19.69% at 90 DAP. When the tuber harvested at 70 DAP the highest amount of starch content was observed in G_{12} (17.94%) which was statistically similar to G_{23} (17.59%) while the lowest amount of starch was noted from G_{31} (11.12%) and was similar to G_{19} (11.23%). In case of tuber harvested at 90 DAP the highest amount of starch was estimated from G_{12} (19.69%) and it was similar to G_{23} (19.35%). The lowest amount of starch content in tuber of 90 DAP was G_{31} (11.75%) and it was statistically similar to G_{19} (11.83%) **(Table 3.6)**.

3.3.1.12. *Total sugar content (%)*

The genotypes exhibited wide range of variation in respect of total sugar content. Total sugar content in tuber ranged from 0.95 to 2.02% and 0.80 to 1.72% at 70 and 90 DAP respectively. The highest amount of total sugar was found in G_{20} (2.02%) which was statistically similar to G_{10} (2.01%) while the lowest amount of total sugar content was recorded from G_{27} (0.95%) and G_{22} (0.95%) which were followed by G_8 (1.08%), G_{25} (1.03%) at 70 DAP. The average amount of total sugar content was 1.50% at 70 DAP. Total sugar content in potato tuber decreased with maturity of tuber and it decreased from 1.50% at 70 DAP to 1.27% at 90 DAP. In case of tuber harvested at 90 DAP the highest amount of total sugar content was estimated from G_{20} (1.72%) which was followed by G_{10} (1.70%), G_{32} (1.62%), G_{26} (1.57%), G_{19} (1.55%) and G_{12} (1.57%). The lowest amount of total sugar content was measured from G_{22} (0.80%) and statistically similar to G_{27} (0.81%) The average amount of total sugar content was 1.27% at 90 DAP **(Table 3.6)**.

Table 3.6 Mean performances of starch and total sugar content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Starch (%)		Total Sugar (%)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	13.274 ^{lm}	14.36 ^{i}	1.293 ^{n}	1.103 ^{p}
G_2	13.802 ^{kl}	14.59 ^{i}	1.623 ^{i}	1.376 ^{j}
G_3	15.246 ^{gh}	16.11 ^{gh}	1.299 ^{n}	1.084 ^{q}
G_4	14.522 ^{ij}	15.34 ^{h}	1.821 ^{de}	1.545 ^{e}
G_5	15.417 ^{fg}	16.59 ^{fg}	1.750 ^{g}	1.485 ^{g}
G_6	15.493 ^{fg}	16.50 ^{fg}	1.387 ^{m}	1.175 ^{n}
G_7	11.843 ^{o}	12.87 ^{j}	1.806 ^{e}	1.523 ^{f}
G_8	16.707 ^{cd}	17.82 ^{cd}	1.077 ^{s}	0.909 ^{v}
G_9	12.494 ^{n}	13.10 ^{j}	1.263 ^{o}	1.137 ^{o}
G_{10}	14.768 ^{hi}	15.89 ^{gh}	2.014 ^{a}	1.698 ^{b}
G_{11}	14.508 ^{ij}	15.98 ^{gh}	1.119 ^{r}	0.968 ^{s}
G_{12}	17.939 ^{a}	19.69 ^{a}	1.836 ^{d}	1.567 ^{d}
G_{13}	15.990 ^{ef}	17.09 $^{d-f}$	1.307 ^{n}	1.058 ^{r}
G_{14}	15.922 ^{ef}	17.04 ^{ef}	1.546 ^{k}	1.275 ^{m}
G_{15}	16.322 ^{de}	18.64 ^{b}	1.776 ^{f}	1.507 ^{f}
G_{16}	14.763 ^{hi}	15.91 ^{gh}	1.140 ^{q}	0.948 ^{t}
G_{17}	13.983 ^{jk}	15.48 ^{h}	1.213 ^{p}	0.984 ^{s}
G_{18}	14.496 ^{ij}	15.49 ^{h}	1.777 ^{f}	1.454 ^{h}
G_{19}	11.233 ^{p}	11.83 ^{k}	1.820 ^{de}	1.551 ^{de}
G_{20}	14.577 ^{ij}	15.63 ^{h}	2.020 ^{a}	1.717 ^{a}
G_{21}	16.185 ^{de}	17.69 $^{c-e}$	1.716 ^{h}	1.428 ^{i}
G_{22}	16.225 ^{de}	17.07 $^{d-f}$	0.950 ^{u}	0.801 ^{x}
G_{23}	17.594 ^{ab}	19.35 ^{a}	1.583 ^{j}	1.335 ^{k}
G_{24}	16.506 ^{de}	18.01 ^{bc}	1.115 ^{r}	0.931 ^{u}
G_{25}	14.547 ^{ij}	15.66 ^{h}	1.033 ^{t}	0.833 ^{w}
G_{26}	14.766 ^{hi}	15.94 ^{gh}	1.858 ^{c}	1.566 ^{d}
G_{27}	12.909 ^{mn}	13.57 ^{j}	0.946 ^{u}	0.808 ^{x}
G_{28}	13.697 ^{kl}	14.45 ^{i}	1.483 ^{l}	1.278 ^{m}
G_{29}	17.145 ^{bc}	18.32 ^{bc}	1.249 ^{o}	1.053 ^{r}
G_{30}	13.670 ^{kl}	14.57 ^{i}	1.762 ^{fg}	1.476 ^{g}
G_{31}	11.124 ^{p}	11.75 ^{k}	1.593 ^{j}	1.297 ^{l}
G_{32}	13.726 ^{kl}	14.48 ^{i}	1.918 ^{b}	1.617 ^{c}
Grand Mean±SE	14.73±0.20	15.84±0.24	1.503±0.01	1.27±0.01
CV %	2.40	2.70	1.16	1.29
Level of significance	**	**	***	***

** and *** indicate significant at 1% and 0.1% level of significance respectively

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.13. *Reducing sugar content (%)*

Significant variation was noticed for reducing sugar percentage in tuber among the different potato genotypes. Reducing sugar content varied from 0.39 to 0.89% when tuber was harvested at 70 DAP. In this stage of growth the highest amount of reducing sugar content was found in G_4 (0.89%) which was followed by G_{31} (0.81%) and G_{10} (0.78%). The lowest amount of reducing sugar content was observed in genotype G_{22} (0.39%) and it was statistically similar to the genotypes G_{11} (0.43%). Reducing sugar content in potato tuber decreased with maturity of tuber and it decreased from 0.62% at 70 DAP to 0.48% at 90 DAP. In case of tuber harvested at 90 DAP maximum reducing sugar content (0.72%) was recorded from G_4 followed by G_{10} (0.62%), G_{31} (0.61%), G_{28} (0.58%), G_{12} (0.57%) and G_{20} (0.56%). Genotype G_{22} (0.30%) showed the lowest amount of reducing sugar content in tuber which is close to G_{11} (0.34%) at 90 DAP **(Table 3.7)**.

3.3.1.14. *Non-reducing sugar content (%)*

The genotypes varied significantly for non-reducing sugar percentage at 70 and 90 DAP. Non-reducing sugar decreased from 0.84% at 70 DAP to 0.75% at 90 DAP. When tuber harvested at 70 DAP the non-reducing sugar content among the genotypes ranged from 0.46 to 1.23%. The highest non-reducing sugar content (1.23%) was found in G_{20} followed by G_{10} (1.17%), G_{32} (1.17%), G_{19} (1.16%) and G_{18} (1.11%). The genotype G_{27} had the minimum non-reducing sugar (0.46%) **(Table 3.7)**. In case of tuber harvested at 90 DAP the non-reducing sugar content among the genotypes ranged from 0.42 to 1.10%. The maximum non-reducing sugar was measured from G_{20} (1.10%) which was followed by G_{32} (1.07%), G_{19} (1.05%) and G_{10} (1.03%) but differ significantly. The lowest non-reducing sugar 0.42% was found in genotype G_{27} which was close to G_{25} (0.45%), G_{22} (0.48%) G_{24} (0.50%) and G_{16} (0.50%) but statistically differed from this genotypes **(Table 3.7).**

Table 3.7 Mean performances of reducing sugar and non-reducing sugar content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Reducing sugar (%)		Non-reducing sugar (%)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	0.542 ^{mn}	0.417 ^{no}	0.714 ^{n}	0.652 ^{m}
G_2	0.628 $^{g-j}$	0.468 ^{j}	0.946 ^{i}	0.862 ^{j}
G_3	0.529 ^{mn}	0.408 ^{no}	0.731 ^{lm}	0.642 ^{m}
G_4	0.893 ^{a}	0.716 ^{a}	0.881 ^{j}	0.787 ^{k}
G_5	0.707 ^{de}	0.536 ^{f}	0.991 ^{h}	0.901 ^{i}
G_6	0.569 $^{j-m}$	0.457 ^{jk}	0.777 ^{k}	0.682 ^{l}
G_7	0.750 ^{cd}	0.558 ^{de}	1.003 ^{gh}	0.917 ^{hi}
G_8	0.458 ^{op}	0.366 ^{p}	0.588 ^{p}	0.516 ^{pq}
G_9	0.507 ^{no}	0.449 ^{kl}	0.719 ^{mn}	0.654 ^{m}
G_{10}	0.783 ^{bc}	0.616 ^{b}	1.170 ^{b}	1.029 ^{d}
G_{11}	0.432 ^{pq}	0.343 ^{q}	0.652 ^{o}	0.594 ^{n}
G_{12}	0.707 ^{de}	0.573 ^{cd}	1.073 ^{e}	0.944 ^{g}
G_{13}	0.618 $^{h-k}$	0.485 ^{i}	0.654 ^{o}	0.544 ^{o}
G_{14}	0.608 $^{i-l}$	0.451 $^{j-l}$	0.892 ^{j}	0.783 ^{k}
G_{15}	0.674 $^{e-h}$	0.537 ^{f}	1.048 ^{f}	0.922 ^{h}
G_{16}	0.564 $^{k-n}$	0.420 ^{mn}	0.547 ^{r}	0.501 ^{q}
G_{17}	0.620 $^{h-k}$	0.436 ^{lm}	0.564 ^{q}	0.521 ^{p}
G_{18}	0.604 $^{i-l}$	0.414 ^{no}	1.114 ^{c}	0.988 ^{e}
G_{19}	0.602 $^{i-l}$	0.446 ^{kl}	1.156 ^{b}	1.050 ^{c}
G_{20}	0.725 ^{de}	0.560 ^{de}	1.230 ^{a}	1.099 ^{a}
G_{21}	0.671 $^{e-h}$	0.509 ^{gh}	0.993 ^{h}	0.873 ^{j}
G_{22}	0.391 ^{q}	0.302 ^{r}	0.531 ^{r}	0.475 ^{r}
G_{23}	0.646 $^{f-i}$	0.512 ^{g}	0.890 ^{j}	0.782 ^{k}
G_{24}	0.511 $^{m-o}$	0.402 ^{o}	0.574 ^{pq}	0.502 ^{q}
G_{25}	0.527 ^{mn}	0.365 ^{p}	0.481 ^{s}	0.445 ^{s}
G_{26}	0.709 ^{de}	0.555 ^{e}	1.092 ^{d}	0.960 ^{f}
G_{27}	0.464 ^{op}	0.365 ^{p}	0.458 ^{t}	0.421 ^{t}
G_{28}	0.671 $^{e-h}$	0.584 ^{c}	0.772 ^{k}	0.660 ^{m}
G_{29}	0.555 $^{l-n}$	0.445 ^{kl}	0.659 ^{o}	0.578 ^{n}
G_{30}	0.696 $^{d-f}$	0.503 ^{gh}	1.013 ^{g}	0.924 ^{h}
G_{31}	0.810 ^{b}	0.609 ^{b}	0.744 ^{l}	0.654 ^{m}
G_{32}	0.683 $^{e-g}$	0.494 ^{hi}	1.173 ^{b}	1.067 ^{b}
Grand Mean±SE	0.620±0.02	0.48±0.006	0.84±0.01	0.75±0.01
CV %	2.46	2.07	2.31	2.34
Level of significance	**	**	**	**

** indicate significant at 1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.15. *Soluble protein content (%)*

The tested potato genotypes exhibited wide range of variation in respect of soluble protein content. Significant variation was observed for soluble protein content in different potato genotypes both in 70 and 90 DAP. The variations ranged from 0.79 to 2.03% at 70 DAP and 0.98 to 2.36% at 90 DAP. The highest soluble protein content at 70 DAP was obtained from G_{22} (2.03%) followed by G_{12} (1.70%), G_{10} (1.61%), G_{13} (1.48%) and G_{27} (1.48%). The lowest soluble protein content was found in G_{30} (0.79%) and statistically similar to the 2nd lowest (0.89%) which was recorded in G_5 and G_{26}. In case of tuber harvested at 90 DAP the highest soluble protein content was observed in G_{22} (2.36%) which was followed by G_{13} (2.25%), G_{12} (2.16%), G_{15} (2.05%), G_{10} (2.03%) and G_{21} (2.02%). The lowest soluble protein content was found in G_{30} (0.98%) statistically differ from other genotypes. It was also revealed that soluble protein content increased with maturity of tuber. The average soluble protein content in tuber 1.25% at 70 DAP was increased to 1.61% at 90 DAP **(Table 3.8)**.

3.3.1.16. *Iron (Fe) content (mg/100 g)*

Potato is the modest source of iron. Potato genotypes under investigation were significantly differed from each other in content of iron. The iron content in tuber increased with the maturity of tuber and it varied from 1.254 mg at 70 DAP to 1.403 mg at 90 DAP. Among the studied genotypes iron content ranged from 0.689 mg to 1.920 mg at 70 DAP and 0.728 mg to 2.082 mg at 90 DAP. When the tuber was harvested at 70 DAP statistically similar higher amount of iron was found in G_{24} (1.920 mg) and G_{13} (1.896 mg) and were followed by G_8 (1.724 mg), G_{16} (1.685 mg), G_{12} (1.658 mg), G_{29} (1.576 mg), G_4 (1.562 mg) and G_{19} (1.542 mg). The lowest amount of iron content was recorded from G_{22} (0.689 mg). In case of tuber harvested at 90 DAP the highest amount of iron was recorded from G_{13} (2.082 mg). Statistically similar amount of iron was observed in G_{24} (2.061 mg) and followed by G_{12} (1.870 mg), G_8 (1.861 mg), G_{16} (1.850 mg), G_4 (1.776 mg), G_{19} (1.756 mg) and G_{29} (1.747 mg) while the lowest amount of iron was recorded from G_{22} (0.728 mg) **(Table 3.8)**.

Table 3.8 Mean performances of soluble protein and iron (Fe) content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Soluble protein (%)		Iron (mg/100 g)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	1.265 ^{jk}	1.619 ^{gh}	1.014 ^{m}	1.268 ^{j}
G_2	1.248 ^{kl}	1.586 ^{hi}	0.876 ^{o}	0.943 ^{m}
G_3	0.971 ^{t}	1.453 ^{k}	1.243 ^{hi}	1.472 ^{fg}
G_4	1.233 ^{l}	1.633 ^{gh}	1.562 ^{d}	1.776 ^{c}
G_5	0.894 ^{u}	1.168 ^{pq}	1.142 ^{kl}	1.350 ^{hi}
G_6	1.126 ^{p}	1.348 $^{l-n}$	1.187 ^{jk}	1.373 ^{h}
G_7	1.364 ^{g}	1.784 ^{e}	0.892 ^{no}	0.952 ^{m}
G_8	1.080 ^{q}	1.119 ^{q}	1.724 ^{b}	1.861 ^{b}
G_9	1.252 ^{k}	1.512 ^{j}	1.289 ^{gh}	1.447 ^{g}
G_{10}	1.605 ^{c}	2.031 ^{d}	1.186 ^{jk}	1.307 ^{ij}
G_{11}	1.032 ^{r}	1.290 ^{o}	1.206 ^{ij}	1.377 ^{h}
G_{12}	1.696 ^{b}	2.162 ^{c}	1.658 ^{c}	1.870 ^{b}
G_{13}	1.475 ^{de}	2.254 ^{b}	1.896 ^{a}	2.082 ^{a}
G_{14}	1.289 ^{i}	1.714 ^{f}	1.142 ^{kl}	1.394 ^{h}
G_{15}	1.328 ^{h}	2.046 ^{d}	0.994 ^{m}	1.282 ^{j}
G_{16}	1.318 ^{h}	1.645 ^{g}	1.685 ^{bc}	1.850 ^{b}
G_{17}	1.143 ^{o}	1.327 $^{m-o}$	0.938 ^{n}	0.961 ^{m}
G_{18}	1.408 ^{f}	1.807 ^{e}	0.904 ^{no}	0.934 ^{mn}
G_{19}	1.068 ^{q}	1.318 $^{m-o}$	1.542 ^{d}	1.756 ^{c}
G_{20}	1.200 ^{m}	1.560 ^{ij}	0.937 ^{n}	0.951 ^{m}
G_{21}	1.460 ^{e}	2.018 ^{d}	1.452 ^{e}	1.563 ^{e}
G_{22}	2.034 ^{a}	2.360 ^{a}	0.689 ^{p}	0.728 ^{o}
G_{23}	1.278 ^{ij}	1.640 ^{gh}	1.348 ^{f}	1.516 ^{ef}
G_{24}	1.354 ^{g}	1.807 ^{e}	1.920 ^{a}	2.061 ^{a}
G_{25}	1.016 ^{s}	1.295 ^{no}	1.278 ^{gh}	1.458 ^{g}
G_{26}	0.892 ^{u}	1.186 ^{p}	1.322 ^{fg}	1.570 ^{e}
G_{27}	1.483 ^{d}	1.725 ^{f}	1.088 ^{l}	1.144 ^{k}
G_{28}	0.984 ^{t}	1.352 ^{lm}	1.428 ^{e}	1.676 ^{d}
G_{29}	1.178 ^{n}	1.586 ^{hi}	1.576 $_{d}$	1.747 ^{c}
G_{30}	0.792 ^{v}	0.984 ^{r}	0.862 ^{o}	0.883 ^{n}
G_{31}	1.120 ^{p}	1.392 ^{l}	1.164 ^{jk}	1.261 ^{j}
G_{32}	1.270 ^{j}	1.796 ^{e}	0.995 ^{m}	1.082 ^{l}
Grand Mean±SE	1.246±0.01	1.61±0.017	1.254±0.013	1.403±0.016
CV %	1.66	1.89	1.77	1.94
Level of significance	**	**	***	***

** and *** indicate significant at 1% and 0.1% level of significance respectively

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.17. *Phosphorous (P) content (mg/100 g)*

Significant variation was noticed for phosphorous content in tuber among the different potato genotypes. Phosphorous content varied from 28.073 mg to 55.413 mg when tuber was harvested at 70 DAP. In this stage of growth the highest amount of phosphorous content was recorded in G_{15} (55.413 mg) which was followed by G_{24} (47.396 mg), G_8 (44.262 mg), G_{17} (43.922 mg) and G_{13} (43.074 mg). The lowest amount of phosphorous content was observed in genotype G_{19} (28.073 mg) and it was statistically similar to the genotypes G_5 (29.124 mg) and G_{25} (28.986 mg). Phosphorous content in potato tuber increased with maturity of tuber and it increased from 37.258 mg at 70 DAP to 42.195 mg at 90 DAP. The highest amount of phosphorous content in tuber at 90 DAP was in genotype G_{15} (58.368 mg) which was followed by G_{24} (52.787 mg), G_8 (50.628 mg) and G_{14} (48.992 mg). Genotype G_{25} (33.286 mg) showed the lowest amount of phosphorous content in tuber at 90 DAP which was statistically similar to G_{19} (33.872 mg) and G_5 (34.078 mg) **(Table 3.9)**.

3.3.1.18. *Calcium (Ca) content (mg/100 g)*

Calcium (Ca) content in tuber significantly varied among the investigated potato genotypes. Calcium content varied from 8.038 mg to 32.475 mg when tuber was harvested at 70 DAP. In this stage of growth maximum amount of calcium was recorded from G_{15} (32.475 mg) which was followed by G_3 (32.014 mg), G_{21} (31.429 mg), and G_{26} (30.474 mg). The lowest amount of calcium content was observed in genotype G_{25} (8.038 mg) and it was statistically similar to the genotypes G_{27} (8.587 mg) and G_{28} (8.544 mg). Calcium content in potato tuber increased with maturity of tuber and it increased from 18.751 mg at 70 DAP to 22.196 mg at 90 DAP. G_3 (39.681 mg), G_{15} (38.704 mg) and G_{21} (39.057 mg) were the statistically similar higher calcium containing genotypes at 90 DAP. Genotype G_{25} (10.102 mg) showed the lowest amount of calcium content in tuber at 90 DAP which was statistically similar to G_{27} (10.940 mg) **(Table 3.9)**.

Table 3.9 Mean performances of phosphorous (P) and calcium (Ca) content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Phosphorous (mg/100 g)		Calcium (mg/100 g)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	37.128 ^{h}	41.446 $^{h-k}$	17.728 ^{j}	19.015 ^{j}
G_2	36.728 ^{h}	40.129 $^{j-m}$	28.132 ^{f}	30.654 ^{d}
G_3	40.321 ^{de}	46.542 ^{d}	32.014 ^{ab}	39.681 ^{a}
G_4	36.984 $_{h}$	41.699 $^{g-j}$	20.129 ^{i}	24.132 ^{g}
G_5	29.124 $_{mn}$	34.078 ^{qr}	23.725 ^{h}	26.250 ^{f}
G_6	38.786 $_{e-g}$	44.072 ^{ef}	28.786 ^{ef}	32.908 ^{c}
G_7	33.720 ^{ij}	37.033 $^{m-o}$	12.842 ^{m}	15.185 ^{m}
G_8	44.262 $_{c}$	50.628 ^{c}	10.418 ^{n}	11.978 ^{no}
G_9	31.904 $^{j-l}$	39.072 $^{l-n}$	20.380 ^{i}	22.795 ^{h}
G_{10}	37.027 ^{h}	44.284 ^{ef}	16.477 ^{k}	22.981 ^{h}
G_{11}	41.382 ^{de}	45.210 ^{de}	13.528 ^{m}	15.642 ^{lm}
G_{12}	38.768 ^{gh}	43.380 $^{e-h}$	29.780 ^{de}	32.702 ^{c}
G_{13}	43.074 ^{cd}	45.049 ^{de}	16.44 ^{k}	19.450 ^{ij}
G_{14}	40.758 ^{ef}	48.992 ^{c}	13.623 ^{m}	19.206 ^{j}
G_{15}	55.413 ^{a}	58.368 ^{a}	32.475 ^{a}	38.704 ^{a}
G_{16}	39.284 ^{fg}	43.783 $^{e-g}$	11.079 ^{n}	13.036 ^{n}
G_{17}	43.922 ^{c}	46.931 ^{d}	10.503 ^{n}	12.528 ^{n}
G_{18}	34.876 ^{i}	39.238 $^{l-n}$	17.324 ^{jk}	20.432 ^{i}
G_{19}	28.073 ^{n}	33.872 ^{qr}	13.136 ^{m}	15.049 ^{m}
G_{20}	37.001 ^{h}	40.684 $^{i-l}$	17.784 ^{j}	24.744 ^{g}
G_{21}	36.894 ^{h}	38.791 $^{l-o}$	31.429 ^{bc}	39.057 ^{a}
G_{22}	37.128 ^{h}	40.925 $^{i-l}$	10.384 ^{n}	12.870 ^{n}
G_{23}	37.039 ^{h}	42.530 $^{f-i}$	15.035 ^{l}	16.387 ^{kl}
G_{24}	47.396 ^{b}	52.787 ^{b}	25.068 ^{g}	27.791 ^{e}
G_{25}	28.986 ^{mn}	33.286 ^{r}	8.038 ^{o}	10.102 ^{p}
G_{26}	32.032 $^{j-l}$	38.082 $^{m-o}$	30.474 ^{cd}	34.812 ^{b}
G_{27}	30.132 ^{lm}	36.627 ^{op}	8.587 ^{o}	10.940 ^{op}
G_{28}	36.873 ^{h}	44.178 ^{ef}	8.544 ^{o}	12.825 ^{n}
G_{29}	31.072 ^{kl}	35.770 ^{pq}	13.876 ^{m}	17.482 ^{k}
G_{30}	40.098 $^{e-g}$	45.120 ^{de}	29.489 ^{de}	33.478 ^{c}
G_{31}	31.084 ^{kl}	37.239 $^{n-p}$	15.012 ^{l}	17.432 ^{k}
G_{32}	33.000 $^{i-k}$	39.428 $^{k-n}$	17.786 ^{j}	20.012 ^{ij}
Grand Mean±SE	37.258±0.62	42.195±0.66	18.751±0.29	22.196±0.344
CV %	2.94	2.83	3.12	2.97
Level of significance	**	**	**	**

** indicate significant at 1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.1.19. *Potassium (K) content (mg/100 g)*

The content of potassium (K) in potato tuber is high. The potato genotypes exhibited wide range of variation in respect of potassium content. Significant variation was observed for potassium content in different genotypes both at 70 and 90 DAP. The variations ranged from 170.245 mg to 636.887 mg at 70 DAP and 178.524 mg to 645.791 mg at 90 DAP. It was also revealed that potassium content increased with maturity of tuber. The average potassium content in tuber was 378.264 mg at 70 DAP which was increased to 390.338 mg at 90 DAP. The highest potassium content in tuber at 70 DAP was obtained from G_{11} (636.887 mg) followed by G_9 (602.123 mg), G_{15} (552.421 mg), G_8 (550.219 mg), G_{25} (532.202 mg), G_{26} (530.213 mg) and mean differences of G_8, G_{15}, G_{25}, and G_{26} were insignificant. The lowest potassium content was found in G_{18} (170.245 mg) and statistically similar potassium content (177.579 mg) which was recorded in G_{28}. G_{11} (645.791 mg) was the highest potassium containing genotype among the investigated genotypes when tuber harvested at 90 DAP and followed by G_9 (605.406 mg), G_{15} (576.446 mg), G_8 (556.849 mg), G_{25} (545.109 mg) and G_{26} (544.926 mg). The lowest potassium content in tuber was recorded from the genotype G_{18} (178.524 mg) which was statistically similar to G_{28} (199.368 mg) **(Table 3.10)**.

3.3.1.20. *Zinc (Zn) content (mg/100 g)*

In this study there were significant differences with regard to zinc content among potato genotypes. Zinc content ranged from 0.193 mg to 0.805 mg when tuber was harvested at 70 DAP. In this stage of growth the highest amount of zinc content was found in G_8 (0.805 mg) which was followed by G_{23} (0.474 mg), G_{29} (0.470 mg), G_5 (0.466 mg), G_{25} (0.466 mg) and G_{11} (0.461 mg) and the mean differences of these genotypes were insignificant. The lowest amount of zinc was observed in genotype G_{20} (0.193 mg). Zinc content in potato tuber increased with maturity of tuber and it increased from 0.372 mg at 70 DAP to 0.393 mg at 90 DAP. In case of tuber harvested at 90 DAP highest zinc content (0.832 mg) was recorded from G_8 followed by statistically similar two genotypes G_{23} (0.523 mg) and G_5 (0.508 mg) while the lowest amount of zinc was recorded from genotype G_{20} (0.206 mg) and it differed from other thirty one genotypes **(Table 3.10)**.

Table 3.10 Mean performances of potassium (K) and zinc (Zn) content in tubers of thirty two potato genotypes harvested at different maturity stages

Genotypes	Potassium (mg/100 g)		Zinc (mg/100 g)	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	462.290 ^{e}	471.611 ^{f}	0.427 ^{c}	0.458 ^{e}
G_2	258.476 ^{k}	265.982 ^{k}	0.425 ^{c}	0.457 ^{e}
G_3	428.873 ^{fg}	446.516 ^{gh}	0.377 ^{ef}	0.395 ^{gh}
G_4	357.624 ^{j}	369.809 ^{j}	0.283 ^{k}	0.295 ^{o}
G_5	387.980 ^{i}	401.200 ^{i}	0.466 ^{b}	0.508 ^{bc}
G_6	435.005 ^{fg}	453.980 ^{fg}	0.351 ^{fg}	0.377 ^{i}
G_7	392.854 ^{hi}	402.913 ^{i}	0.398 ^{d}	0.417 ^{f}
G_8	550.219 ^{c}	556.849 ^{cd}	0.805 ^{a}	0.832 ^{a}
G_9	602.123 ^{b}	605.406 ^{b}	0.340 ^{hi}	0.355 $^{j-l}$
G_{10}	385.023 ^{i}	400.910 ^{i}	0.310 ^{j}	0.320 ^{n}
G_{11}	636.887 ^{a}	645.791 ^{a}	0.461 ^{b}	0.485 ^{d}
G_{12}	347.213 ^{j}	360.599 ^{j}	0.386 ^{de}	0.403 ^{fg}
G_{13}	414.736 ^{gh}	431.211 ^{h}	0.311 ^{j}	0.335 ^{mn}
G_{14}	442.649 $^{e-g}$	455.739 ^{fg}	0.418 ^{c}	0.450 ^{e}
G_{15}	552.421 ^{c}	576.446 ^{c}	0.337 ^{hi}	0.364 ^{ik}
G_{16}	227.333 ^{l}	238.975 ^{lm}	0.338 ^{hi}	0.356 $^{j-l}$
G_{17}	398.057 ^{hi}	402.969 ^{i}	0.360 ^{fg}	0.379 ^{hi}
G_{18}	170.246 ^{n}	178.524 ^{o}	0.338 ^{hi}	0.353 $^{j-l}$
G_{19}	508.339 ^{d}	522.445 ^{e}	0.275 ^{k}	0.297 ^{o}
G_{20}	215.823 ^{lm}	218.533 ^{mn}	0.193 ^{n}	0.206 ^{r}
G_{21}	347.640 ^{j}	361.797 ^{j}	0.380 ^{e}	0.399 ^{g}
G_{22}	213.049 ^{op}	219.156 ^{mn}	0.220 ^{m}	0.229 ^{q}
G_{23}	431.344 ^{fg}	459.886 ^{fg}	0.474 ^{b}	0.523 ^{b}
G_{24}	203.125 ^{m}	217.623 ^{mn}	0.352 ^{gh}	0.369 ^{ij}
G_{25}	532.202 ^{c}	545.109 ^{d}	0.466 ^{b}	0.499 ^{cd}
G_{26}	530.213 ^{c}	544.926 ^{d}	0.370 ^{ef}	0.398 ^{g}
G_{27}	258.645 ^{k}	265.822 ^{k}	0.399 ^{d}	0.420 ^{f}
G_{28}	177.579 ^{n}	199.368 ^{no}	0.256 ^{l}	0.267 ^{p}
G_{29}	459.072 ^{e}	466.784 ^{fg}	0.470 ^{b}	0.494 ^{cd}
G_{30}	269.033 ^{k}	274.942 ^{k}	0.328 ^{i}	0.339 ^{lm}
G_{31}	231.891 ^{l}	243.122 ^{l}	0.232 ^{m}	0.240 ^{q}
G_{32}	277.492 ^{k}	285.86 ^{k}	0.331 ^{i}	0.349 $^{k-m}$
Grand Mean±SE	378.264±6.95	390.338±7.19	0.372±0.006	0.393±0.006
CV %	3.52	3.36	2.92	2.57
Level of significance	**	**	**	**

** indicate significant at 1% level of significance

DAP= Days after planting

Mean values in a column followed by the same letters are not significantly different at 5% level of significance according to DMRT

3.3.2. **Genetic Parameters**

In the present study different genetic parameters *viz.,* genotypic variance (δ^2g), Phenotypic variance (δ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2b), genetic advance (GA), genetic advance as percentage of mean for different nutritional quality characters of thirty two potato genotypes were estimated to compare the variation among the genotypes. Results obtained on different genetic parameters are presented in T**able 3.11** and described separately.

3.3.2.1. *Genotypic (δ^2g) and phenotypic (δ^2p) variances*

The estimated genotypic variance among all the studied nutritional quality characters of thirty two potato genotypes revealed that the highest genotypic variance (δ^2g) was recorded for potassium content in tuber (17172.29) at 70 DAP and it was followed by total phenolics (272.08), calcium (62.24), phosphorous (33.97) and dry matter (4.49) contents. The lowest genotypic variance (δ^2g) was estimated for specific gravity (0.0001). Phenotypic variances for all the characters studied among the genotypes were also estimated and the highest value of phenotypic variance (δ^2p) was recorded for the character potassium content in tuber (17349.67) followed by total phenolics (273.58), calcium (62.58), phosphorous (35.17) and dry matter (5.46) contents. The lowest phenotypic variance (δ^2p) was estimated for specific gravity (0.0001)**.** When tuber harvested at 90 DAP the highest genotypic variance (δ^2g) was recorded for potassium content in tuber (17428.29) and it was followed by calcium (80.19), total phenolics (70.65), phosphorous (30.70) and dry matter (5.28) contents. The lowest genotypic variance (δ^2g) was estimated for specific gravity (0.0001). Phenotypic variances for all the characters studied among the genotypes were also estimated and the highest value of phenotypic variance (δ^2p) was also recorded for the character potassium content in tuber (17600.29) followed by calcium (80.63), total phenolics (71.56), phosphorous (32.13) and dry matter (6.35) contents. The lowest phenotypic variance (δ^2p) was estimated for specific gravity (0.0001) **(Table 3.11).**

3.3.2.2. *Genotypic (GCV) and phenotypic (PCV) coefficients of variation*

The values of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for thirty two potato genotypes was presented in **Table 3.11**. GCV

ranged from 0.912 to 42.073 and 0.982 to 40.346 at 70 and 90 DAP respectively PCV ranged from 1.005 to 42.189 and 1.078 to 40.455 at 70 and 90 DAP respectively. The maximum GCV was estimated for calcium content in tuber (42.073) at 70 DAP which was followed by total phenolics (35.488), potassium (34.643), zinc (29.145), non-reducing sugar (27.548), iron (25.296), total sugar (21.947), titratable acidity (20.880) and soluble protein (20.267) contents in tuber. The lowest GCV was for specific gravity (0.912). GCV value was also higher for calcium content in tuber (40.346) at 90 DAP and followed by potassium (33.821), zinc (29.064), non-reducing sugar (27.633), iron (25.743), total phenolics (24.870), total sugar (22.181), soluble protein (21.083) and titratable acidity (20.037) contents in tuber. The lowest GCV was for specific gravity (0.982). High value for PCV was estimated for calcium content in tuber (42.189) at 70 DAP followed by total phenolics (35.586), potassium (34.822), zinc (29.29), non-reducing sugar (27.645), iron (25.358), total sugar (21.978), titratable acidity (20.927) and soluble protein (20.334) contents in tuber. The lowest PCV was for specific gravity (1.005). PCV value was also higher for calcium content in tuber (40.455) at 90 DAP and followed by potassium (33.988), zinc (29.178), non-reducing sugar (27.731), iron (25.816), total phenolics (25.029), total sugar (22.218), soluble protein (21.168) and titratable acidity (20.128) contents in tuber while the lowest PCV was for specific gravity (1.078).

3.3.2.3. *Broad sense heritability (h^2b)*

In the present study estimated broad sense heritability was high for all the characters except for pH both at 70 and 90 DAP. pH (33.78%) at 70 DAP showed moderate heritability, on the other hand at 90 DAP, pH (18.18%) showed low heritability. The highest broad sense heritability (h^2b) at 70 DAP was exhibited in total sugar content in tuber (99.72%) followed by titratable acidity (99.56%), iron (99.51%), calcium (99.45%) and total phenolics (99.45%) contents in tuber and at 90 DAP the highest broad sense heritability (h^2b) was also observed in total sugar content in tuber (99.66%) followed by zinc (99.63%), calcium (99.46%), iron (99.44) and ash (99.31%) contents in tuber and the rest of the traits both at 70 and 90 DAP also showed above 90% heritability **(Table 3.11)**.

3.3.2.4. *Genetic advance (GA) and genetic advance as percentage of mean*

The maximum genetic gain of 86.43% (expressed as % of mean) was observed in calcium content in tuber at 70 DAP followed by total phenolics (72.90%), potassium (71.00%), zinc (59.74%), non-reducing sugar (56.55%) and iron (51.98%) contents in tuber and rest of the nutritional quality traits under investigation showed below 50.00% of genetic gain (expressed as %). The minimum genetic gain of 1.70% was found in specific gravity of tuber at 70 DAP. pH value of the tuber juice at 70 DAP was also showed minimum genetic gain (1.79%) and it was close to specific gravity. Characters like calcium, total phenolics, potassium, zinc, non-reducing sugar and iron contents in tuber showed high heritability value as well as high value of genetic advance as percent of mean. The other characters except specific gravity and pH showed high heritability and moderate genetic advance as percentage of mean. Specific gravity showed high heritability and low genetic advance as percent of mean. pH showed moderate heritability but low genetic advance as percentage of mean **(Table 3.11)**.

In case of tuber harvested at 90 DAP the highest genetic gain of 82.89% (expressed as % of mean) was observed in calcium content in tuber followed by potassium (69.33%), zinc (59.64%), non-reducing sugar (56.72%), iron (52.88%) and total phenolics (50.91%) contents in tuber and rest of the nutritional quality traits under investigation showed below 50.00% of genetic gain (expressed as % of mean). The minimum genetic gain of 0.90% was found in pH. Specific gravity of tuber at 90 DAP was also showed minimum genetic gain (1.85%) and it is close to pH. Nutritional quality characters like calcium, potassium, zinc, non-reducing sugar, iron and total phenolics contents in tuber showed high heritability value as well as high value of genetic advance as percentage of mean. The other characters except specific gravity and pH showed high heritability and moderate genetic advance as percentage of mean. Specific gravity showed high heritability and low genetic advance as percentage of mean. pH had low heritability and also low genetic advance as percentage of mean **(Table 3.11)**.

3.3.3. **Correlation Studies Among Tuber Yield and Nutritional Quality Characters of Tuber**

Correlation coefficients between tuber yield and nutritional quality characters and correlation coefficients among tuber nutritional quality characters of the studied potato genotypes at genotypic and phenotypic levels were presented in T**able 3.12** and **Table 3.13.**

3.3.3.1. *Genotypic correlation coefficients among tuber yield and nutritional quality characters of tuber*

Genotypic correlation coefficients between tuber yield and its nutritional quality characters and among the nutritional quality characters both at 70 and 90 DAP are presented in **Table 3.12.** Dry matter content in tuber showed significantly negative correlation with tuber yield/ha (r_g= -0.242) at 70 DAP and negative but non-significant correlation with tuber yield (r_g= -0.103) at 90 DAP. Dry matter content in tuber showed highly significant positive correlation with starch (r_g=0.985 and r_g=0.983), vitamin C (r_g=0.339 and r_g=0.493), total phenolics (r_g=0.277 and r_g=0.309), soluble protein (r_g=0.301 and r_g=0.434), iron (r_g=0.360 and r_g=0.355) and phosphorous (r_g=0.432 and r_g=0.487) contents both at 70 and 90 DAP respectively. Calcium content in tuber exhibited significant positive correlation with dry matter (r_g=0.254) at 70 DAP but showed highly significant at 90 DAP (r_g=0.332) and zinc content in tuber showed significant positive correlation with dry matter (r_g=0.286) at 90 DAP but highly significant at 70 DAP (r_g=0.286). Dry matter content in tuber exhibited positive but non-significant correlation with potassium content in tuber (r_g=0.013 and r_p=0.042) both at 70 and 90 DAP respectively. In case of total sugar content and reducing sugar contents in tuber showed non-significant negative correlation with dry matter content both at 70 DAP (r_g= -0.070 and r_g= -0.160) and 90 DAP (r_g= -0.056 and r_g= -0.031) respectively.

It was revealed that total phenolic content decreased with the increase of tuber yield/ha both at 70 and 90 DAP because total phenolic content in tuber showed highly significant negative correlation with tuber yield/ha (r_g= -0.298) at 70 DAP and significant negative correlation with tuber yield/ha (r_g= -0.213) at 90 DAP. Total phenolic content in tuber showed highly significant positive correlation with starch (r_g=0.272 and r_g=0.316), soluble protein (r_g=0.327 and r_g=0.455), iron (r_g=0.378 and

r_g=0.430) and phosphorous (r_g=0.366 and r_g=0.288) contents in tuber both at 70 and 90 DAP respectively. Total phenolic content in tuber had significant positive relationship towards vitamin C (r_g=0.227) when tuber harvested at 70 DAP but positive non-significant relationship when harvested at 90 DAP (r_g=0.182). Total phenolic content in tuber showed positive but non-significant correlation with total sugar (r_g=0.012), reducing sugar (r_g=0.118), calcium (r_g=0.019), potassium (r_g=0.038) and zinc contents in tuber (r_g=0.028) at 70 DAP. In case of tuber harvested at 90 DAP positive but non-significant correlation was observed between total phenolic content and reducing sugar (r_g=0.096), potassium (r_g=0.069) and zinc contents in tuber (r_g=0.090). It was also observed that total phenolic content in tuber showed negative and non-significant correlation with total sugar (r_g= -0.051) and calcium (r_g=0.036) content in tuber at 90 DAP.

Vitamin C content in tuber showed non-significant positive correlation with tuber yield/ha (r_g=0.164 and r_g=0.018) both at 70 and 90 DAP respectively. High significant positive correlation was observed between vitamin C and starch contents in tuber both at 70 DAP (r_g=0.344) and 90 DAP (r_g=0.484). Vitamin C content of 90 DAP harvested tuber had positive significant relationship with soluble protein (r_g=0.258), phosphorous (r_g=0.257) and zinc (r_g=0.220) contents in tuber. On other hand when tuber harvested at early maturity stage *i.e* at 70 DAP vitamin C content had positive but non-significant correlation with those quality traits and the values of correlation were r_g=0.200, r_g=0.192, and r_g=0.040 for soluble protein, phosphorous and zinc contents in tuber respectively. Vitamin C content in tuber showed non-significant positive correlation with iron (r_g=0.105 and r_g=0.123) and calcium (r_g=0.035 and r_g=0.027) contents both at 70 and 90 DAP respectively. Vitamin C content exhibited highly significant negative correlation with total sugar (r_g= -0.381) and reducing sugar (r_g= -0.276) content in tuber when harvested at 90 DAP and significant negative correlation with total sugar (r_g= -0.231) content but non-significant negative relationship with reducing sugar (r_g= -0.106) content in tuber at 70 DAP. Potassium content in tuber showed non-significant negative correlation with vitamin C content at 70 DAP (r_g= -0.066) but non-significant positive correlation when harvested at 90 DAP (r_g=0.102).

It was revealed that starch content in tuber and tuber yield/ha both at 70 and 90 DAP had negative correlation. When tuber harvested at 70 DAP the relation was significant (r_g= -0.238) but at 90 DAP non-significant (r_g= -0.090). Starch content in tuber showed highly significant positive correlation with soluble protein (r_g=0.283 and r_g=0.351), iron (r_g=0.361 and r_g=0.364), phosphorous (r_g=0.466 and r_g=0.473), calcium (r_g=0.264 and r_g=0.303) and zinc (r_g=0.350 and r_g=0.362) contents in tuber both at 70 and 90 DAP respectively. Starch content in tuber had positive non-significant relationship with potassium (r_g=0.080 and r_g=0.139) content in tuber at 70 and 90 DAP respectively. Starch content in tuber showed negative non-significant correlation with total sugar (r_g= -0.129 and r_g= -0.105) and reducing sugar (r_g= -0.199 and r_g= -0.092) contents at 70 and 90 DAP respectively. It was observed that the correlation value was higher in tuber of 70 DAP than the tuber of 90 DAP both for total sugar and reducing sugar contents.

Significant negative correlation was observed between total sugar content and tuber yield/ha at 90 DAP (r_g= -0.231) but the relationship was non-significant at 70 DAP (r_g= -0.175). Total sugar content in tuber had high significant positive correlation with reducing sugar (r_g=0.840 and r_g=0.778) and calcium (r_g=0.426 and r_g=0.464) contents in tuber at 70 and 90 DAP respectively. Total sugar content in tuber exhibited highly negative significant correlation with zinc (r_g= -0.340 and r_g= -0.324) content at 70 and 90 DAP respectively. Total sugar content in tuber showed non-significant negative correlation with iron (r_g= -0.200 and r_g= -0.168), phosphorous (r_g= -0.130 and r_g= -0.126) and potassium (r_g= -0.139 and r_g= -0.104) contents at 70 and 90 DAP respectively. In case of soluble protein content in tuber the relationship with total sugar was non-significant negative at 70 DAP (r_g= -0.091) but non-significant positive relation at 90 DAP (r_g=0.049).

Reducing sugar content in tuber was highly significant negative correlation with tuber yield/ha (r_g= -0.283 and r_g= -0.275) at 70 and 90 DAP respectively. Reducing sugar content exhibit highly significant positive correlation with calcium (r_g=0.275 and r_g=0.332) content in tuber at 70 and 90 DAP respectively. Reducing sugar content in tuber exhibited highly significant negative correlation with zinc (r_g= -0.387 and r_g= -0.366) content at 70 and 90 DAP respectively. Reducing sugar content had

significant negative correlation with potassium (r_g= -0.234) content at the early stage of tuber *i.e.* at 70 DAP but at 90 DAP (r_g= -0.146) it was non-significant. In case of 70 DAP reducing sugar content in tuber exhibited non-significant negative correlation with soluble protein (r_g= -0.145), iron (r_g= -0.048) and phosphorous (r_g= -0.136) contents. But at maturity stage of tuber *i. e.* at 90 DAP soluble protein (r_g=0.038) and iron (r_g=0.105) contents exhibited non-significant positive and phosphorous (r_g= -0.060) non-significant negative relationship with reducing sugar content in tuber**.**

Significant negative correlation was observed between soluble protein content and tuber yield/ha (r_g= -0.212) at 90 DAP but at 70 DAP the relation was negative and non-significant (r_g= -0.005). Soluble protein content in tuber was highly significant negative correlated with potassium (r_g= -0.305) content in tuber at 70 DAP and zinc (r_g= -0.326) content in tuber at 90 DAP. Significant negative correlation was observed between soluble protein and zinc (r_g= -0.241) contents at 70 DAP and potassium (r_g= -0.258) content at 90 DAP. Soluble protein content in tuber showed non-significant negative correlation with iron (r_g= -0.043), calcium (r_g= -0.131) contents at 70 DAP but iron (r_g=0.026) and calcium (r_g=0.081) contents were non-significant positive correlation with soluble protein content at 90 DAP. Phosphorous content in tuber had non-significant positive correlation with soluble protein (r_g=0.129 and r_g=0.178) content at 70 and 90 DAP respectively.

Iron content in tuber showed negative correlation with tuber yield/ha both the stages and this relation was significant at 70 DAP (r_g= -0.204) and non-significant at 90 DAP (r_g= -0.153). Iron content in tuber exhibited highly significant positive correlation with potassium (r_g=0.280) content at 90 DAP. Iron and zinc (r_g=0.236 and r_g=0.246) contents in tuber were significant and positively correlated at 70 and 90 DAP. Positive but non-significant correlations was observed between iron and phosphorous (r_g=0.121) and potassium (r_g=0.165) contents at 70 DAP, phosphorous (r_g=0.182) and calcium (r_g=0.026) contents at 90 DAP. Calcium content in tuber at 70 DAP was non-significant negatively correlated with iron (r_g=0.011) content.

Phosphorous content in tuber had non-significant negative correlation with tuber yield/ha (r_g= -0.139 and r_g= -0.059) at 70 DAP and 90 DAP respectively.

Phosphorous content in tuber showed positive and highly significant correlation with calcium (r_g=0.304 and r_g=0.272) content and non-significant correlation with potassium (r_g=0.066 and r_g=0.083) and zinc (r_g=0.095 and r_g=0.111) contents both at 70 and 90 DAP respectively.

Calcium content in tuber was highly significant negatively correlated with tuber yield/ha (r_g= -0.330 and r_g= -0.480) both at 70 and 90 DAP. Calcium content in tuber showed non-significant positive correlation with potassium (r_g=0.062 and r_g=0.055) content and negative correlation with zinc (r_g= -0.090 and r_g= -0.138) content at 70 and 90 DAP respectively.

Potassium content showed non-significant negative correlation with tuber yield/ha (r_g= -0.026 and r_g= -0.061) both at 70 and 90 DAP respectively. Potassium and zinc content in tuber were highly significant positively correlated with each other (r_g=0.494 and r_g=0.504) both at 70 and 90 DAP.

Zinc content in tuber was also negatively correlated with tuber yield/ha (r_g= -0.208 and r_g= -0.029) at 70 and 90 DAP respectively and the relationship was significant at 70 DAP.

3.3.3.2. *Phenotypic correlation coefficients among tuber yield and nutritional quality characters of tuber*

Phenotypic correlation coefficients between tuber yield and its nutritional quality characters and among the nutritional quality characters both at 70 and 90 DAP are presented in **Table 3.13**. Dry matter content in tuber showed significantly negative correlation with tuber yield/ha (r_p= -0.216) at 70 DAP and negative but non-significant correlation with tuber yield/ha (r_p= -0.102) at 90 DAP. Dry matter content in tuber had highly significant positive correlation with starch (r_p=0.958 and r_p=0.954), vitamin C (r_p=0.380 and r_p=0.461), total phenolics (r_p=0.287 and r_p=0.306), soluble protein (r_p=0.305 and r_p=0.423), iron (r_p=0.353 and r_p=0.322) and phosphorous (r_p=0.462 and r_p=0.497) contents in tuber both at 70 and 90 DAP respectively. Calcium content in tuber had significant positive correlation with dry matter (r_p=0.255) content at 70 DAP but highly significant at 90 DAP (r_p=0.311) and zinc content in tuber showed significant positive correlation with dry matter (r_p=0.256) content at 90 DAP but highly significant at 70 DAP (r_g=0.298). Dry matter

content in tuber exhibited positive but non-significant correlation with potassium (r_p=0.049 and r_p=0.074) content in tuber both at 70 and 90 DAP respectively. Total sugar content in tuber showed non-significant negative correlation with dry matter (r_p= -0.043 and r_p= -0.044) content both in tuber harvested at 70 DAP and 90 DAP. Reducing sugar content was non-significant negatively correlated with dry matter (r_p= -0.056) content at 70 DAP but non-significant positively correlated with dry matter (r_p=0.004) content at 90 DAP.

It was revealed that total phenolic content decreased with the increase of tuber yield/ha both at 70 and 90 DAP because total phenolic content in tuber showed highly significant negative correlation with tuber yield/ha (r_p= -0.289) at 70 DAP and significant negative correlation with tuber yield/ha (r_p= -0.208) at 90 DAP. Total phenolic content in tuber showed highly significant positive correlation with starch (r_p=0.283 and r_p=0.320), soluble protein (r_p=0.331 and r_p=0.454), iron (r_p=0.381 and r_p=0.428) and phosphorous (r_p=0.374 and r_p=0.291) contents in tuber both at 70 and 90 DAP respectively. Total Phenolic content in tuber had significant positive relationship towards vitamin C (r_p=0.238) content when tuber harvested at 70 DAP but positive non-significant relationship when harvested at 90 DAP (r_p=0.190). Total phenolic content in tuber showed positive but non-significant correlation with total sugar (r_p=0.016), reducing sugar (r_p=0.131), calcium (r_p=0.024), potassium (r_p=0.045) and zinc (r_p=0.036) contents in tuber when tuber harvested at 70 DAP. In case of tuber harvested at 90 DAP positive but non-significant correlation was observed between total phenolic content and reducing sugar (r_p=0.100), potassium (r_p=0.073) and zinc (r_p=0.095) content in tuber. It was also observed that total phenolic content in tuber showed negative and non-significant correlation with total sugar (r_p= -0.050) and calcium (r_p=0.034) contents in tuber at 90 DAP.

Vitamin C content in tuber showed non-significant positive correlation with tuber yield/ha (r_p=0.157 and r_p=0.014) both at 70 and 90 DAP respectively. Highly significant positive correlation was observed between vitamin C and starch (r_p=0.368 and r_p=0.475) contents in tuber both at 70 and 90 DAP respectively. Vitamin C content in tuber had positive significant relationship with soluble protein (r_p=0.211 and r_p=0.256) and phosphorous (r_p=0.220 and r_p=0.256) contents in tuber both at 70

and 90 DAP. Vitamin C content had positive and significant correlation with zinc (r_p=0.220) content at 90 DAP but non-significant when harvested at 70 DAP (r_p=0.057). Vitamin C content in tuber showed non-significant positive correlation with iron (r_p=0.115 and r_p=0.126) and calcium (r_p=0.046 and r_p=0.028) contents both at 70 and 90 DAP respectively. Vitamin C content exhibited highly significant negative correlation with total sugar (r_p= -0.375) and reducing sugar (r_p= -0.268) contents in tuber when harvested at 90 DAP and significant negative correlation with total sugar (r_p= -0.218) content but non-significant negative relationship with reducing sugar (r_p= -0.062) content in tuber at 70 DAP. Potassium content in tuber showed non-significant negative correlation with vitamin C (r_p= -0.048) content at 70 DAP but non-significant positive correlation when harvested at 90 DAP (r_p=0.104).

It was revealed that starch content in tuber and tuber yield/ha both at 70 and 90 DAP had negative correlation. When tuber harvested at 70 DAP the relation was significant (r_p= -0.277) and at 90 DAP negative non-significant (r_p= -0.090). Starch content in tuber showed highly significant positive correlation with soluble protein (r_p=0.292 and r_p=0.357), iron (r_p=0.366 and r_p=0.354), phosphorous (r_p=0.484 and r_p=0.487), calcium (r_p=0.270 and r_p=0.301) and zinc (r_p=0.360 and r_p=0.368) contents in tuber both at 70 and 90 DAP respectively. Positive but non-significant relationship was observed between starch and potassium (r_p=0.096 and r_p=0.152) contents in tuber at 70 and 90 DAP respectively. Starch content in tuber showed negative non-significant correlation with total sugar (r_p= -0.116 and r_p= -0.100) and reducing sugar (r_p= -0.148 and r_p= -0.074) contents at 70 and 90 DAP respectively. It was also observed that the correlation value was higher in tuber of 70 DAP than the tuber of 90 DAP both for total sugar and reducing sugar.

Significant negative correlation was observed between total sugar content and tuber yield/ha at 90 DAP (r_p= -0.228) but the relationship was non-significant at 70 DAP (r_p= -0.170). Total sugar content in tuber had high significant positive correlation with reducing sugar (r_p=0.819 and r_p=0.773) and calcium (r_p=0.427 and r_p=0.464) contents in tuber at 70 and 90 DAP respectively. Total sugar content in tuber exhibited highly significant negative correlation with zinc (r_p= -0.333 and r_p= -0.320)

content both at 70 and at 90 DAP. Total sugar content in tuber showed non-significant negative correlation with iron (r_p= -0.195 and r_p= -0.167), phosphorous (r_p= -0.119and r_p= -0.121) and potassium (r_p= -0.133 and r_p= -0.101) contents both at 70 and 90 DAP respectively. In case of soluble protein content in tuber the relationship with total sugar was non-significant negative (r_p= -0.087) at 70 DAP but showed non-significant positive relation (r_p=0.049) at 90 DAP.

Reducing sugar content in tuber exhibited negative significant correlation with tuber yield/ha (r_p= -0.257) at 70 DAP but highly significant (r_p= -0.270) at 90 DAP. Reducing sugar content exhibited highly significant positive correlation with calcium (r_p=0.275 and r_p=0.330) content in tuber at 70 and 90 DAP respectively. Highly significant negative correlation was observed between reducing sugar and zinc (r_p= -0.353 and r_p= -0.357) contents at 70 and 90 DAP respectively. Reducing sugar content had significant negative correlation with potassium (r_p= -0.205) content at the early stage of tuber *i.e.* at 70 DAP but at 90 DAP (r_p= -0.138) it was non-significant. In case of 70 DAP reducing sugar content in tuber exhibited non-significant negative correlation with soluble protein (r_p= -0.122), iron (r_p= -0.031) and phosphorous (r_p= -0.091) contents. But at maturity stage of tuber *i. e.* at 90 DAP soluble protein (r_p=0.046) and iron (r_p=0.106) contents exhibited non-significant positive and phosphorous (r_p= -0.039) content non-significant negative relationship with reducing sugar content in tuber.

Soluble protein content in tuber showed non-significant negative correlation with yield/ha at 70 DAP (r_p= -0.005) but significant negative correlation with tuber yield/ha (r_p= -0.208) at 90 DAP. Soluble protein content in tuber was highly significant negatively correlated with potassium (r_p= -0.295) content in tuber at 70 DAP and zinc (r_p= -0.318) content in tuber at 90 DAP. Significant negative correlation was observed between soluble protein and zinc (r_p= -0.232) contents at 70 DAP and potassium (r_p= -0.250) content at 90 DAP. Soluble protein content in tuber showed non-significant negative correlation with iron (r_p= -0.037) and calcium (r_p= -0.126) contents at 70 DAP but iron (r_p=0.027) and calcium (r_p=0.082) contents were non-significant positive correlation with soluble protein at 90 DAP.

Phosphorous content in tuber had non-significant positive correlation with soluble protein (r_p=0.141 and r_p=0.191) content at 70 and 90 DAP respectively.

Iron content in tuber showed non-significant negative correlation with tuber yield/ha (r_p= -0.199 and r_p= -0.151) both the harvesting situations. Iron content in tuber exhibited highly significant positive correlation with potassium (r_p=0.278) content at 90 DAP. Iron and zinc (r_p=0.241 and r_p=0.245) contents in tuber were significantly positively correlated both at 70 and 90 DAP. Positive but non-significant correlations was observed between iron and phosphorous (r_p=0.130) and potassium (r_p=0.170) contents at 70 DAP, phosphorous (r_p=0.181) and calcium (r_p=0.026) contents at 90 DAP. Calcium content in tuber at 70 DAP was non-significant negatively correlated with iron (r_p= -0.007) content.

Phosphorous content in tuber exhibited non-significant negative correlation with tuber yield/ha (r_p= -0.134 and r_p= -0.058) at 70 DAP and 90 DAP respectively. Phosphorous content in tuber had positive and highly significant correlation with calcium (r_p=0.309 and r_p=0.269) content and non-significant correlation with potassium (r_p=0.081 and r_p=0.094) and zinc (r_p=0.111 and r_p=0.120) contents both at 70 and 90 DAP respectively.

Calcium content in tuber was highly significant negatively correlated with tuber yield/ha (r_p= -0.323 and r_p= -0.469) both at 70 and 90 DAP respectively. Calcium content in tuber showed non-significant positive correlation with potassium (r_p=0.067 and r_p=0.056) content and negative correlation with zinc (r_p= -0.083 and r_p= -0.135) content at 70 and 90 DAP respectively.

Potassium content showed non-significant negative correlation with tuber yield/ha (r_p= -0.025 and r_p= -0.063) at 70 and at 90 DAP respectively. Highly significant positive correlation was observed between potassium and zinc (r_p=0.498 and r_p=0.507) content in tuber both at 70 and 90 DAP respectively.

Zinc content in tuber also showed negative correlation with tuber yield/ha (r_p= -0.203 and r_p= -0.032) at 70 and 90 DAP respectively and the relationship was significant at 70 DAP.

3.3.4. Genetic Divergence

In order to find out the extent of genetic diversity for nutritional quality at different maturity stages of tuber among the 32 potato genotypes, principal component analysis (PCA), principal coordinate analysis (PCO), cluster analysis, cluster diagram, cluster means, canonical variate analysis (CVA) were performed for 12 important nutritional characters. The results derived from these analyses are described below.

3.3.4.1. *Principal component analysis*

The principal components analysis (PCA) yielded eigen values of each principal component axes of coordination of genotypes in which the first axes totally accounting for the variation among the genotypes, whereas the first five of these eigen values above unity accounted for 77.22 cumulative percentage when tuber harvested at 70 DAP and 79.25 cumulative percentage at 90 DAP. The first three principal axes accounted for 60.57 and 62.84 cumulative percentage of the total variation among the 12 nutritional characters described in 32 potato genotypes **(Table 3.14)** at 70 and 90 DAP respectively. The first two axes scored 27.45%, 29.13% and 19.05%, 20.40% of the total variation when tuber harvested at 70 and 90 DAP respectively.

Table 3.14 Eigen values and percentage of variation for corresponding twelve nutritional quality characters in thirty two potato genotypes harvested at different maturity stages.

SL. NO.	Principal component axis	Latent roots (Eigen values)		% of total variation accounted for		Cumulative percentage	
		70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
1.	DM	3.294	3.495	27.45	29.13	27.45	29.13
2.	TPC	2.286	2.448	19.05	20.40	46.50	49.53
3.	VC	1.689	1.597	14.07	13.31	60.57	62.84
4.	SC	1.128	1.233	9.40	10.28	69.97	73.12
5.	TS	0.870	0.736	7.25	6.13	77.22	79.25
6.	RS	0.798	0.656	6.65	5.47	83.87	84.72
7.	SP	0.683	0.588	5.69	4.90	89.56	89.62
8.	Fe	0.520	0.507	4.33	4.23	93.89	93.85
9.	P	0.364	0.389	3.03	3.24	96.92	97.09
10.	Ca	0.244	0.203	2.03	1.69	98.95	98.78
11.	K	0.105	0.128	0.87	1.07	99.82	99.85
12.	Zn	0.020	0.018	0.18	0.15	100	100

DAP= Days after planting, DM= Dry matter, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc

Table 3.15 Mean principal component scores from analysis of variance of first two PCs of thirty two potato genotypes harvested at different maturity stages

Genotypes	PC1		PC2	
	70 DAP	90 DAP	70 DAP	90 DAP
G_1	-84.01	-81.25	-3.26	4.20
G_2	119.79	124.37	-8.17	-6.40
G_3	-50.66	-56.24	-0.68	-16.47
G_4	20.57	20.50	16.89	-2.52
G_5	-8.68	-10.83	-8.53	-0.65
G_6	-56.75	-63.67	-9.50	-9.46
G_7	-14.56	-12.54	2.73	7.92
G_8	-171.96	-166.54	3.91	6.23
G_9	-223.83	-215.03	-4.67	2.76
G_{10}	-6.77	-10.60	4.59	-1.95
G_{11}	-258.59	-255.42	-6.57	7.20
G_{12}	31.04	29.70	-9.76	-10.44
G_{13}	-36.65	-41.01	40.70	-3.35
G_{14}	-64.43	-65.43	13.80	0.45
G_{15}	-174.29	-186.25	10.34	-20.30
G_{16}	150.92	151.33	9.06	4.97
G_{17}	-19.79	-12.61	2.62	8.23
G_{18}	208.02	211.85	2.69	1.99
G_{19}	-129.98	-132.00	-12.80	11.79
G_{20}	162.46	171.78	-2.41	-3.28
G_{21}	30.45	28.41	30.53	-17.92
G_{22}	165.28	171.23	-9.15	8.51
G_{23}	-53.12	-69.59	12.27	3.15
G_{24}	175.05	172.62	9.60	-10.24
G_{25}	-153.82	-154.65	-14.77	16.15
G_{26}	-151.95	-154.60	-7.33	-9.19
G_{27}	119.67	124.58	0.66	11.88
G_{28}	200.76	191.03	-9.43	8.31
G_{29}	-80.71	-76.37	-17.46	7.75
G_{30}	109.25	115.40	-14.94	-9.61

G_{31}	146.46	147.30	-13.99	7.40
G_{32}	100.81	104.52	-6.92	3.19

3.3.4.2. *Construction of scatter diagram*

Based on the values of principal component scores 1 and 2 obtained from the principal component analysis **(Table 3.15),** a two dimensional scatter diagram was constructed for tuber harvested at 70 DAP using component score 1 as X-axis and component score 2 as Y-axis which was presented in F**igure 3.1**. In case of tuber harvested at 90 DAP another two dimensional scatter diagram was constructed, based on the values of principal component scores 1 and 2 obtained from the principal component analysis **(Table 3.15)** using component score 1 as X-axis and component score 2 as Y-axis which was presented in F**igure 3.2**. The scatter diagram revealed that apparently there were mainly seven clusters. The positions of the genotypes in the scatter diagram were random, which indicated the considerable diversity for nutritional quality characters among the genotypes included in the cluster.

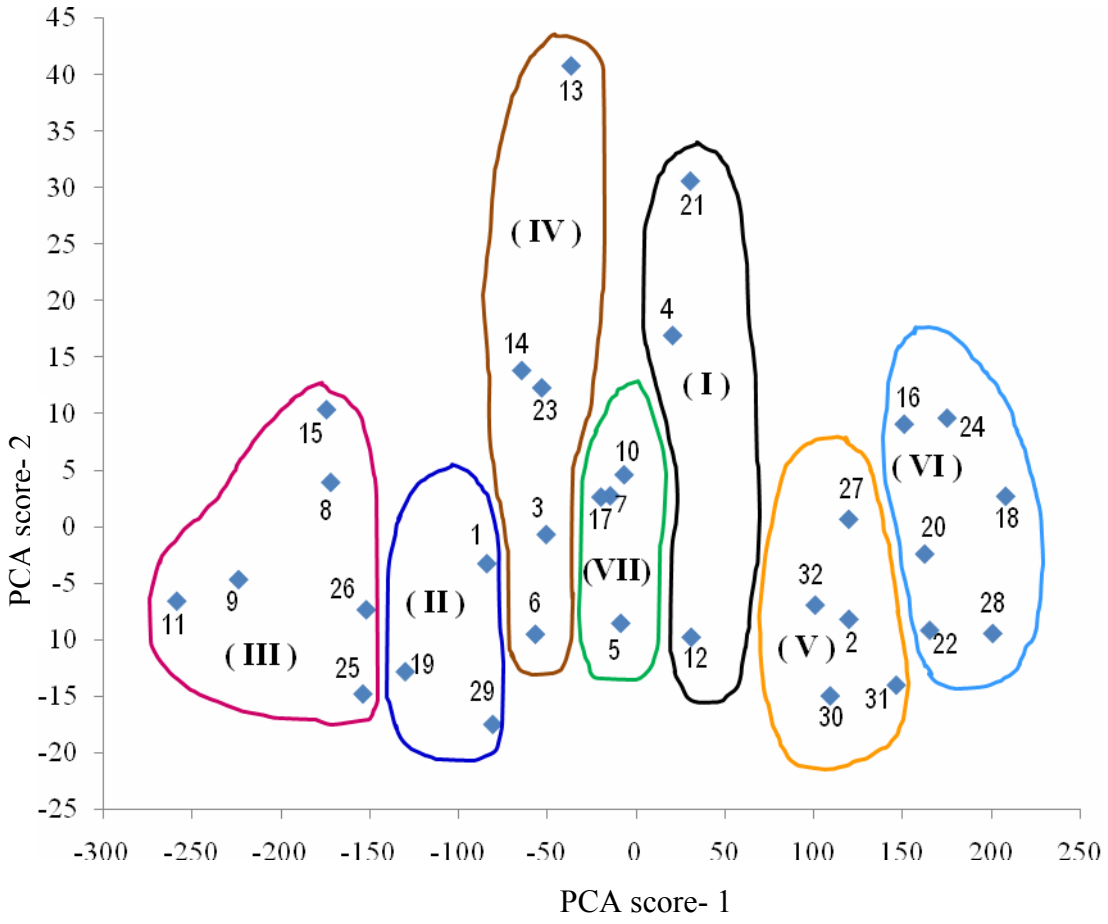

Figure 3.1 Scatter diagram of thirty two potato genotypes harvested at 70 DAP based on their principal component scores for nutritional quality component superimposed with clustering

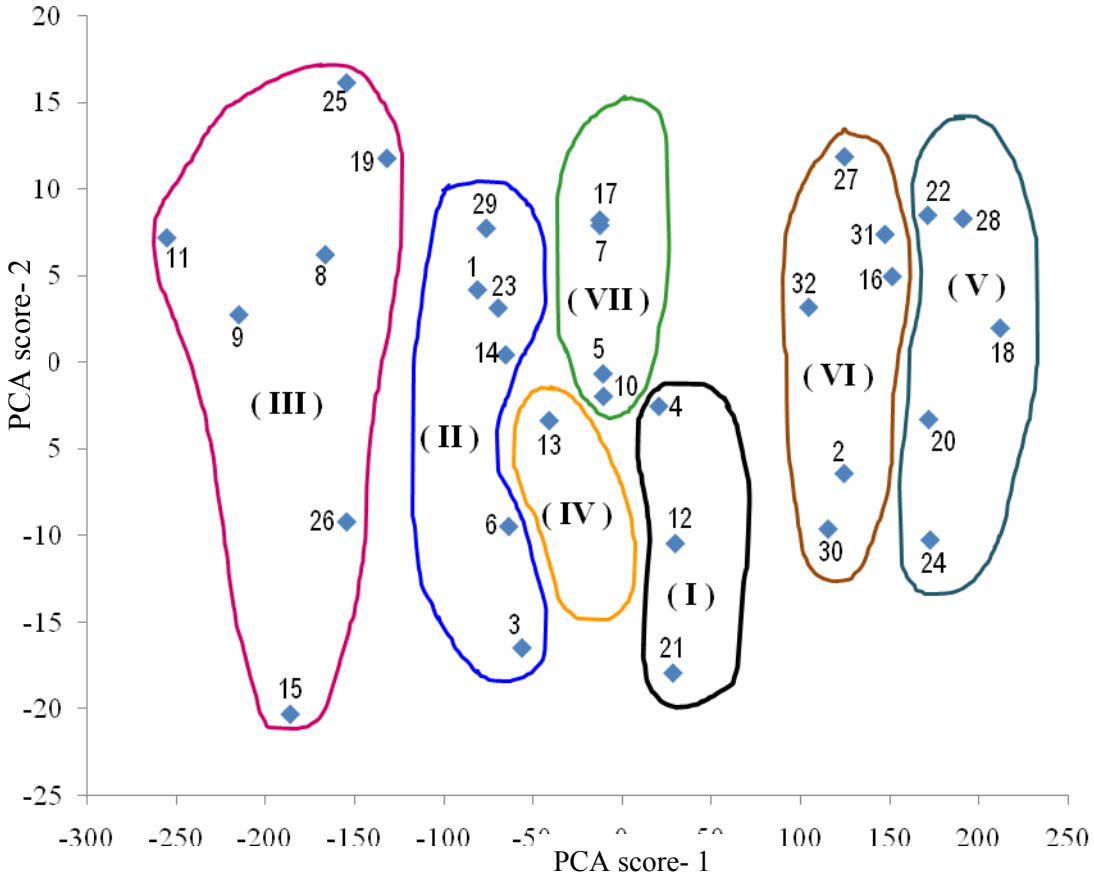

Figure 3.2 Scatter diagram of thirty two potato genotypes harvested at 90 DAP based on their principal component scores for nutritional quality component superimposed with clustering

3.3.4.3. *Cluster analysis*

On the basis of D^2 values, 32 potato genotypes were grouped into seven different clusters using the non-hierarchical clustering method by GENSTAT version 5.13 software programme in such a way that the genotypes within the cluster had smaller D^2 values among themselves than those belong to different cluster. Compositions of different clusters with their corresponding genotypes in each cluster for both the situation when tuber harvested at 70 and 90 DAP were presented in **Table 3.16**. It was revealed from **Table 3.16** that the thirty two potato genotypes were grouped into seven clusters for both the harvesting situation (70 and 90 DAP). Cluster III and VI contain the same number of genotypes and it was the maximum 6 (six) genotypes accounted 18.75% of the total genotypes, followed by cluster IV and V which contained 5 (five) genotypes each and accounted 15.63% of the total genotypes when tuber harvested at 70 DAP. The minimum number of genotypes were in cluster I and II and each of this cluster contained 3 (three) genotypes and covered 9.38% each. Cluster I consisted of three genotypes *viz.,* G_4, G_{12} and G_{21} and cluster II also three genotypes G_1, G_{19} and G_{29}. Cluster III contained six genotypes G_8, G_9, G_{11}, G_{15}, G_{25} and G_{26}. Cluster IV consisted of five genotypes G_3, G_6, G_{13}, G_{14} and G_{23}. Cluster V consisted of five genotypes G_2, G_{27}, G_{30}, G_{31} and G_{32}. Cluster VI contained six genotypes G_{16}, G_{18}, G_{20}, G_{22}, G_{24} and G_{28} and lastly cluster VII consisted of four genotypes G_5, G_7, G_{10} and G_{17}.

In case of tuber harvested at 90 DAP clusters III had the maximum 7 (seven) genotypes and accounted 21.88% of the total genotypes, followed by cluster II and VI each containing 6 (six) genotypes and accounted 18.75% of the total genotypes. The minimum number of genotype was in cluster IV containing 1 (one) genotype and covered only 3.13% of the total genotypes. Cluster I consisted of three genotypes *viz.,* G_4, G_{12} and G_{21}. Cluster II consisted of six genotypes G_1, G_3, G_6, G_{14}, G_{23} and G_{29}. Cluster III contained seven genotypes G_8, G_9, G_{11}, G_{15}, G_{19}, G_{25} and G_{26}. Cluster IV had only one genotype G_{13}. Cluster V consisted of five genotypes G_{18}, G_{20}, G_{22}, G_{24} and G_{28}. Cluster VI contained six genotypes G_2, G_{16}, G_{27}, G_{30}, G_{31} and G_{32} and lastly cluster VII consisted of four genotypes G_5, G_7, G_{10} and G_{17}.

Table 3.16 Distribution of thirty two potato genotypes in seven clusters based on nutritional quality characters of tuber harvested at different maturity stages

Cluster	DAP	No. of genotypes	Genotypes in different clusters
I	70	3	G_4, G_{12},G_{21}
	90	3	G_4, G_{12}, G_{21}
II	70	3	G_1, G_{19}, G_{29}
	90	6	G_1, G_3, G_6, G_{14}, G_{23}, G_{29}
III	70	6	G_8, G_9, G_{11}, G_{15}, G_{25}, G_{26}
	90	7	G_8, G_9, G_{11}, G_{15}, G_{19}, G_{25}, G_{26}
IV	70	5	G_3, G_6, G_{13}, G_{14}, G_{23}
	90	1	G_{13}
V	70	5	G_2, G_{27}, G_{30}, G_{31}, G_{32}
	90	5	G_{18}, G_{20}, G_{22}, G_{24}, G_{28}
VI	70	6	G_{16}, G_{18}, G_{20}, G_{22}, G_{24}, G_{28}
	90	6	G_2, G_{16}, G_{27}, G_{30}, G_{31}, G_{32}
VII	70	4	G_5, G_7, G_{10}, G_{17}
	90	4	G_5, G_7, G_{10}, G_{17}

3.3.4.4. *Cluster means*

Cluster means in respect of nutritional quality characters were computed and presented in T**able 3.17.** An appreciable variation was observed for cluster means. Percentage of dry matter had the highest mean value (23.10) in the cluster I for 70 DAP and (24.51) in cluster IV for 90 DAP followed by cluster IV (22.92) at 70 DAP and cluster I (24.39) at 90 DAP. The genotypes of cluster V showed the lowest (18.93) percentage of dry matter at 70 DAP. When tuber was harvested at 90 DAP the genotypes of cluster VI showed the lowest (20.28) percentage of dry matter content. The highest amount of total phenolic content (57.62 mg/100g) was produced by the genotypes under the cluster I at 70 DAP and it was followed by cluster IV (56.44 mg/100 g). The lowest mean value for this trait was showed by cluster II (35.99 mg/100 g). In case of tuber harvested at 90 DAP the highest mean value (63.05 mg/100 g) for total phenolic content was recorded from the genotypes under the cluster IV followed by cluster I (39.32 mg/100 g). The lowest mean value for total phenolic content was observed in cluster VI (31.17 mg/100 g). Vitamin C content in tuber at 70 DAP had the highest mean value (14.05 mg/100 g) in the cluster IV which was followed by cluster I (13.89 mg/100 g). The genotypes under cluster V produced the lowest amount (11.73 mg/100 g) of vitamin C. The highest mean value (17.54 mg/100 g) for vitamin C content in tuber at 90 DAP was observed in cluster II followed by cluster V (17.00 mg/100 g). The lowest mean value (13.47 mg/100 g) for vitamin C content in tuber was calculated from the genotypes under the cluster VI. Mean starch content 16.22 g/100 g was the highest value for the genotypes under cluster I followed by cluster IV (16.05 g/100 g) when tuber was harvested at 70 DAP. The lowest cluster mean for starch was calculated from cluster V (13.05 g/100 g). In case of tuber harvested at 90 DAP the highest (17.57 g/100 g) mean value for starch was found from cluster I which was followed by cluster IV (17.09 g/100 g). The lowest value (14.14 g/100 g) of cluster mean for starche at 90 DAP was observed in cluster VI. The maximum total sugar content in tuber at 70 DAP was found in cluster I (1.79 g/100 g) followed by cluster VII (1.70 g/100 g). The lowest total sugar content in tuber at 70 DAP was observed in cluster III (1.35 g/100 g) which was close to cluster VI (1.41 g/100 g). The highest total sugar content in tuber at 90 DAP was

found from the genotypes included in cluster I (1.51 g/100 g) followed by cluster VII (1.42 g/100 g). The lowest total sugar content in tuber (1.06 g/100 g) at 90 DAP was calculated from cluster IV and 2nd lowest (1.17 g/100 g) from cluster II. The highest cluster mean value (0.76 g/100 g) for reducing sugar content in tuber at 70 DAP was estimated in cluster I and followed by cluster VII (0.71 g/100 g). In case of tuber harvested at 90 DAP the highest reducing sugar content in tuber was also observed in cluster I (0.60 g/100 g) followed by cluster VII (0.54 f/100 g). The lowest cluster mean of reducing sugar content in tuber at 90 DAP was recorded in cluster III (0.44 g/100 g) which was very close to cluster II and V (0.45 g/100 g). The highest soluble protein content in tuber was found in cluster I (1.46 g) followed by cluster VI (1.38 g/100 g) when tuber was harvested at 70 DAP. In this stage of tuber growth the lowest average soluble protein content was in cluster III (1.10 g/100 g). In case of tuber at 90 DAP the highest amount of soluble protein (2.25 g/100 g) was estimated from the genotypes under cluster IV followed by cluster I (1.94 g/100 g). The lowest average soluble protein content (1.40 g/100 g) was found in cluster III. Cluster mean value for iron content was highest (1.56 mg/100 g) in cluster I when tuber was harvested at 70 DAP and it was followed by cluster II (1.38 mg/100 g). The lowest value (1.00 mg/100 g) of cluster mean for iron content at 70 DAP was found in cluster V which was close to cluster VII (1.04 mg/100 g). The highest iron content (2.08 mg/100 g) was recorded from the genotypes under cluster IV at 90 DAP followed by cluster I (1.78 mg/100 g). Cluster VII showed the lowest mean value for iron content (1.14 mg/100 g) in tuber at 90 DAP and it was close to cluster VI (1.19 mg/100 g). Mean phosphorous content (40.40 mg/100 g) in tuber at 70 DAP was the highest in cluster IV followed by the cluster III (39.00 mg/100 g). The minimum amount of phosphorous content in tuber at 70 DAP was found in cluster II (32.09 mg/100 g). Maximum amount of phosphorous (45.05 mg/100 g) in tuber at 90 DAP was observed from cluster IV which was followed by cluster V (43.56 mg/100 g). Cluster VI showed the minimum value (40.39 mg/100 g) for cluster mean of phosphorous at 90 DAP. The cluster mean of calcium content (27.11 mg/100 g) in tuber at 70 DAP of cluster I was the highest value among the seven clusters and it was followed by cluster IV (21.18 mg/100 g). The lowest cluster mean (14.91 mg/100 g) of calcium content was found in cluster II. In case of tuber harvested at 90 DAP the

highest cluster mean of calcium was found in cluster I (31.96 mg/100 g) followed by cluster II (24.11 mg/100 g). The lowest was observed from cluster VII (19.24 mg/100 g). Cluster mean value of potassium content was highest (567.34 mg/100 g) in cluster III when tuber was harvested at 70 DAP and it was followed by cluster II (476.57 mg/100 g). The lowest value (201.19 mg/100 g) of cluster mean for potassium content at 70 DAP was found in cluster VI. The highest potassium content (571.00 mg/100 g) was recorded from the genotypes under cluster III at 90 DAP followed by cluster II (459.09 mg/100 g). Cluster V showed the lowest mean value of potassium content (206.64 mg/100 g) in tuber at 90 DAP. The highest cluster mean value (0.46 mg/100 g) for zinc content in tuber was found in cluster III both at 70 and 90 DAP and followed by cluster II and IV (0.39 mg/100 g) at 70 DAP and cluster II (0.45 mg/100 g) at 90 DAP. The lowest cluster mean of zinc content in tuber was recorded in cluster VI (0.28 mg/100 g) and cluster V (0.28 mg/100 g) at 70 and 90 DAP respectively.

3.3.4.5. *Average intra and inter-cluster distances*

Principal coordinate analysis and canonical variate analysis were performed to compute intra and inter-cluster Mahalanobis's values. The intra and inter clusters D^2 values among 32 potato genotypes are presented in **Table 3.18**. The inter cluster distances in all cases were larger than the intra cluster distance which indicated that wider diversity was present among the genotypes of distance group. The genotypes included within a cluster had less diversity among themselves. Intra cluster distance (average D^2 value) ranged from 0.643 to 0.913 and 0.000 to 0.879 for 70 and 90 DAP respectively. In case of tuber harvested at 70 DAP it was revealed that cluster II showed minimum intra cluster (0.643) distance followed by cluster VII (0.685), whereas, maximum intra cluster distance (0.913) was shown by cluster III followed by cluster VI (0.798). When tuber harvested at 90 DAP minimum intra cluster (0.000) distance was observed in cluster IV with one genotype which was followed by cluster I (0.588), whereas, maximum intra cluster distance (0.879) was shown by cluster III followed by cluster VI (0.794). The genotypes in the cluster having maximum intra cluster distances indicated very diverse among them and was due to both natural and artificial selection forces among the genotypes**.** The inter cluster distance ranged from 3.556 to 23.313 and 3.448 to 18.269 for 70 and 90 DAP respectively. Minimum inter cluster distance was observed between the clusters I and VII (3.556) for tuber harvested at 70 DAP and cluster II and VII (3.448) for tuber harvested at 90 DAP indicated close relationship among the genotypes included in these clusters. The maximum inter clusters distance was observed between the clusters III and VI (23.313) followed by cluster III and V (17.787) for tuber harvested at 70 DAP and for tuber harvested at 90 DAP the highest inter cluster distance was found between cluster III and V (18.269) followed by cluster III and VI (15.508).

Table 3.18 Intra (bolt) and inter cluster distances (D^2) among the thirty two potato genotypes based on nutritional quality characters of tuber harvested at different maturity stages

Clusters	DAP	I	II	III	IV	V	VI	VII
I	70	**0.718**						
	90	**0.588**						
II	70	6.637	**0.643**					
	90	5.269	**0.622**					
III	70	10.630	7.633	**0.913**				
	90	10.525	5.920	**0.879**				
IV	70	4.084	5.309	7.932	**0.736**			
	90	6.796	6.400	8.473	**0.000**			
V	70	9.013	11.357	17.787	10.976	**0.778**		
	90	9.448	12.566	18.269	14.158	**0.770**		
VI	70	14.208	16.704	23.313	15.926	6.791	**0.798**	
	90	6.985	10.116	15.508	11.870	4.443	**0.794**	
VII	70	3.556	4.946	9.204	3.651	9.011	14.814	**0.685**
	90	3.953	3.448	8.747	7.018	10.052	7.447	**0.650**

3.3.4.6. *Cluster Diagram*

With the help of D^2 values within and between clusters an arbitrary cluster diagram was constructed. **Figur 3.3 and 3.4** were the cluster diagram of 32 potato genotypes when tuber harvested at 70 and 90 DAP respectively. The cluster diagram showed the relationship between different genotypes. However, the diagram was not drawn following the exact scale. It was apparent from the figure that the genotypes included in the cluster III was far diverse from genotypes of the cluster VI followed by cluster V, whereas, the genotypes belonging to clusters I and VII were least diverse for nutritional quality when tuber harvested at 70 DAP. In case of tuber harvested at 90 DAP the genotypes included in the cluster III was far diverse from genotypes of the cluster V and followed by cluster VI, whereas, the genotypes belonging to clusters II and VII were least diverse on the basis of nutritional quality characters.

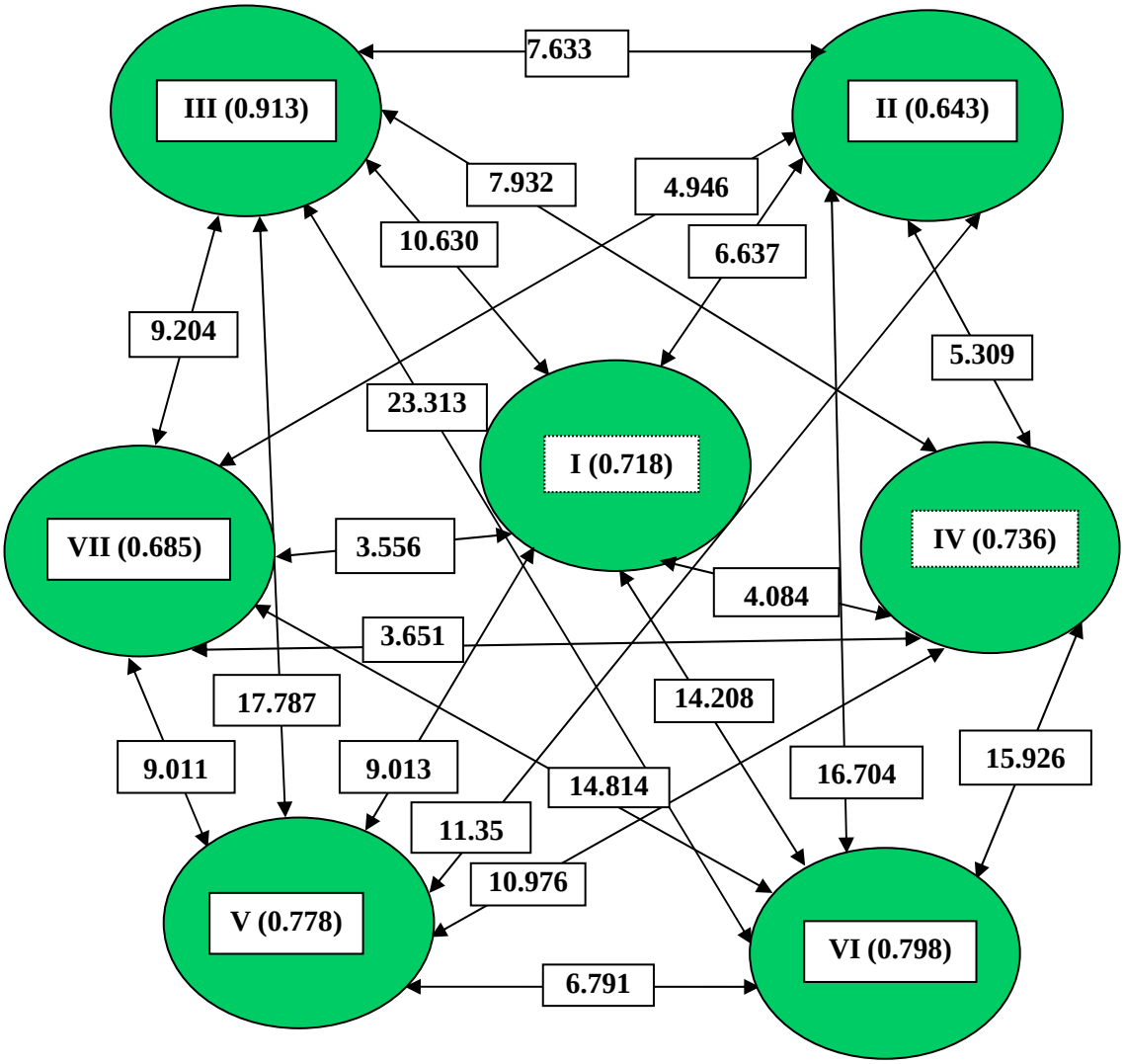

Figure 3.3 Diagram showing intra and inter cluster distance for twelve nutritional quality characters of thirty two potato genotypes harvested at 70 DAP

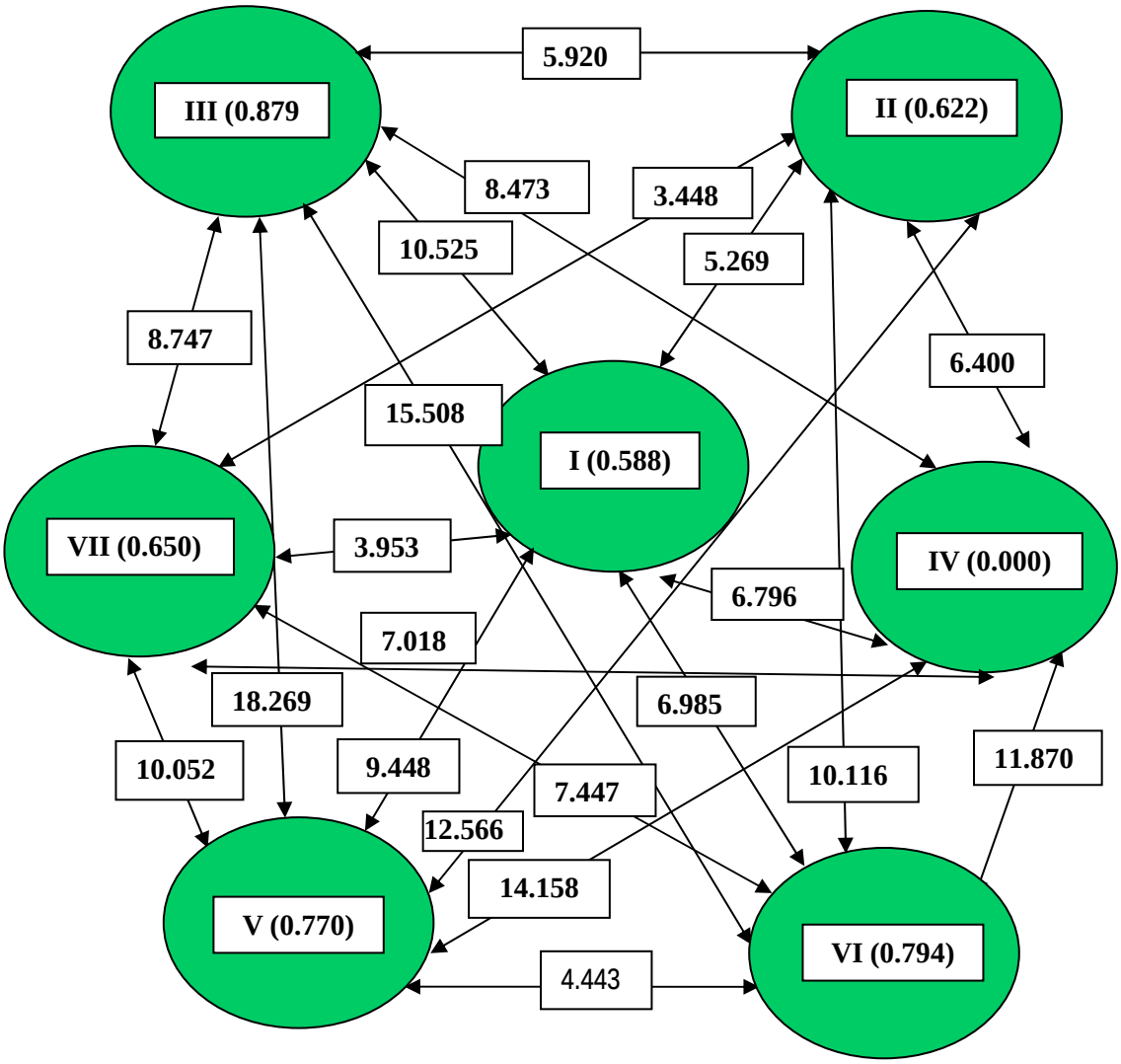

Figure 3.4 Diagram showing intra and inter cluster distance for twelve nutritional quality characters of thirty two potato genotypes harvested at 90 DAP

3.3.4.7. *Inter genotypic distances*

The results obtained from principal coordinate analysis (PCO) showed that the highest inter genotypic distance was made by G_{15} **(Table 3.19)** at 70 DAP. The genotype G_{15} made the top two and 5th highest genotypic distances with G_{28} (1.8087), G_{27} (1.6542) and G_{22} (1.6326). The 3rd and 4th highest inter genotypic distances were recorded between G_{21} and G_{25} (1.6440) and G_{26} and G_{28} (1.6368) respectively. The lowest inter genotypic distance was found between G_{14} and G_{23} (0.2828) followed by G_2 and G_{30} (0.3523) and G_3 and G_6 (0.3670).

In case of tuber harvested at 90 DAP G_{15} made the top three highest inter genotypic distance. The genotype G_{15} made the highest inter genotypic distance with G_{28} (1.6128) followed by G_{27} (1.5989) and G_{22} (1.5840). The lowest distance at 90 DAP was found in between G_3 and G_6 (0.2619) followed by G_1 and G_{14} (0.2909) and G_{14} and G_{23} (0.3344). The distance between the highest and lowest inter genotypic distance indicated the enormous variability among the studied thirty two potato genotypes.

Table 3.19 Five highest and five lowest inter genotypic distances among the thirty two potato genotypes based on nutritional quality characters of tuber harvested at different maturity stages

Inter genotypic distance							
SL. No.	DAP	Genotypic combination	Highest distance	SL. No.	DAP	Genotypic combination	Lowest distance
1	70	G_{15} - G_{28}	1.8087	1	70	G_{14} - G_{23}	0.2828
	90	G_{15} - G_{28}	1.6128		90	G_{3} - G_{6}	0.2619
2	70	G_{15} - G_{27}	1.6542	2	70	G_{2} - G_{30}	0.3523
	90	G_{15} - G_{27}	1.5989		90	G_{1} - G_{14}	0.2909
3	70	G_{21} - G_{25}	1.6440	3	70	G_{3} - G_{6}	0.3670
	90	G_{15} - G_{22}	1.5840		90	G_{14} - G_{23}	0.3344
4	70	G_{26} - G_{28}	1.6368	4	70	G_{18} - G_{20}	0.3732
	90	G_{21} - G_{25}	1.5800		90	G_{2} - G_{30}	0.3363
5	70	G_{15} - G_{22}	1.6326	5	70	G_{31}-G_{32}	0.3883
	90	G_{22} - G_{26}	1.5384		90	G_{18}-G_{20}	0.3691

3.3.4.8. *Contribution of characters towards divergence of the genotypes*

Contribution of characters towards divergence of the genotypes was obtained from canonical variate analysis (CVA) and presented in **Table 3.20**. Vector I and vector II revealed that both the vectors had positive values for dry matter (0.824, 1.900), total phenolics (0.023, 0.071), reducing sugar (24.091, 9.056), soluble protein (2.091, 0.010), calcium (0.124, 0.074) and potassium (0.061, 0.001) contents in tuber when harvested at 70 DAP. In case of tuber harvested at 90 DAP vector I and vector II both had the positive values for dry matter (0.603, 0.291), total phenolics (0.033, 0.101), iron (1.320, 0.728), phosphorous (0.062, 0.114), calcium (0.009, 0.061), potassium (0.049, 0.001) and zinc (1.016, 0.029) contents in tuber. The results indicated that dry matter, total phenolics, reducing sugar, soluble protein, iron, phosphorous, calcium potassium and zinc contents in tuber had the highest contribution towards genetic divergence for nutritional quality among the 12 characters of 32 potato genotypes. The positive values of vector-I and negative value for vector-II for the character like zinc content in tuber indicated the responsibility of primary differentiation. Responsibilities of secondary differentiation were noticed in vitamin C content in tuber. In case of tuber harvested at 90 DAP the positive value of vector-I and negative value for vector-II for the character like total sugar indicated the responsibility of primary differentiation. Responsibilities of secondary differentiation were noticed in reducing sugar and soluble protein content.

Table 3.20 Relative contributions of twelve nutritional quality characters to the total divergence in thirty two potato genotypes harvested at different maturity stages

SL. No.	Characters	Vector- I		Vector- II	
		70 DAP	90 DAP	70 DAP	90 DAP
1.	DM	0.824	0.603	1.900	0.291
2.	TPC	0.023	0.033	0.071	0.101
3.	VC	-0.148	-0.006	0.071	-0.049
4.	SC	-0.839	-0.743	-1.877	-0.216
5.	TS	-6.013	0.970	-3.205	-2.671
6.	RS	24.091	-2.202	9.056	9.539
7.	SP	2.091	-0.489	0.010	1.600
8.	Fe	-1.658	1.320	-1.140	0.728
9.	P	-0.101	0.062	-0.030	0.114
10.	Ca	0.124	0.009	0.074	0.061
11.	K	0.061	0.049	0.001	0.001
12.	Zn	9.512	1.016	-1.028	0.029

DAP= Days after planting, DM= Dry matter, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc

Table 3.11 Variability and genetic parameters for different nutritional quality characters in tuber of thirty two potato genotypes harvested at different maturity stages

Characters	Range		Mean ± SE		Variance			
					δ^2g		δ^2p	
	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
DM	16.64-25.41	17.52-26.96	21.07±0.56	22.35±0.61	4.492	5.276	5.463	6.347
SG	1.07-1.11	1.07-1.11	1.08±0.003	1.09±0.003	0.0001	0.0001	0.00012	0.0001
Ash	0.81-1.00	0.90-1.20	0.944±0.003	1.005±0.003	0.003	0.003	0.003	0.004
pH	5.95-6.44	6.18-6.54	6.25±0.07	6.36±0.08	0.009	0.004	0.026	0.023
TSS	5.80-7.00	6.20-7.50	6.38±0.09	6.86±0.09	0.139	0.116	0.163	0.141
TA	0.21-0.47	0.177-0.339	0.34±0.003	0.253±0.003	0.005	0.003	0.005	0.003
TPC	28.75-86.19	21.97-63.05	45.54±0.66	33.80±0.56	272.081	70.654	273.584	71.561
VC	10.21-17.42	11.62-21.10	13.09±0.20	15.85±0.20	3.196	4.848	3.312	4.966
SC	11.12-17.94	11.75-19.69	14.73±0.20	15.84±0.24	2.908	3.901	3.033	4.083
TS	0.95-2.02	0.80-1.72	1.503±0.01	1.27±0.01	0.109	0.079	0.109	0.079
RS	0.39-0.89	0.30-0.72	0.620±0.02	0.48±0.006	0.013	0.008	0.014	0.008
NRS	0.46-1.23	0.42-1.10	0.84±0.01	0.75±0.01	0.053	0.043	0.054	0.043
SP	0.79-2.03	0.98-2.36	1.246±0.01	1.61±0.017	0.064	0.115	0.065	0.116
Fe	0.69-1.92	0.73-2.08	1.254±0.013	1.40±0.016	0.101	0.130	0.101	0.131
P	28.07-55.41	33.29-58.37	37.26±0.62	42.20±0.66	33.972	30.698	35.171	32.125
Ca	8.04-32.48	10.10-39.68	18.75±0.29	22.20±0.344	62.237	80.192	62.580	80.628
K	170.24-636.89	178.52-645.79	378.26±6.95	390.34±7.19	17172.29	17428.29	17349.67	17600.29
Zn	0.19-0.81	0.21-0.83	0.37±0.006	0.393±0.006	0.012	0.013	0.012	0.013

Table 3.11 Contd.

Characters	GCV		PCV		h^2b (%)		GA		GA (%) of mean	
	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
DM	10.060	10.279	11.095	11.274	82.22	83.12	3.959	4.314	18.79	19.30
SG	0.912	0.982	1.005	1.078	82.22	83.12	0.018	0.020	1.70	1.85
Ash	5.302	5.831	5.335	5.851	98.76	99.31	0.103	0.120	10.85	11.97
pH	1.496	1.024	2.573	2.400	33.78	18.18	0.112	0.057	1.79	0.90
TSS	5.839	4.955	6.324	5.480	85.25	81.75	0.708	0.633	11.11	9.23
TA	20.880	20.037	20.927	20.128	99.56	99.10	0.145	0.104	42.92	41.09
TPC	35.488	24.870	35.586	25.029	99.45	98.73	33.886	17.21	72.90	50.91
VC	13.660	13.891	13.907	14.059	96.48	97.63	3.617	4.482	27.64	28.28
SC	11.576	12.472	11.822	12.760	95.88	95.54	3.440	3.977	23.35	25.11
TS	21.947	22.181	21.978	22.218	99.72	99.66	0.679	0.577	45.15	45.62
RS	18.145	19.012	18.847	19.123	92.69	98.84	0.223	0.186	35.99	38.94
NRS	27.548	27.633	27.645	27.731	99.30	99.30	0.474	0.424	56.55	56.72
SP	20.267	21.083	20.334	21.168	99.34	99.20	0.518	0.696	41.61	43.26
Fe	25.296	25.743	25.358	25.816	99.51	99.44	0.652	0.742	51.98	52.88
P	15.644	13.131	15.917	13.433	96.59	95.56	11.800	11.157	31.67	26.44
Ca	42.073	40.346	42.189	40.455	99.45	99.46	16.21	18.398	86.43	82.89
K	34.643	33.821	34.822	33.988	98.78	99.02	268.565	270.621	71.00	69.33
Zn	29.145	29.064	29.291	29.178	99.00	99.63	0.222	0.234	59.74	59.64

DAP= Days after planting, SE= Standard error, δ^2g= Genotypic variance, δ^2p= Phenotypic variance, GCV= Genotypic coefficient of variation, PCV= Phenotypic coefficient of variation, h^2b= Heritability in broad sense, GA= Genetic advance, DM= Dry matter, SG= Specific gravity, TSS= Total soluble solids, TA= Titratable acidity, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, NRS= Non-reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc

Table 3.12 Genotypic correlation coefficients among tuber yield and nutritional quality characters of thirty two potato genotypes harvested at different maturity stages

Characters	DAP	TPC	VC	SC	TS	RS	SP	Fe	P	Ca	K	Zn	Y/ha
DM	70	0.277**	0.339**	0.985**	-0.070	-0.160	0.301**	0.360**	0.432**	0.254*	0.013	0.286**	-0.242*
	90	0.309**	0.493**	0.983**	-0.056	-0.031	0.434**	0.355**	0.487**	0.332**	0.042	0.245*	-0.103
TPC	70		0.227*	0.272**	0.012	0.118	0.327**	0.378**	0.366**	0.019	0.038	0.028	-0.298**
	90		0.182	0.316**	-0.051	0.096	0.455**	0.430**	0.288**	-0.036	0.069	0.090	-0.213*
VC	70			0.344**	-0.231*	-0.106	0.200	0.105	0.192	0.035	-0.066	0.040	0.164
	90			0.484**	-0.381**	-0.276**	0.258*	0.123	0.257*	0.027	0.102	0.220*	0.018
SC	70				-0.129	-0.199	0.283**	0.361**	0.466**	0.264**	0.080	0.350**	-0.238*
	90				-0.105	-0.092	0.351**	0.364**	0.473**	0.303**	0.139	0.362**	-0.090
TS	70					0.840**	-0.091	-0.200	-0.130	0.426**	-0.139	-0.340**	-0.175
	90					0.778**	0.049	-0.168	-0.126	0.464**	-0.104	-0.324**	-0.231*
RS	70						-0.145	-0.048	-0.136	0.275**	-0.234*	-0.387**	-0.283**
	90						0.038	0.105	-0.060	0.332**	-0.146	-0.366**	-0.275**
SP	70							-0.043	0.129	-0.131	-0.305**	-0.241*	-0.005
	90							0.026	0.178	0.081	-0.258*	-0.326**	-0.212*
Fe	70								0.121	-0.011	0.165	0.236*	-0.204*
	90								0.182	0.026	0.280**	0.246*	-0.153
P	70									0.304**	0.066	0.095	-0.139
	90									0.272**	0.083	0.111	-0.059
Ca	70										0.062	-0.090	-0.330**
	90										0.055	-0.138	-0.480**
K	70											0.494**	-0.026
	90											0.504**	-0.061
Zn	70												-0.208*
	90												-0.029

*and ** indicate significant at 5% and 1% level of significance respectively

DAP= Days after planting, DM= Dry matter, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc.

Table 3.13 Phenotypic correlation coefficients among tuber yield and nutritional quality characters of thirty two potato genotypes harvested at different maturity stages

Characters	DAP	TPC	VC	SC	TS	RS	SP	Fe	P	Ca	K	Zn	Y/ha
DM	70	0.287**	0.380**	0.958**	-0.043	-0.056	0.305**	0.353**	0.462**	0.255*	0.049	0.298**	-0.216*
	90	0.306**	0.461**	0.954**	-0.044	0.004	0.423**	0.322**	0.497**	0.311**	0.074	0.256*	-0.102
TPC	70		0.238*	0.283**	0.016	0.131	0.331**	0.381**	0.374**	0.024	0.045	0.036	-0.289**
	90		0.190	0.320**	-0.050	0.100	0.454**	0.428**	0.291**	-0.034	0.073	0.095	-0.208*
VC	70			0.368**	-0.218*	-0.062	0.211*	0.115	0.220*	0.046	-0.048	0.057	0.157
	90			0.475**	-0.375**	-0.268**	0.256*	0.126	0.256*	0.028	0.104	0.220*	0.014
SC	70				-0.116	-0.148	0.292**	0.366**	0.484**	0.270**	0.096	0.360**	-0.227*
	90				-0.100	-0.074	0.357**	0.354**	0.487**	0.301**	0.152	0.368**	-0.090
TS	70					0.819**	-0.087	-0.195	-0.119	0.427**	-0.133	-0.333**	-0.170
	90					0.773**	0.049	-0.167	-0.121	0.464**	-0.101	-0.320**	-0.228*
RS	70						-0.122	-0.031	-0.091	0.275**	-0.205*	-0.353**	-0.257*
	90						0.046	0.106	-0.039	0.330**	-0.138	-0.357**	-0.270**
SP	70							-0.037	0.141	-0.126	-0.295**	-0.232*	-0.005
	90							0.027	0.191	0.082	-0.250*	-0.318**	-0.208*
Fe	70								0.130	-0.007	0.170	0.241*	-0.199
	90								0.181	0.026	0.278**	0.245*	-0.151
P	70									0.309**	0.081	0.111	-0.134
	90									0.269**	0.094	0.120	-0.058
Ca	70										0.067	-0.083	-0.323**
	90										0.056	-0.135	-0.469**
K	70											0.498**	-0.025
	90											0.507**	-0.063
Zn	70												-0.203*
	90												-0.032

*and ** indicate significant at 5% and 1% level of significance respectively

DAP= Days after planting, DM= Dry matter, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc.

Table 3.17 Cluster means for twelve nutritional quality characters of thirty two potato genotypes harvested different maturity stages

Characters	Cluster													
	I		II		III		IV		V		VI		VII	
	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
DM	23.10	24.39	19.32	23.50	21.11	21.70	22.92	24.51	18.93	23.14	21.65	20.28	20.28	21.78
TPC	57.62	39.32	35.99	32.27	42.82	32.40	56.44	63.05	36.90	31.45	44.52	31.17	46.45	33.95
VC	13.89	16.10	12.17	17.54	12.81	15.29	14.01	16.50	11.73	17.00	13.80	13.47	13.05	16.10
SC	16.22	17.57	13.88	16.95	14.89	15.56	16.05	17.09	13.05	16.13	15.04	14.14	14.00	15.21
TS	1.79	1.51	1.45	1.17	1.35	1.21	1.42	1.06	1.57	1.24	1.41	1.25	1.70	1.42
RS	0.76	0.60	0.57	0.45	0.55	0.44	0.59	0.48	0.66	0.45	0.58	0.48	0.71	0.54
SP	1.46	1.94	1.17	1.56	1.10	1.40	1.23	2.25	1.18	1.78	1.38	1.52	1.25	1.58
Fe	1.56	1.78	1.38	1.46	1.30	1.54	1.36	2.08	1.00	1.27	1.26	1.19	1.04	1.14
P	37.55	41.29	32.09	43.23	39.00	42.65	40.40	45.05	34.21	43.56	38.76	40.39	35.95	40.83
Ca	27.11	31.96	14.91	24.11	19.22	21.30	21.18	19.45	19.80	19.73	15.03	20.93	15.89	19.24
K	350.83	364.07	476.57	459.09	567.34	571.00	430.52	431.21	259.11	206.64	201.19	262.45	390.73	402.00
Zn	0.35	0.37	0.39	0.45	0.46	0.46	0.39	0.34	0.34	0.28	0.28	0.36	0.38	0.41

DAP= Days after planting, DM= Dry matter, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc.

3.4. DISCUSSION

In this part of the present research genetic divergence in 32 potato genotypes for nutritional quality characters at different maturity stages were studied. Different quality characters *viz.,* moisture (M), dry matter (DM), specific gravity (SG), ash, pH, total soluble solids (TSS), titratable acidity (TA), total phenolic content (TPC), β-carotene, vitamin C (VC), starch content (SC), soluble protein (SP), total sugar (TS), reducing sugar (RS), non-reducing sugar (NRS), iron (Fe), phosphorous (P), calcium (Ca), potassium (K) and zinc (Zn) content were determined from tubers harvested at two different maturity stages. Statistical analyses were done for analysis of variance, mean performances, genetic parameters, correlation coefficient and genetic diversity with D^2- statistics. The results obtained in this part of investigation are discussed with an endeavor to justify them.

Water is the major constituent of potato tuber. It is directly related to the dry matter content of tuber. In the present study moisture content in tuber ranged between 74.59 to 83.36% at 70 DAP and 73.04 to 82.48% at 90 DAP. These values are in general agreement with the values reported by Ekin (2011) in 8 cultivars (78.9 to 81.9%), Andre *et al.* (2007a) in 74 cultivated potato genotypes (70.0 to 81.5%) and Casanas *et al.* (2002) in five cultivars (77.1 to 81.9%). Low moisture content related to dry matter, improves crispiness of the fried products and prevents excessive fat absorption in frying (Storey and Davies, 1992).

The dry matter (DM) or 'solids content' of tubers is one of the prime characters used by potato processors. Potatoes with high DM are most suitable for the manufacture of dehydrated food products and stock feed and is especially good for the production of fried foods. For chips, French fries and dehydrated products, tuber dry matter needs to be more than 20% (Ezekiel *et al.*, 1999). Kabira and Berga (2003) reported that potatoes with a dry matter content of 20 to 24% are ideal for making French fries while those with a dry matter content of up to 24% are ideal for preparing crisps. DM content is extremely variable in potato tuber. Tuber dry matter content differs considerably between cultivars and is a strong genetic based character (Toolangi, 1995). DM content increases during the growing season and is highest in the vascular system, intermediate in the cortex and lowest in the pith. The genotypes containing higher amount of dry matter might be due to easy and early sprouting which in return

help the plant to attain maximum dry matter content (Kabir, 2014). The interactive factors *viz.*, variety, climate and soil conditions, agricultural practices, length of growing season, incidence of pest and diseases influenced tuber DM have been reviewed at length by Burton (1966) and more briefly by Grison (1973). Some author also stated that the differences in dry matter content among the cultivars could be due to variation in hereditary factors, agro-climatic conditions as well as agronomic practices followed for raising the crop (Singh and Ezekel, 2008; Sood *et al.* 2008; Talburt and Smith, 1975; Lisinska and Leszczynski, 1989; Abong *et al.* 2010; Kumar *et al.*, 2003). For maximum dry matter photo assimilates should be translocated to the tubers efficiently. Profuse distribution of conductive tissues in erect and solid stem (Artschwager, 1918) might be associated with fast translocation of photo assimilates in bulking tubers where number and size of cells increase rapidly (Moorby, 1978). Therefore, genotypes with fast bulking habit with erect growth, solid stem (efficient conducting system) must accumulate more dry matter in tubers (Nandekar *et al*., 1990). The results of the present research are in good agreement with many earlier researchers. Dry matter content of 33 potato genotypes varied from 16.3 to 26.2% (Ezekiel and Rani, 2006b) and 16.78 to 25.24% (Rajani, 2015). Abbas *et al.* (2011) found that dry matter of 32 cultivars ranged from 14.86% to 25.60%. Dry matter content 18.27 to 25.92% and 20.33 to 27.33% were reported by Addisu *et al.* (2014) and Elfnesh *et al.* (2011) respectively. A sample of 100 g of potato contains on an average 22 g DM and 78 g of moisture (Wu Leung and Flores, 1961; Wu leung *et al.*, 1968; Wu *et al.* 1978). The differences in DM content among the genotypes have also been reported by Sogut and Ozturk (2011), Anonymous (1987b), Schwimmer and Burr (1967), Uppal and Khurana (2003) and Singh *et al*. (2003). Ali *et al.* (2003) stated that dry matter content increased with the maturity from 19.60% at 60 DAP to 21.31% at 90 DAP which is in agreement with the present finding. Similar results have also been reported by Sogut and Ozturk (2011) and Khan (1995). Initially tuber growth is accomplished more by cell elongation with relatively low dry matter accumulation, which may begin after cessation of vegetative growth (Marwaha, 1998). Elfnesh *et al.* (2011) also reported that dry matter of the tuber was positively and strongly (r=0.80**) correlated with day to physiological maturity i.e. delaying maturity has substantially contributed for dry matter increment.

Specific gravity is an important character used by potato processors. In general, tubers with high specific gravity are preferred for processing (Adams, 2004). Fitzpatrick *et al.* (1964) categorized tuber specific gravity as low (1.077), intermediate (between 1.077 and 1.086) and high (>1.086). The specific gravity of the studied genotypes was nearer to many earlier researchers. Addisu *et al.* (2014) conducted an experiment and observed variation for specific gravity among the genotypes with a range of 1.068 to 1.103. Abbas *et al.* (2011) observed 32 potato genotypes and found variation in respect of specific gravity and it ranged from 1.034 to 1.144. Similar results were also reported by Elfnesh *et al.* (2011) from 1.078 to 1.110, Samih *et al.* (2011) from 1.05 to 1.07 and Amoros *et al.* (2000) from 1.121 to 1.141. Bhattacharjee *et al.* (2014) conducted an experiment with four potato varieties and reported that specific gravity showed significant variation for different varieties and it increased with the maturity of tubers which is in agreement with the present finding. The result of the present finding also supported by the finding of Ali *et al.* (2003) who reported that specific gravity of potato tubers increased with the maturity of tuber from 1.075 at 60 DAP to 1.083 at 90 DAP. Similarly Solaiman *et al.* (2015) reported that the specific gravity of tubers significantly increased from 1.050 to 1.085 with increasing harvesting time from 80 to 110 DAP. Gradual increase in specific gravity with maturity was observed by Jeong *et al.* (1996), Marwaha, 1998 and Sogut and Ozturk (2011). Specific gravity illustrated a positive relationship with starch and dry matter content (Feltran *et al.*, 2004; walter *et al.*, 1997). A decrease in starch would be expected to decrease the specific gravity of the tuber (Rowe and Powelson, 2002). Scheele *et al.* (1937) demonstrated a high correlation between DM and specific gravity when a large number of samples (56) were employed. However, the reliability of the relationship between specific gravity and total solids may be reduced when individual tubers containing intercellular air space or the phenomenon known as “hollow heart” are included in the measurements (Porter *et al.*, 1964; Burton, 1966). The regression lines calculate for the relationship can vary with factors such as soil type, growing conditions and location (Porter *et al.*, 1964; Schippers, 1976) and even cultivars (Schippers, 1976).

Significant variation in ash content in tuber was observed and the amount increased with the increase of maturity. The ash content in potato tuber at 90 DAP of the present

finding was supported by the findings of Abbas *et al.* (2011) who found that ash content in tubers of 32 cultivars ranged from 0.71% to 1.51%. Singh and Kaur (2009) reported that average ash content in potato tuber is 1% and ranged from 0.44 to 1.90%. Ash constitutes about 1% of the tuber fresh weight (Woolfe, 1987). Variation in ash may be a varietal character as mentioned by earlier researchers (Ereifej *et al.*, 1997; Sandhu and Parhawk, 2002). Addisu *et al.* (2014) observed varietal variation for total ash content in tuber. Investigations of Abong *et al.* (2009b and 2010), Dorota *et al.* (2011) and Kaur and Aggarwal (2014) came to the same trend of the present study that ash content in tuber is affected by cultivar of potato.

Significant variation was observed among the genotypes for pH of tuber juice both at 70 and 90 DAP. The value of pH in the present investigation slightly increased with the maturity of tuber. pH influences the enzyme activity in tuber which involves starch-sugar conversion. Elfnesh *et al.* (2011) reported that there was a significant difference in pH among the genotypes and the pH ranged from 6.18 to 6.37. pH of the present finding varied from 6.18 to 6.54 among the genotypes at 90 DAP which is in agreement with the finding of Elfnesh *et al.* (2011). The result is also in agreement with the findings of Nourian *et al.* (2002) who reported that pH of raw potatoes to be usually around 6.0. Feltran *et al.* (2004) reported comparatively lower pH (range 5.16 to 5.94) but significant variation was observed. Hyde and Morison (1964) investigated that relatively high pH values at harvest may be due to lower level of reducing sugar which causes the juice to become weak acid. Similar result was also observed in the present investigation.

Significant variation was observed among the genotypes in case of total soluble solids (TSS) content in tuber harvested both at 70 and 90 DAP and increased with tuber maturity. Genetic variation studies for three physicochemical traits were carried out by Verma (1997) and reported that total soluble solids (TSS) ranged from 4.1% to 6.1%. Solaiman *et al.* (2015) reported significant variation among the potato genotypes for TSS content and it ranged from 6.18 to 7.38%. They also observed that TSS content increased with tuber maturity. These results were the confirmation of the present findings. Feltran *et al.* (2004) found a significant variation for TSS content in potato genotypes and it ranged from 3.91 to 6.72%. Significant difference in potato

genotypes for total soluble solids (TSS) was observed by Nipa *et al.* (2013). They also reported that TSS content increased with delay harvesting. Variations for TSS content had also been reported by Rajani (2015), Singh and Singh (1988), Mishra (2002) and Dalakoti *et al*. (2003).

Acidity content in tuber differed significantly among the genotypes and decreased with the maturity of tuber. Organic acids serve as important precursor for the synthesis of many compounds and occupy a central position in the metabolism of plants. Organic acids also influence pH and thus alter enzyme activities. Curl and Nelson (1940) reported that the principle organic acids in potato are citric acid and malic acid with a ratio of approximately 20**:**1. Beevers *et al.* (1966) stated that the organic acids particularly citric and malic acids make notable contributions to the acidity of plant extracts. Feltran *et al.* (2004) found variation among the genotypes for titratable acidity and it range from 0.140 to 0.178%. Minina (1953) reported that citric acid content was higher in tuber than malic acid and both the acids decreased towards the end of plant vegetative period which is in agreement with the present investigation (decreased from 0.337 at 70 DAP to 0.253% as citric acid at 90 DAP). Similarly Badshah and Iritani (1989) reported that citric acid content in tuber decreased at the later stage of growth.

Significant variation was noticed for total phenolic content in tuber among the different potato genotypes both at 70 and 90 DAP. Phenolics are vital for plant development, reproduction and connected to diverse role such as protein synthesis, enzyme biosythesis, anti-pathogen, anti tumour and aids in the detection of symbionts. They also protect live plants against oxidative stress and promote healing (Shahidi and Naczk, 1995). Phenolic is an antioxidant that helps to reduce the risk of chronic diseases, including cancer, age related neuronal degeneration, or cardiovascular diseases (Ames *et al.,* 1993; Hercberg *et al.*, 1998; Velioglu *et al.*, 1998; Tamimi *et al.*, 2002). Potato is an important source of dietary phenolics. One study evaluated the contribution of 34 fruits and vegetables to phenolic intake in the American diet and concluded that potatoes were the third most important source after apple and oranges (Chun *et al*., 2005). Potato tubers contain a number of phenolic compounds. Significant variation was observed by Andre *et al.* (2007a) who reported an eleven

folds variation in total phenolic content. Navarre *et al.* (2009) found a 15 fold difference in phenolic compounds when comparing hundreds of potato genotypes, where white fleshed potatoes were reported to contain significantly less phenolics than purple fleshed wild species. Generally, purple and red fleshed genotypes contained higher amounts of total phenolic content than a cream or white flesh. The average total phenolic content in the tested genotypes at 90 DAP was 33.798 mg/100 g and ranged from 21.97 to 63.05 mg/100 g fresh potato tubers. Similar phenomenon was reported by many earlier researchers. Total phenolic content of potato was reported to be high and ranged from 530 to 1770 µg/g (Al-Saikhan *et al.*, 1995). Total phenolic content of the potato tuber ranges from 5 to 30 mg/100 g FM reported by Lisinska and Leszczynski (1989). Woolfe (1987) reported that total phenolic content ranged from 17 to 59 mg/100 g FM of potato tubers which is in agreement of the present findings. Reyes *et al.* (2004) observed that total phenolic content decreased with tuber growth and maturity but total yield of phenolics content increased through time. Similar trend was observed in the present investigation where total phenolic content decreased from 45.54 mg/100 g at 70 DAP to 33.80 mg/100 g at 90 DAP. The variation in total phenolic content in potato is an excellent example of the potential to further increase its nutritional value by more utilizing existing germplasm.

Potato contains low amount of carotenoids, such as β-carotene (Brown, 2005). The most potent dietary source of vitamin A is β-carotene (pro-vitamin A), indicating that potato is a good sources of pro-vitamin A (β-carotenes). Significant variation was existed for β-carotene among the different potato genotypes. Among the thirty two potato genotypes only six genotypes exhibited remarkable β-carotene content and rest of the potato genotypes showed either no or negligible (trace) amount of β-carotene. Potato being low fat food is also being considered as an imperative source of vitamins A and B (Lachman *et al*., 2000). There are many reports describing on the amounts of pro-vitamin A or carotene or β-carotene in potato tubers. Potato's pro-vitamin A ranged from 11 to 56 µg/100 g FM (Lisinska and Leszczynski, 1989). Carotene content in potato tubers is 24 µg/100 g FM (Ahmed, 1977). Daniel and Deuber (2012) reported that the amount of β-carotene in potato cultivars ranged from 2 to 10 µg/100 g FM of tubers. The amount of β-carotene content varies, depending on flesh color.

Cream flesh and yellow flesh colored potato contains 16 and 8 µg β-carotene/100 g of fresh weight potato respectively (CIP, 2000). Brown (2008) reported that potato with white flesh color contain less carotenoid as compared to cultivars with yellow or orange color and the amount of total carotenoid range 50-350 µg/100 g (FW) and 800-2000 µg/100 g (FW) in white and yellow flesh color respectively. β-carotene content is directly correlated with total carotenoid content and yellow flesh color, which is a heritable character. Typically "white" flesh potato contains 0.01-0.05 mg of carotenoid/100 g FM while "yellow" flesh contains 0.11-0.34 mg of carotenoid/100 g FM (Gross, 1991). Kotikova *et al.* (2007) reported that significant variation was present among the varieties in their ability to accumulate carotenoids. Significant variation for vitamin A in tuber among the potato genotypes have also been reported by Dalakoti *et al*. (2003). Total carotenoid content was found to be higher in immature tubers and it decreased with tuber maturity (Kotikova *et al.,* 2007; Morris *et al.*, 2004). It is thought that the tendency for a high carotenoid content is determined by a single dominant gene, although there are modifying genes (Brown *et al.,* 1993). Different methods of vitamins analysis can lead to varying results (Finglas and Faulks, 1984).

Vitamin C, including ascorbic acid and dehydroascorbic acid is one of the most important nutritional quality factors in many horticultural crops and has many biological activities in human body. Potato is considered to be a good source of vitamin C or ascorbic acid. There are many reports describing in respect of vitamin C content in tubers. Vitamin C content in the present investigation at 90 DAP ranged from 11.62 mg to 21.10 mg/100 g is in agreement with the findings of Mahamud *et al.* (2015) who reported the range of vitamin C 11.82 to 27.02 mg/100 g. The result is also supported by the findings of Love *et al.* (2004) who examined tuber vitamin C in 75 genotypes and found concentrations ranging from 11.5 to 29.8 mg/100 g. Significant variation for vitamin C (ascorbic acid) content was reported by Rajani (2015), Daniele and Deuber (2012), Brown (2005), Dalakoti *et al*. (2003) and Woolfe (1987). The total amount of the vitamin C (ascorbic acid and dehydroascorbic acid) in potato tubers ranges from 1 to 54 mg/100 g FM, although most frequently it is between 10 to 25 mg/100 g. Ascorbic acid content of tuber has been studied and it's high quality verified by several investigations (Kapoor *et al*., 1975). In the present

investigation it was observed that vitamin C content in tuber was increased with maturity of tuber is an agreement with Hrabovska *et al.* (2013) who reported an increasing amount of vitamin C with maturity.

Significant variation was noted in starch content among the 32 potato genotypes and it increased with the maturity of tuber. Starch content was proportional to the dry matter (Uppal, 1999). Starch comprises 65-80% of the dry weight of tubers (Kadam *et al.*, 1991). Distribution of starch follows that of the DM, increasing from the skin inwards as far as the vascular ring and then decreasing inwards to the central medullary region, while the 'heel' end contains more starch than the rose end. The starch content plays very important roles in the quality of potato products and varies with potato cultivars. Potatoes with higher starch content are well suited for food uses, processing or starch manufacture (Liu *et al.*, 2003). In this connection, Esendal (1990) suggested that starch content values should be assembled into four groups: the highest starch content (Contents higher than 19.0%, mashing), high starch content (content between 16.0 and 19.0%, roasting), intermediate starch content (contents between 13.0 and 15.9%, cooking and roasting) and low starch content (content <13.0%, boiling). Starch content in the present investigation is an agreement with the finding of Abbas *et al.* (2011) who reported a range of 9.50 to 20.01% among 32 potato genotypes. CIP (1982) reported that potato tuber contains 15% starch fresh weight basis is also in agreement with present finding. Similar result was also reported by (Lisinska and Leszczynski, 1989). Jansen *et al.* (2001) reported that cultivated potatoes contain 11.0- 30.4% starch on fresh weight basis (mean 18.8%) and wild species ranged from 3.8 to 39.6% with a mean of 18.1%. However, these data were not grouped based on maturity type. The differences in starch content among the cultivars may be due to the differences in morphology of tubers as well as internal distribution of nutrients (Kroner and Volksen, 1950; Taltburt and Smith, 1975) and their differential root absorption pattern and translocation to aerial parts, finally distribution to potato tubers for their various metabolic activities (Sood *et al.*, 2008). Maturity type is far more important than remaining genetic variation for tuber yield and starch content (Van Eck, 2007). Bhattacharjee *et al.* (2014) reported that starch content in tuber significantly varied among the genotypes and increased with tuber maturity. The late maturing cultivars tend to produce much greater tuber and starch yield compared with

the early maturing cultivars (Sogut and Ozturk, 2011). Ali *et al.* (2003) reported that starch content increased with maturity from 14.79% at 60 DAP to 15.65% at 90 DAP. The result of the present finding is in agreement with these observations. With increase in future growth from 1 cm to 2.5 cm in diameter, the starch gradually increases from 11.4 to 16.0% and from 6.6 to 11.5% with white skin and red skin varieties respectively (Khuda, 1964).

Sucrose, glucose and fructose comprise the major sugars of the potato tuber and its content is influenced by genotype, location, degree of maturity of tubers, growing conditions and physiological development of tuber (Cargill *et al*., 1986; Forbush 1989; Uppal and Verma 1990; Gray and Hughes, 1978). In the present investigation significant variation was observed among the 32 potato genotypes in respect of total sugar, reducing sugar and non-reducing sugar. Glucose and fructose are reducing sugar causes brown or black of fries. Sucrose is non-reducing sugar and once in tuber it is either converted into starch or break down into glucose and fructose. Carbohydrate is supplied to the growing tuber via sucrose, which is then converted to starch (Fernie *et al.*, 2002). The range of total sugar, reducing sugar and non-reducing sugar in the present study is in agreement with Leo Mustonen (2004) who found the range from 1.2 to 1.8%, 0.3 to 0.7% and 0.7 to 1,2% for total sugar, reducing sugar and non-reducing sugar respectively. The range of total sugar and reducing sugar in different potato cultivars 1.17 to 1.57% and 0.86 to 1.11% respectively was observed by Lucia *et al.* (1981). A range of reducing sugar 0.01-0.6% (Storey, 2007) and 117.02-252.02 mg/100g (Rajani, 2015) on fresh weight basis were reported. Abbas *et al.* (2011) reported a significant variation among the 32 genotypes for total sugar, reducing sugar and non-reducing sugar from 0.20 to 0.75%, 0.01 to 0.65% and 0.10 to 0.42% respectively. Bhattacharjee *et al.* (2014) also reported that total sugar, reducing sugar and non-reducing sugar content significantly varied among the genotypes and tuber maturity. Sucrose levels are higher in young tubers and reach a low point once the aboveground plant enters senescence (Kolb and Stephan-Beckman, 1997). Ali *et al.* (2003) also reported that total sugar content decreased with tuber maturity and it decrease from 707.75 mg/100 g at 60 DAP to 549.50 mg/100 g at 90 DAP due to the conversion of sugar to starch is in agreement with present investigation. Since the free sugars were converted to starch as the tubers approached maturity. It is expected that

it will be decreased further with increase in harvesting dates (Jewell and Stanley, 1989; Marwaha, 1998; Singh *et al.*, 1999). Abong *et al.* (2009a) found a significant higher amount (0.33-0.45%) of reducing sugar at early harvesting than harvesting at maturity (0.15-0.37%). Thus it is clear that early harvested potatoes have not only low starch but also high sugar content which is negatively correlated with chip color and tuber edible quality (Sinha *et al.*, 1992).

Potatoes are a significant source of protein for their high per capita consumption, the estimation of total protein intake is 3.4% (Harris, 1992). Potato contains high quality protein because it has an adequate ratio of total essential amino acids to total amino acids and a balance among individual essential amino acid concentrations to meet the needs of infants and small children. Potato tuber protein content has been studied and it's high quality verified by several investigators (Nakasone *et al*., 1972; Stagman *et al*., 1973; Kapoor *et al*., 1975; Racusen and Foote, 1980). Protein exists in potato tubers in both soluble and insoluble forms. The soluble protein (true protein) constitutes 50% and insoluble protein about 10% of the total nitrogen content (Rahman, 1990). In the present investigation the average soluble protein percentages at 90 DAP was 1.61 and range was 0.79 to 2.03. This finding is in conformity with the earlier findings. Soluble protein ranged from 0.37 to 1.24 g/100 g fresh tuber reported by Van Gelder and Vonk (1980). Potato tubers contain 0.72 to 3.40% (Abbas *et al.,* 2011) and 1.14 to 2.58% (Rajani, 2015) protein on fresh weight basis. The average protein content in potato tuber was found 2% and ranged 0.70 to 4.60% (Singh and Kaur, 2009). In a previous report, protein content of Kufri Jyoti and Kufri Sinduri was 1.82 and 2.12% respectively (Sandhu and Parhawk, 2002). Protein content in tuber varied with potato cultivars (Gaur *et al*., 1978a; Singh and Singh, 1988; Uppal, 1999; Mishra, 2002) and growth time (Ekin, 2011). The variation in the proximate composition might be due to genetic and non-genetic factors. Higher content of protein in the tubers may be due to efficiency of the plant in uptake of nitrogen (Randhawa *et al*., 1980).

Though iron (Fe) present fairly low amounts, it may make a contribution to dietary intake. Significant difference in Fe content was observed among the studied genotypes. Fe, in association with chlorogenic acid, causes after-cooking darkening of potatoes. Of all the micronutrients, Fe is required by plants in the largest amount. The

result of the present finding is nearer to a study of cultivated varieties showed 0.3- 2.3 mg of Fe in a 100 g tuber (True *et al.,* 1978). Fe content of the potato cultivars ranged from 48.87 to 72.64 mg/kg was observed by Ozturk *et al.* (2011). Ekin (2011) found Fe concentration of 75.03 to 122.69 mg/kg dry weight basis among eight varieties. Fe content of the potato cultivars ranged from 2.5 to 7.2 mg and 2.61 to 7.15 mg/100 g DM were observed by Lisinska and Leszczynski (1989) and Lampit and Goldenberg (1940) respectively. Significant variations in Fe content in tuber were also observed by Andre *et al.* (2007a), Wills *et al.* (1984) and Smith (1968). Fe contents in potato tuber is 1.8 mg/100 g FM reported by CIP is in agreement with present finding.

The macro and micro minerals are important potato quality criteria because of their physiological and nutritional value in human food (Hogy and Frangmeier, 2009). Phosphorous is one of the main mineral present in potato tuber. It has role in the human body and is a key player for healthy cells, teeth and bones. Phosphorous content in potato tuber was found to be difference in the present investigation and it increased with tuber maturity. Ekin (2011) conducted a two year experiment and observed a considerable variation in phosphorous content among the eight potato genotypes. The two years mean range of P content was 0.223 to 0.280% on dry weight basis, converted in 43.93 to 50.68 mg/100 g fresh weight which is in agreement with the present finding. Abong *et al.* (2009b) estimated P and found variation among the cultivars from 132 mg/100 g to 200 mg /100 g (DW). Burton (1989) reported a significant variation in P content among the potato genotypes and found a range of 150-300 mg/100 g (DW). Similarly significant variation in P content in potato tubers were also reported by Woolfe (1987), Smith (1968), Lisinska and Leszczynski (1989), Randhawa *et al* (1984) and Sanchez-Castillo *et al.* (1998).

Significant variation in Ca content was observed among the 32 potato genotypes. Its content increased with the maturity of tuber. Calcium plays a crucial role in providing rigidity to the skeleton and is involved in neuromuscular function, blood clotting and many metabolic processes (Frossard *et al.*, 2000). Deficiency may result in muscle spasms and cramps in the short term and osteoporosis (Andre *et al.*, 2007a). Potatoes are a significant source of calcium (Ca), with a wide range reported. Mostly it is

present in the skin and the vascular system in the potato. The results of the present investigation are in agreement with earlier findings. Two studies reported Ca content in potato tubers up to 130 mg/100 g DM and 455 mg/kg FM (Lisinska and Leszczynski, 1989; Randhawa, *et al.* 1984). Variation in tuber Ca concentrations among different potato cultivars was 10-130 mg/100 g DM (Lampit and Goldenberg, 1940). Ekin (2011) reported a range of 0.107 to 0.146% (two years mean) of Ca on dry weight basis among eight potato varieties. Wide range of variations for Ca among the potato genotypes were also observed by Burton (1989), Vander (1981) and Andre *et al.* (2007a). Wild *Solanum* species vary the ability to accumulate tuber Ca (Bamberg *et al.,* 1998). High levels of tuber Ca are associated with resistance to pathogens (McGuire and Kelman, 1986) and abiotic stress (Tawfik *et al.*, 1996).

Potato tubers are an important source of different dietary minerals and are best known as an important source of dietary potassium which plays a fundamental role in acid -base regulation and human fluid balances (Addisu *et al.*, 2014). It required for optimal functioning of the heart, kidneys, muscles, nerves and digestive systems. Potassium (K) stimulates leaf growth, tuber growth and tuber enlargement. K is found as the major cation in potato tubers. Higher concentrations of K are present in the skin and directly beneath it than the interior of the potato tuber. In the present experiment, the range of K contents in the genotypes at 90 DAP was 178.52 to 645.79 mg/100 g and average K content of the genotypes was 390.338 mg/100 g. This finding is in conformity with the earlier findings. Woolfe (1987) reported that K content ranged from 204.9 to 900.5 mg and mean was 564 mg/100 g FM potato tubers. Potato tuber contains 1.6% K of FM reported by Vander (1981). K varies from 3550-8234 µg/g FM (Casanas *et al.*, 2002; Rivero *et al.*, 2003; Sanchez-Castillo, *et al.*, 1998). K content of 100 g fresh weight of potatoes is 425 mg reported by Philip *et al.* (2009). Variations in the K contents of 100 g DM were 1400-2500 mg (adapted from Lisinska and Leszczynski, 1989) and 1394-2825 mg (Lampit and Goldenberg, 1940). K content increased during the entire growing season (Lisinska and Leszczynski, 1989).
Zinc (Zn) is an essential component of various enzyme systems for energy production and its deficiency has serious consequences for health (Andre *et al.*, 2007a). This metal is important in number of key activities, ranging from protein and carbohydrate metabolism to the immune system, wound healing, growth and vision (WHO, 2004).

In addition, Zn plays an important role in protecting cellular components from oxidation and dietary deficiencies may enhance the risk of cancer (Ho, 2004). Significant differences in Zn content occur in potatoes in the present investigation. The average Zn content in the present study was nearer to the findings of Ereifej *et al.* (1998) and True *et al.* (1978) who found 20.4 mg/kg DM and 0.41 mg/100 g FM respectively. Ekin (2011) found Zn concentration of 15.21 to 18.96 mg/kg dry weight basis among eight varieties. The Zn content ranges from 1.8 to 10.2 µg/g FM (Andre *et al.*, 2007a; Randhawa *et al.*, 1984; Rivero *et al.*, 2003), 8.3 to 20.2 mg/kg dry matter (Burgos *et al.*, 2007), 8.7 to 17.1 mg/kg DW (Hogy and Frangmeier, 2009) and 13.17 to 20.83 mg/kg DW (Tekalign and Hammes, 2005). Yellow fleshed potatoes from different cultivars contain Zn in 0.5-4.6 µg/g FM (Dugo *et al.*, 2004). In a study of 74 Andean landraces, the Zn content varied from 12.6 to 28.83 µg/g DM (Andre *et al.*, 2007a).

Identification of genotypes with high variability and heritability for desirable characters are pre-requisite in the development of new varieties with nutritionally enriched and high yield potential. Information on the nature and magnitude of variation in the populations, the extent of environmental influence on the expression of characters is necessary for fruitful gain in breeding programme. The genetic parameters also help in the prediction of possible genetic advance through selection based on phenotypic value. However, reports on the inheritance of qualitative and quantitative characters of potato (*Solanum tuberosum* L.) are limited. Studies on the variability, heritability, phenotypic and genotypic coefficient of variation would help in identification of effective nutritional quality relating characters for the improvement of nutrition enriched varieties. In the present study different genetic parameters *viz.* genotypic variance (δ^2g), Phenotypic variance (δ^2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2b), genetic advance (GA), genetic advance as percentage of mean for different nutritional quality characters of thirty two potato genotypes were estimated to compare the variation among the genotypes.

In the present study the estimation of genetic parameters revealed that the genotypic variance (δ^2g) followed the same trend of phenotypic variance (δ^2p) for all the

nutritional characters studied, indicating that phenotypic variability may be considered as a reliable measure of genetic variability. The differences between phenotypic variance (δ^2p) and genotypic variance (δ^2g) were low in most of the characters indicating less environmental influence on these characters.

High GCV as well as PCV percentage was observed for all the characters studied except specific gravity and pH. These results suggested that greater variability for these characters among the studied genotypes was due to genetic causes which was less affected by environment and hence could be improved through selection. The genotypic coefficient of variation (GCV) values were lower than corresponding phenotypic coefficient of variation (PCV) values for all the studied characters indicating the influence of environment in the expression of these characters. It revealed that the observed variation for these traits were due to environmental and genetic factors. High phenotypic variation composed of high genotypic variations and on contrary less environmental variation indicates the presence of high genetic variability for different traits and less influence of environment. In the present investigation the genotypic coefficient of variation (GCV %) for majority of the traits was quite close to the estimated phenotypic coefficient of variation (PCV %) indicating negligible environmental role and the genotypic performance appeared to be well adapted to the environment for the fullest phenotypic expression of the traits. Sattar *et al.* (2007) observed lower difference between PCV and GCV for dry matter. The phenotypic coefficient of variation (PCV) was slightly higher in magnitude than genotypic coefficient of variation (GCV) for all the parameters were reported by Singh *et al.* (2013) and Ummyiah *et al.* (2010). Ummyiah *et al.* (2010) also reported higher GCV and PCV for total soluble solids (TSS). The characters having high GCV indicated high potential for effective selection (Burton, 1957). Roy and Singh (2006a) evaluated 18 genotypes of potato under four environments and reported that dry matter percentage, total sugar and total starch exhibited moderate value for genotypic and phenotypic coefficient of variation in all the four environments and also on pooled basis. Patel *et al*. (2013); conducted an experiment to explicated genetic variability of total 24 potato genotype and found a wide range of phenotypic variability for reducing sugar and tuber dry matter content. High genotypic coefficient of variation (GCV) was observed for reducing sugar. Tekalign (2009) recorded the

lowest phenotypic coefficient of variation (PCV) for specific gravity (1.07%). Similarly, the lowest genotypic coefficient of variation (GCV) was recorded for tuber specific gravity (0.77%) and also found smaller difference between GCV and PCV for all other traits which indicated that these traits were less influenced by environment. In the present investigation the lowest GCV and PCV was also estimated for specific gravity both at 70 and 90 DAP. Rahman (2015) reported that the GCV and PCV for DM (10.20 and 11.26%), Specific gravity (11.84 and 15.80%) and for total sugar (11.36 and 13.47%) respectively. Similarly Mondal (2003) reported that the GCV and PCV values for DM were 9.65 and 11.36% respectively. Singh *et al.* (2009) and Kita (2002) noted that the variation of dry matter in different potato varieties was the genetic variation. Similarly, Toolangi (1995) reported that tuber dry matter content differs considerably between cultivars and is a strongly genotypic based character.

The genotypic coefficient of variation alone is not sufficient to assess the heritable variation hence estimation of heritability becomes necessary. For more reliable conclusion, estimation of heritability and genetic gain should be considered together (Johnson *et al.*, 1955). Heritability estimates are useful in selection on the basis of phenotypic performance of the quantitative characters. Heritability is the quantitative statement of the relative importance of heredity and environment. The partitioning of phenotypic variation in genetic and environmental variation was first done by Fisher (1918). The characters with high heritability value could be improved straight way through selection since they are less affected by the environment. The degree of success of a selection programme also depends upon the magnitude of heritable variation. According to Robinson *et al.* (1949) heritability between 0-30% categorized as low, 30-60% as moderate and 60% or above as high heritability traits. Jones *et al.* (1986) stated that heritability estimates above 60% are adequate for good selection. The characters having lowest heritability was the least suggesting for selection because this trait was greatly influenced by environment. Kim *et al.* (1993) observed more than 70% heritability for dry matter content in tuber for early and late harvested potato which is in agreement with present findings (82.22% and 83.12%) at 70 and 90 DAP respectively. Das *et al.* (2014) found 99.70% and 98% heritability for dry matter content in tuber harvested at 75 and 90 DAP respectively. Solankey *et al.* (2015) observed high heritability for dry matter (97.10%), moisture (89.74%), total soluble

solids (94.91%), starch (96.99%), total sugar (98.94%) and total carotenoids (99.34%) content in sweet potato. Similar results was obtained in the present investigation. Gaur *et al.* (1978a) studied genetic components of tuber yield, number of tuber/plant, average tuber weight and tuber quality by using dihaploids *Solanum tuberosum* L. Broad sense heritability estimates for all these characters were high. Singh *et al.* (2013) recorded the high heritability for reducing sugar content. Rasul *et al.* (1990) reported high heritability values for specific gravity. Patel *et al*. (2013) also reported that high heritability value was noted for reducing sugar (99.98 and 99.96) in 75 days and 95 days of harvest, respectively. Among the quality characters, the tuber protein content was expected to show better response to selection than either tuber dry matter or tuber starch (Gaur *et al.,* 1978a). 416 andigena potato genotypes were studied by Birhman and Kaul (1989), for estimating genetic parameters and found high heritability for dry matter content, specific gravity. Heritability and genetic variability in twenty potato genotypes were studied by Dixit *et al*. (1994) and reported that heritability ranged from 58.73 per cent (dry matter content) to 70.56 per cent (specific gravity).

Estimation of heritability in conjunction with genetic advance and genetic advance as percentage of mean is effective for selection and more reliable for conclusion. Johnson *et al.* (1955) suggested that heritability and genetic advance when calculated together are more useful for predicting the resultant effect of selection the best individual than heritability and genetic advance calculated alone. High heritability value along with high value of genetic advance as percentage of mean is most effective condition for selection (Gandhi *et al.,* 1964). Panse (1957) suggested that effective selection may be done for the characters having high heritability accompanied with high genetic advance which is due to the additive gene effect. He also reported that low heritability accompanied with genetic advance is due to non-additive gene effects for the particular character and would offer less scope for selection, because that was under the influence of environment. It was suggested that selection of these characters could be more straightforward and effective (Masud *et al.*, 1998). In the present investigation the nutritional quality characters *viz.*, dry matter, titratable acidity, total phenolics, vitamin C, starch, total sugar, reducing sugar, non-reducing sugar, soluble protein, iron, phosphorous, calcium, potassium,

and zinc contents in tuber both at 70 and 90 DAP showed high heritability as well as high genetic advance as percentage of mean. Therefore, these quality traits of tuber would be more fruitful to consider in selection for further improvement of tuber nutritional quality. The estimated heritability for those characters were higher but the genetic advance as percentage of mean were not equally high as compared to heritability are not equally effective for selection. On the other hand characters had low genetic advance values coupled with low heritability considered less effective for selection. The genetic variability and genetic advance for twelve morphological and tuber quality characters in 67 potato varieties/hybrids were studied by Gaur *et al.* (1978a). The expected genetic advance was relatively higher for protein in fresh tubers, than for other characters. Patel *et al*. (2013); conducted an experiment to explicated genetic variability of total 24 potato genotype and observed the highest value of GA (as % mean) for reducing sugar 95.34 and 97.24 in 75 days and 95 days of harvest, respectively. Roy and Singh (2006a) recorded high heritability and genetic advance for dry matter percentage, total sugar and total starch percentage. While Sattar *et al.* (2007) found low genetic advance for dry matter. On the other hand Mondal (2003) reported high heritability but low GA (as % mean) for dry matter. A field experiment of eight potato cultivars was conducted by Munshi (1986) for genetic variation. He reported non-significant variation for specific gravity of tubers while the significant genetic variation was observed for tuber dry matter. Desai and Jaimini (1997a) evaluated thirty six genotypes of potato and protein content was found to be high genotypic coefficient of variation, heritability and high genetic advance irrespective of environments. A study on genetic variability parameters, heritability and genetic advance was done by Sharma (1999) with fifty nine true potato seed populations. Genetic variability was low for dry matter and harvest index. However, heritability in broad sense was high for these characters. Singh *et al.* (2013) recorded the high heritability along with high genetic advance as percentage of mean for reducing sugar content. Rahman (2015) estimated high heritability for DM (81.99%) and total sugar (71.11%) and moderate for specific gravity (56.18%) couple with GA (as % mean) 19.02, 18.28 and 19.73 for DM, specific gravity and total sugar respectively. Rasul *et al.* (1990) estimated higher genetic gain for starch content in tuber when evaluating the variability among 15 potato genotypes. Ummyiah *et al.*

(2010) recorded the high heritability with high genetic gain indicating that these characters could be considered as reliable tools for selection as they indicated dominance of additive gene effect.

Thus the results of the present study indicated that dry matter, titratable acidity, total phenolics, vitamin C, starch, total sugar, reducing sugar, non-reducing sugar, soluble protein, iron, phosphorous, calcium, potassium and zinc contents in tuber exhibited high GCV %, high heritability as well as high GA (% of mean) confirmed additive gene action suggesting effective selection could be made for these characters. Alternate systems like random mating, inter-mating, bi-parental mating, crossing of selected sibs in early generation and dialel selective mating system may therefore, be advocated to improve the tuber nutritional quality by effective selection.

It is important to know the relationship between tuber yield and nutritional quality characters and among various nutritional quality traits for improving nutritional quality with satisfactory yield potential. Yield is a complex character associated with many interrelated components (Murat & Vahdettin, 2004). The original concept of correlation was given by Galton (1988) who suggested the need of coefficient of correlation to describe the degree of association between dependent and independent variables. In the present investigation relationships between tuber yield and its nutritional quality characters and among different nutritional characters were studied at genotypic and phenotypic levels.

The results of correlation coefficient between tuber yield/ha and nutritional quality characters of tuber in the present study revealed that in most of the cases, the values of genotypic correlation coefficient (r_g) were higher than the corresponding phenotypic correlation coefficient (r_p) indicating that there is a strong inherent association between the characters studied and less pronounced environmental effect. Higher genotypic correlations than phenotypic ones might be due to modifying or masking effect of environment in the expression of these characters under study as explained by Nandpuri *et al*. (1973). Johnson *et al.* (1955) also reported that higher genotypic correlation than phenotypic correlation indicated an inherent association between various characters. Similarly Fekadu *et al*. (2013); conducted a field experiment with thirteen (13) potato genotypes and reported that genotypic correlation coefficient was higher in magnitude

than that of phenotypic correlation coefficients, which clearly indicated the presence of inherent association among various characters. Higher and wider genotypic correlation than phenotypic correlations have been reported by Panigrahi *et al.* (2017), Rahman (2015) and Das *et al.* (2014) in potato; Sarkar *et al*. (1999) in pointed gourd and Sharma and Swarup (1964) in cabbage. Tyagi (1987) and Dhanda *et al*. (1984) also reported higher magnitude of genotypic correlation coefficient over phenotypic ones between yield and yield contributing characters.

Tuber yield/ha both at 70 and 90 DAP was found to be negatively associated with most of the nutritional quality characters. Among the different nutritional characters dry matter, total phenolics, starch, reducing sugar, calcium and zinc contents in tuber at 70 DAP were negative and significantly correlated with tuber yield/ha both at genotypic and phenotypic level indicated that dry matter, total phenolics, starch, reducing sugar, calcium and zinc contents in tuber decreased with the increase of tuber yield/ha at 70. Iron content in tuber at 70 DAP had negative and significant association with tuber/ha at genotypic level but non-significant at phenotypic level. Tuber yield/ha at 70 DAP was non-significant but negatively correlated with total sugar, soluble protein, phosphorous and potassium contents both at genotypic and phenotypic level. Total phenolics, total sugar, reducing sugar, soluble protein and calcium contents in tuber at 90 DAP were also negative and significantly correlated with tuber yield/ha both at genotypic and phenotypic level. Dry matter, starch, iron, phosphorous, potassium and zinc contents in tuber were non-significant but negatively correlated with tuber yield/ha at 90 DAP both at genotypic and phenotypic level. This indicated that these nutritional quality characters in tuber decreased with the increased of tuber yield/ha. Higher yielding genotype have lower concentration of mineral elements than those of lower yielding genotypes when grown in the same environment because of a dilution effect caused by plant growth rate exceeding the ability of plants to acquire the elements (Jarrell and Beverly, 1981) that is impacted by both environment and genetic factors (Davis, 2005; Davis *et al.,* 2004) is an agreement with the present findings.

Among the nutritional quality characters highly significant (significant at 1% level of significant) positive correlation was observed between dry matter-total phenolics, dry

matter-vitamin C, dry matter-starch, dry matter-protein, dry matter-iron, dry matter-phosphorous, total phenolics-starch, total phenolics-soluble protein, total phenolics-iron, total phenolics-phosphorous, vitamin C-starch, starch-soluble protein, starch-iron, starch-phosphorous, starch-calcium, starch-zinc, total sugar-reducing sugar, total sugar-calcium, reducing sugar-calcium, phosphorous-calcium and potassium-zinc contents in tuber at genotypic and phenotypic level both at 70 and 90 DAP harvested tuber. Positive and significant at 1% level of significance relationship at genotypic and phenotypic level was also observed between dry matter and zinc content in tuber when harvested at 70 DAP. The relationship between dry matter-calcium and iron-potassium content in tuber at 90 DAP showed positive and significant at 1% level of significance both at genotypic and phenotypic level. At 70 DAP the relationship between dry matter-calcium, total phenolics-vitamin C and iron-zinc were positive and significant at 5% level of significance both at genotypic and phenotypic level and vitamin C-soluble protein, vitamin C-phosphorous only at phenotypic level. In case of 90 DAP the correlation coefficients between dry matter-zinc, vitamin C-soluble protein, vitamin C-phosphorous, vitamin C-zinc and iron-zinc were positive and significant at 5% level of significance both at genotypic and phenotypic levels. The positive relationship particularly indicates the increase in one of the characters may lead to increase in the other. The positive association of these characters will help breeder for selection of nutritionally enriched genotypes.

Among the nutritional quality characters highly significant (significant at 1% level of significance) negative correlation was observed between total sugar-zinc and reducing sugar-zinc at genotypic and phenotypic levels both in 70 and 90 DAP respectively. Negative and significant at 1% level of significance relationship at genotypic and phenotypic levels was also observed between protein-potassium content in tuber when harvested at 70 DAP. The relationship between vitamin C-total sugar, vitamin C-reducing sugar and protein-zinc content in tuber at 90 DAP showed negative and significant at 1% level of significance both at genotypic and phenotypic levels. At 70 DAP the relationship between vitamin C-total sugar, reducing sugar-potassium and protein-zinc was negative and significant at 5% level of significance both at genotypic and phenotypic levels. In case of tuber harvested at 90 DAP the correlation coefficient between protein-potassium was negative and

significant at 5% level of significance both at genotypic and phenotypic levels. The rest pairs of the traits showed non-significant relationship. The negative relationship particularly indicates the increase in one of the characters may lead to decrease in the other. It was also observed that the correlation value was higher in tuber of 70 DAP than the tuber of 90 DAP both for total sugar and reducing sugar. This indicated that at the early stage of growth tuber contain minimum starch and higher amount of total sugar and reducing sugar contents and the ratio decreased with the maturity of tuber as the sugar content decreased and starch content increased.

The results of the present findings are in accordance with the findings of Abbas *et al.* (2011) who reported a significant positive correlations between ash-dry matter, ash-specific gravity, ash-starch, dry matter-protein, dry matter-specific gravity, dry matter-starch, total sugar-reducing sugar, total sugar-non-reducing sugar; protein-specific gravity, protein-starch; specific gravity-starch. They found significant negative correlations between ash-reducing sugar, dry matter-total sugar, dry matter-reducing sugar, reducing sugar-non reducing sugar, protein-total sugar, protein-reducing sugar, reducing sugar-specific gravity, reducing sugar-starch, specific gravity-total sugar and starch-total sugar. A non-significant relationship was also observed by Abbas *et al.* (2011) between ash-non-reducing sugar, ash-protein, ash-total sugar, dry matter-non-reducing sugar, non-reducing sugar-protein, non-reducing sugar-specific gravity and non-reducing sugar-starch. Specific gravity illustrated a positive relationship with starch content and dry matter content but negatively correlated with reducing sugar (Feltran *et al.*, 2004). Gusain (2010) calculated correlation studies in 168 genotypes and 4 checks. The results indicated that tuber yield was positively and significantly correlated with specific gravity, ascorbic acid while dry matter content showed negative correlation with tuber yield which is in agreement with present finding. DM was negatively correlated with tuber yield reported by Mondal (2003). Similar result was also observed by Rahman (2015) who showed negative correlation of tuber yield with DM and total sugar but specific gravity showed positive correlation with tuber yield. He also showed that DM, total sugar and specific gravity are positively correlated with each other. Gaur *et al.* (1978b) reported negative and significant correlation of ascorbic acid with tuber yield in potato. Rajani (2015) also found negative correlation of tuber yield with ascorbic

acid. She also found negative relation of tuber yield with TSS and reducing sugar. Rasul *et al.* (1990) reported the variability and some genetic parameters of 15 potato varieties to select parents for a hybridization programme. Correlation studies showed that dry matter content, starch content and specific gravity were negatively correlated with tuber yield but they were highly interrelated which supported the present findings. Garg and Bhutani (1991) studied twenty eight potato hybrids and observed sugar content was negatively associated with total tuber yield. Mishra (2002) studied the correlation and observed negative correlation for dry matter and specific gravity of tuber with tuber yield while Tuncturk and Cftc (2005) observed positive and significant relationships of tuber yield with dry matter content and non-significant negative relationship with specific gravity. Specific gravity showed positive correlation with starch, pulp pH, TSS and negative correlation with reducing sugar content. Reducing sugar was also negatively correlated with starch, pH and acidity and starch exhibited positive correlation with pulp pH, acidity and TSS (Feltran *et al.*, 2004; Salamoni *et al.*, 2000; Gould, 1988). A negative correlation between pulp pH and reducing sugar was found by Feltran *et al.* (2004) and Iritani and Weller, (1973). Dixit *et al*. (1994) reported that protein content was negatively correlated with tuber yield. Khayatnezhad *et al.* (2011) found stronger positive and significant correlations between starch content and dry matter content (r=1).

Genetic diversity is one of the important tools to quantify genetic variability in both cross and self pollinated crops (Griffing and Lindstrom, 1954; Murty and Arunachalam, 1966; Gaur *et al.,* 1978c). The quantification of genetic diversity through biometrical procedures has made it possible to choose genetically diverse parents for a successful hybridization programme (Rao, 1952; Jain *et al.,* 1975). Tomooka (1991) reported that evaluation of genetic diversity is important to know the source of gene for a particular trait within the available germplasm. Nutritional enriched parents with greater genetic diversity are required to develop nutritionally enriched variety. For identifying genetically diverse parents for hybridization, multivariate analysis (Mahalanobis's D^2 statistic) has been used in potato. It is a powerful tool for quantification of genetic divergence among the parents. Genetically divers and geographically isolated lines express a wide range of variation when brought together. Mahalanobis (1936) generalized distance estimated by D^2 statistic,

which has been used as an efficient tool in the quantitative estimation of genetic diversity and a rational of potential parents for a breeding programme. In order to find out the extent of genetic divergence for 12 nutritional quality characters at different maturity stages among the 32 potato genotypes and scope for improvement of nutritionally enriched potato variety principal component analysis (PCA), principal coordinate analysis (PCO), cluster analysis, cluster diagram, cluster means, canonical variate analysis (CVA) were performed.

Principal component analysis (PCA) was performed to assess the relative importance of each quantitative character to characterize genotypes. PCA is a technique that identifies plant characters that contribute more to the observed variation within a group of genotypes (Fundora *et al.,* 2004). In the present investigation dry matter, total phenolics, vitamin C, starch content, total sugar and reducing sugar contents contributed maximum towards divergence.

Cluster analysis revealed that the thirty two potato genotypes were grouped into seven different clusters for both at 70 and 90 DAP harvesting situation. Cluster III and VI contained the maximum number of genotypes (each containing six genotypes) and accounted 18.75% of the total genotypes at 70 DAP. The minimum number of genotypes were in cluster I and II and each of this cluster contained 3 (three) genotypes cover 9.38% each. In case of tuber harvested at 90 DAP clusters III had the maximum 7 seven) genotypes and accounted 21.88% of the total genotypes and minimum in cluster IV containing 1 (one) genotype and covered only 3.13% of the total genotypes. Pattern of distribution of genotypes among various clusters reflected the considerable genetic variability for nutritional quality characters is present in the studied potato genotypes. At 90 DAP among the seven clusters cluster IV consisted a single genotypes which indicate high genotypic differences among the 32 genotypes. The clustering pattern revealed that the genotypes collected from the different location (different parts of Bangladesh and Abroad) were grouped into different clusters. This showed that geographic diversity is not always related to genetic diversity and therefore it is not adequate as an index of genetic diversity. Datta *et al.* (2015) grouped 35 potato varieties into ten clusters and found single genotype in two clusters. They also suggested that genotypes did not follow the geographic

distribution. 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. Desai and Jaimini (1997b) evaluated thirty six potato genotypes for genetic divergence by using the Mahalanobis D^2 statistic. They grouped the populations into 9 clusters and maximum 7 genotypes fall in cluster I. Rajani (2015) grouped 45 genotypes into 8 clusters. Five clusters were reported by Mondal *et al.* (2007) using 31 potato genotypes. Similar work was done by Sattar *et al.* (2011) grouped twenty eight potato genotypes into five clusters. Shanmugam and Rangasamy (1982) reported that falling of materials of same origin into different clusters was an indication of the broader genetic base of the genotypes belonging to that origin. Therefore, genotypes originated at same place may have different genetic architecture or vice-versa. Moreover, Masud *et al.* (1995) in pumkin, Masud *et al.* (2001) in sponge gourd, Masud *et al.* (2003a and 2003b) in ridge gourd and sweet gourd, Chowdhury *et al.* (1998) in soyabean, Bhadra and Akhtar (1991) in mung bean, Natarajan *et al.* (1988) in green gram and Anand and Rawat (1984) in brown mustard found no relationship between geographic distribution and genetic diversity of the crop. The results however, suggested that geographic isolation is not only factor causing genetic diversity and this point should be considered in selection parents for hybridization. The absence of relationship between genetic diversity and geographical distance indicates that forces others than geographical origin, such as exchange of genetic stocks, genetic drift, spontaneous variation, natural and artificial selection are responsible for genetic diversity. This would be suggested that it was not necessary to choose diverse parents for diverse geographic regions for hybridization.

The intra-cluster distance indicated the divergence among the genotypes falling in the same cluster. On the other hand, inter cluster divergence suggest the distance (divergence) between the genotypes of different clusters. In the present study maximum intra cluster distance was noted in cluster III and minimum in cluster II when tuber harvested at 70 DAP. In this stage of tuber growth the highest inter cluster distance was observed between clusters III and VI and minimum between clusters I and VII. In case of tuber harvested at 90 DAP the highest intra cluster distance was estimated in cluster III and lowest in cluster IV which contained only a single genotype. The highest inter cluster distance between cluster III and V and lowest

between cluster II and VII was observed at 90 DAP. Maximum inter cluster distances indicated that the genotypes belongings to these groups were genetically most divergent and the genotypes included in these clusters can be used as a parent in hybridization programme to get higher heterotic hybrids from the segregant population (Mehta and Asati, 2008). Several authors also reported profound diversity in the germplasm of rice by assessing genetic divergence on the basis of quantitative traits following Mahalanobis D^2 statistics (Ovung *et al*., 2012; Thomas and Lal, 2012; Chakravorty *et al*., 2013). Datta *et al.* (2015) also found higher inter cluster distances than intra cluster distances in potato germplasm for nutritional quality characters. Similar result was reported by Panigrahi *et al.* (2014). Intra-cluster distance was being lower than the inter cluster one, suggesting homogenous and heterogeneous nature of the genotypes within and between the clusters, respectively. This was farther supported by an appreciable variation observed for cluster means.

A wide range of variation for several characters among single as well as multi-genotypic clusters was observed. However, the differences were clear for dry matter, total phenolics, vitamin C, starch, total sugar, reducing sugar, phosphorous, calcium and potassium content in tuber. Comparatively higher cluster mean values were observed under various clusters for the characters. Pandey and Gupta (1995) also observed comparatively higher cluster mean values under various clusters for characters like dry matter, protein, total soluble solids while working with 16 varieties of potatoes. Similarly Datta *et al.* (2015) reported that comparatively higher cluster mean values were found under different clusters in their investigation with 35 potato germplasm. Rymuza (2015) also found comparatively higher cluster mean values under various clusters for characters starch, dry matter and vitamin C contents. So, it may be seen here that the findings of the present investigation have corroborated well the results of Pandey and Gupta (1995) and Datta *et al.* (2015). Desai and Jaimini (1997b) evaluated thirty six potato genotypes for genetic divergence by using the Mahalanobis D^2 statistic. They observed that higher cluster mean values of sugar content, dry matter, starch and protein content were in different clusters. They differed significantly for all the characters, suggesting a good scope of selection. The grouping of genotypes in clusters reflects the relative divergence of cluster and allows a convenient selection group of genotypes with their overall phenotype similarity for

hybridization programme facilitating better exploitation of germplasm. Cluster I, III and IV at 70 DAP and cluster IV and I at 90 DAP were recorded to have highest mean for maximum traits under study. Thus genotypes belonging to these clusters can be used for developing nutritionally enriched potato varieties.

The canonical variate analysis revealed that in vector I the important characters responsible for genetic divergence in the major axis of differentiation were dry matter, total phenolics, reducing sugar, soluble protein, calcium, potassium and zinc. In vector II which was the second axis of differentiation for dry matter, total phenolics, vitamin C, reducing sugar, soluble protein, calcium and potassium were important when tuber harvested at 70 DAP. The role of dry matter, total phenolics, reducing sugar, soluble protein, calcium and potassium for both the vectors were positive across two axes indicating the important components of genetic divergence in these materials. In case of tuber harvested at 90 DAP in vector I the important characters responsible for genetic divergence in the major axis of differentiation were dry matter, total phenolics, total sugar, iron, phosphorous, calcium, potassium and zinc. In vector II which was the second axis of differentiation for dry matter, total phenolics, reducing sugar, soluble protein, iron, phosphorous, calcium, potassium and zinc were important. The role of dry matter, total phenolics, iron, phosphorous, calcium, potassium and zinc for both the vectors were positive across two axes indicating the important components of genetic divergence in these characters. Sanjoy *et al*. (2015) in a study reported ascorbic acid content, protein content and total soluble solids (TSS) content of tuber were the major traits in contribution towards divergence in potato. Panigrahi *et al.* (2014) in another study found that the character causing genetic divergence was dry matter percentage.

3.5 SUMMARY

The present part of investigation was carried out to study the extent of variability and genetic diversity of nutritional quality characters among the thirty two potato (*Solanum tuberosum* L.) genotypes harvested at 70 and 90 DAP. Statistical procedure of mean, analysis of variance, DMRT, genetic parameters, correlation and genetic diversity for nutritional quality characters were studied. Analysis of variance for nutritional quality characters of tuber both at 70 and 90 DAP revealed significant differences for all the characters indicated the presence of considerable nutritional variations among the studied genotypes. Mean performances of different quality characters of 32 potato genotypes were also found significantly different as revealed by the DMRT test. High GCV as well as PCV percentage was observed for all the characters studied except specific gravity, ash, pH and TSS both at 70 and 90 DAP harvesting situations. The differences between GCV and PCV values were low for all the characters under studied suggested that the greater variability among the genotypes were due to genetic causes and lower environmental influence for the phenotypic expression of these characters and hence could be improved nutritional quality of tuber through selection. All the nutritional quality characters of the tuber both at 70 and 90 DAP except specific gravity, ash, pH and TSS showed high heritability along with higher genetic advance as percentage of mean would helpful in predicting the genetic gain under selection. Specific gravity, ash and TSS showed high heritability but low genetic advance as percentage of mean for both 70 and 90 DAP tubers. pH showed low heritability along with low genetic advance as percentage of mean. Correlation coefficient study revealed that dry matter, total phenolics, reducing sugar, starch and mineral contents like iron, calcium and zinc were negatively correlated with tuber yield both at 70 DAP both at genotypic and phenotypic level. In case 0f 90 DAP total phenolics, TS, RS, soluble protein and Ca showed significant negative correlation with tuber both at genotypic and phenotypic level. Again starch and mineral contents showed positive correlation with dry matter. On the other hand reducing sugar showed negative correlation with dry matter which is desirable. From this study it was revealed that lower yielding genotypes have higher amount of dry matter and minerals than that of higher yielding genotypes which would be helpful for the improvement of nutritional quality both at 70 and 90 DAP. In order to find out the extent of genetic diversity for nutritional quality both at 70 and 90 DAP among the thirty two potato genotypes principal component analysis (PCA), principal coordinate analysis (PCO), canonical variate analysis (CVA) and cluster

analysis were performed. The principal component axes and scatter plotting diagram revealed that considerable variability existed among the genotypes. Thirty two potato genotypes were grouped into seven different clusters based on nutritional quality characters both at 70 and 90 DAP. The clustering pattern showed that there was no parallelism between geographical and genetic divergence. Cluster III and VI contained the maximum six genotypes and cluster I and II contained the minimum three for tuber harvested at 70 DAP. For tuber harvested at 90 DAP cluster III contains the maximum seven and cluster IV contained the minimum one genotype. The inter cluster distance in both the harvesting situations were higher than the intra cluster distance suggesting heterogeneous and homogeneous nature between and within groups and also indicating wider genetic diversity among the genotypes of different groups. The highest inter-cluster distance was observed between the clusters III and VI (23.313) followed by cluster III and V (17.787) for tuber harvested at 70 DAP and for tuber harvested at 90 DAP the highest inter cluster distance was found between cluster III and V (18.269) followed by cluster III and VI (15.508) indicated that the genotypes belonging to these groups were genetically most divergent and the genotypes included in these clusters can be used as a parent in hybridization programme to get higher heterotic hybrids from the segregant population. The cluster means of 32 potato genotypes showed that the mean value of clusters varied in magnitude for all the nutritional quality parameters. Genotypes in cluster I showed the maximum dry matter (23.10%), total phenolics (57.62 mg/100 g), starch (16.22%), total sugar (1.79%), reducing sugar (0.76%), protein (1.46%), iron (1.56 mg/100 g) and calcium (27.11 mg/100 g) contents where as cluster III showed the highest mean performance for potassium (567.34 mg/100 g) and zinc (0.46 mg/100 g) contents and cluster IV showed highest vitamin C (14.01 mg/100 g) and phosphorous (40.40 mg/100 g) contents when tuber harvested at 70 DAP. In case of tuber harvested at 90 DAP cluster I showed the highest mean for starch (17.57%), total sugar (1.51%), reducing sugar (0.60%) and calcium (31.96 mg/100 g) contents, cluster II showed the maximum vitamin C (17.54 mg/100 g) content, cluster III showed the highest amount potassium (571.00 mg/100 g) and zinc (0.46 mg/100 g) contents. Highest mean for dry matter (24.51%), total phenolics (63.05 mg/100 g), protein (2.25%), iron (2.08 mg/100 g) and phosphorous (45.05 mg/100 g) contents were shown by the genotypes in cluster IV. Canonical variate analysis revealed that dry matter, total phenolics, reducing sugar, soluble protein, Fe, P, Ca, K and Zn contents were contributed effectively towards genetic divergence among the genotypes.

Chapter IV

4. **CONCLUSION AND RECOMMENDATION**

4.1. CONCLUSION

Based on the findings of present investigation it can be concluded that there was a wide range of variation for tuber yield and yield attributing characters among the studied genotypes. The variation was due to the genetic causes. Foliage coverage, chlorophyll content and single tuber weight showed high heritability along with higher genetic advance as percentage of mean and had significant positive correlation with tuber yield and also had positive direct effect on tuber yield. So, these traits should be considered for selecting tuber yield potential genotypes suitable for early (at 70 DAP) or late (at 90 DAP) harvest. Nutritional quality analysis revealed that wide range of genetic variation for nutritional quality existed among the studied potato genotypes at both the harvesting conditions (70 and 90 DAP) which could be used in hybridization programme for improving nutritionally enriched variety. Dry matter, total phenolics, vitamin C, starch, total sugar, reducing sugar, protein, iron, phosphorous, calcium, potassium and zinc contents contributed effectively towards genetic divergence. So, these traits should be considered for improvement of nutritional quality through rational selection of parental genotypes for future potato breeding.

4.2. RECOMMENDATION

The following recommendations are suggested based on the data obtained from the present investigation:

- G_9 (Granola) and G_{11} (Courage) may be cultivated as higher yielder genotypes suitable for harvesting at 70 DAP.
- G_{20} (Cardinal), G_{22} (Diamont) and G_{28} (Ultra) may be cultivated as higher yielder genotypes suitable for harvesting at 90 DAP.
- Genotype G_8 (Lady Rosetta) for zinc, G_{12} (Hagrai) for dry matter, starch, protein and total sugar contents, G_{21} (Vandarpur) for total phenolics and calcium contents, G_{13} (Indurkani) for iron and phosphorous contents and G_{23}

(JPR) for vitamin C and β-carotene contents should be selected as parents for improving nutritional quality through efficient hybridization programme with early (70 DAP) harvested higher yielder genotypes.

- Genotype G8 (Lady Rosetta) for zinc, G_{12} (Hagrai) for starch and total sugar contents, G_{21} (Vandarpur) for calcium content, G_{13} (Indurkani) for dry matter, total phenolics, protein, iron and phosphorous contents, G_{23} (JPR) for β-carotene content and G_{24} (All Red) for vitamin C content should be selected as parents for improving nutritional quality through efficient hybridization programme with higher yielder genotypes harvested at 90 DAP.

- The concentration of one nutrient correlated with other would help the breeder for the possibility to combine selection for correlated nutrients in a single trait.

Chapter V

5. **REFERENCES**

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APPENDICES

Appendix I Daily records of rainfall, maximum and minimum temperature and relative humidity during the study period

Date	Rainfall (mm)	Temperature (^{0}C)			Relative humidity (%)	Remarks
		Min.	Max.	Mean		
01.11.14	0.0	18.5	31.2	24.9	79	
02.11.14	0.0	19.2	31.1	25.2	81	
03.11.14	0.0	20.1	32.3	26.2	80	
04.11.14	0.0	19.8	31.9	25.9	81	
05.11.14	0.0	19.7	31.9	25.8	78	
06.11.14	0.0	20.2	31.0	25.6	76	
07.11.14	0.0	19.8	32.6	26.2	78	
08.11.14	0.0	19.5	33.6	26.6	78	
09.11.14	0.0	21.0	33.8	27.4	76	
10.11.14	0.0	17.5	31.9	24.7	77	
11.11.14	0.0	17.4	31.5	24.5	80	
12.11.14	0.0	17.8	31.6	24.7	84	
13.11.14	0.0	16.4	31.0	23.7	75	
14.11.14	0.0	13.4	30.1	21.8	74	
15.11.14	0.0	12.9	29.1	21.0	77	
16.11.14	0.0	14.0	29.4	21.7	79	
17.11.14	0.0	16.0	29.6	22.8	75	
18.11.14	0.0	16.8	29.6	23.2	75	
19.11.14	0.0	14.7	27.7	21.2	76	
20.11.14	0.0	13.8	29.5	21.7	79	
21.11.14	0.0	14.5	29.8	22.2	79	
22.11.14	0.0	13.0	28.6	20.8	80	
23.11.14	0.0	12.8	28.6	20.7	70	
24.11.14	0.0	11.3	28.6	20.0	78	
25.11.14	0.0	12.5	28.2	20.4	76	
26.11.14	0.0	11.6	27.6	19.6	76	
27.11.14	0.0	11.4	27.8	19.6	77	
28.11.14	0.0	11.7	27.8	19.8	77	
29.11.14	0.0	11.6	27.8	19.7	82	
30.11.14	0.0	13.0	27.6	20.3	83	

Appendix I Contd.

Date	Rainfall (mm)	Temperature (^{0}C)			Relative humidity (%)	Remarks
		Min.	Max.	Mean		
01.12.14	0.0	13.8	27.8	20.8	84	
02.12.14	0.0	14.2	27.6	20.9	86	
03.12.14	0.0	14.0	26.8	20.4	87	
04.12.14	0.0	14.3	27.6	21.0	85	
05.12.14	0.0	16.5	28.1	22.3	85	
06.12.14	0.0	15.6	26.0	20.8	89	
07.12.14	0.0	15.3	20.7	18.0	92	
08.12.14	0.0	10.2	26.0	18.1	86	
09.12.14	0.0	11.2	27.0	19.1	82	
10.12.14	0.0	10.4	23.4	16.9	91	
11.12.14	0.0	11.1	17.4	14.3	94	
12.12.14	0.0	10.1	22.6	16.4	90	
13.12.14	0.0	12.0	24.5	18.3	87	
14.12.14	0.0	15.4	22.0	18.7	92	
15.12.14	0.0	15.5	27.9	21.7	78	
16.12.14	0.0	14.8	25.5	20.2	81	
17.12.14	0.0	12.8	24.0	18.4	76	
18.12.14	0.0	9.4	24.6	17.0	78	
19.12.14	0.0	12.4	25.9	19.2	76	
20.12.14	0.0	11.8	25.4	18.6	75	
21.12.14	0.0	13.0	24.5	18.8	79	
22.12.14	0.0	11.6	25.1	18.4	76	
23.12.14	0.0	10.0	25.4	17.7	72	
24.12.14	0.0	9.4	24.8	17.1	83	
25.12.14	0.0	9.8	21.8	15.8	87	
26.12.14	0.0	10.5	19.2	14.9	91	
27.12.14	0.0	7.6	20.7	14.2	91	
28.12.14	0.0	8.8	23.7	16.3	79	
29.12.14	0.0	8.8	24.5	16.7	81	
30.12.14	0.0	9.3	24.4	16.9	80	
31.12.14	0.0	13.1	26.6	19.9	80	

Appendix I Contd.

Date	Rainfall (mm)	Temperature (^{0}C)			Relative humidity (%)	Remarks
		Min.	Max.	Mean		
01.1.15	0.0	13.4	28.0	20.7	92	
02.1.15	0.0	17.3	28.7	23.0	80	
03.1.15	0.0	20.8	24.0	22.4	87	
04.1.15	6.0	16.7	26.0	21.4	89	
05.1.15	7.8	14.0	22.9	18.5	87	
06.1.15	0.0	11.6	22.0	16.8	87	
07.1.15	0.0	10.8	21.7	16.3	86	
08.1.15	0.0	9.2	21.5	15.4	88	
09.1.15	0.0	12.7	23.1	17.9	83	
10.1.15	0.0	10.5	21.4	16.0	86	
11.1.15	0.0	9.4	19.5	14.5	85	
12.1.15	0.0	8.5	23.9	16.2	83	
13.1.15	0.0	11.0	23.7	17.4	85	
14.1.15	0.0	11.4	23.4	17.4	90	
15.1.15	0.0	11.6	26.5	19.1	79	
16.1.15	0.0	13.0	27.3	20.2	75	
17.1.15	0.0	11.0	20.7	15.9	86	
18.1.15	0.0	10.3	16.4	13.4	92	
19.1.15	0.0	9.9	16.4	13.2	90	
20.1.15	0.0	6.7	21.0	13.9	87	
21.1.15	0.0	8.5	24.0	16.3	81	
22.1.15	0.0	10.0	26.4	18.2	86	
23.1.15	0.0	9.2	27.0	18.1	78	
24.1.15	0.0	12.0	27.1	19.6	75	
25.1.15	0.0	11.0	26.3	18.7	77	
26.1.15	0.0	10.3	25.0	17.7	79	
27.1.15	0.0	11.5	28.8	20.2	79	
28.1.15	0.0	11.8	25.8	18.8	81	
29.1.15	0.0	13.6	22.0	17.8	91	
30.1.15	0.0	14.7	23.4	19.1	81	
31.1.15	0.0	8.2	22.8	15.5	76	

Appendix I Contd.

Date	Rainfall (mm)	Temperature (^{0}C)			Relative humidity (%)	Remarks
		Min.	Max.	Mean		
01.2.15	0.0	7.6	23.0	15.3	77	
02.2.15	0.0	9.0	26.0	17.5	78	
03.2.15	0.0	9.3	28.0	18.7	76	
04.2.15	0.0	11.0	29.7	20.4	76	
05.2.15	0.0	13.3	27.2	20.3	71	
06.2.15	0.0	11.6	22.5	17.1	84	
07.2.15	0.0	10.2	25.5	17.9	79	
08.2.15	0.0	10.5	26.5	18.5	79	
09.2.15	0.0	11.8	26.7	19.3	76	
10.2.15	0.0	13.3	26.3	19.8	77	
11.2.15	0.0	11.5	27.8	19.7	76	
12.2.15	0.0	9.1	26.7	17.9	71	
13.2.15	0.0	11.6	27.6	19.6	74	
14.2.15	0.0	11.5	28.0	19.8	76	
15.2.15	0.0	14.7	28.0	21.4	79	
16.2.15	0.0	14.6	28.8	21.7	79	
17.2.15	0.0	14.5	29.0	21.8	78	
18.2.15	0.0	17.4	28.8	23.1	81	
19.2.15	1.0	16.9	28.2	22.6	85	
20.2.15	13.4	16.8	27.2	22.0	90	
21.2.15	0.0	17.1	29.5	23.3	83	
22.2.15	0.0	17.7	31.3	24.5	80	
23.2.15	0.0	19.5	32.5	26.0	80	
24.2.15	0.0	20.4	30.8	25.6	84	
25.2.15	0.0	19.3	31.2	25.3	84	
26.2.15	0.0	19.3	34.6	27.0	87	
27.2.15	0.0	20.0	33.0	26.5	73	
28.2.15	0.0	20.3	33.0	26.7	81	

Appendix I Contd.

Date	Rainfall (mm)	Temperature (^{0}C)			Relative humidity (%)	Remarks
		Min.	Max.	Mean		
01.3.15	0.0	21.0	33.6	27.3	71	
02.3.15	0.0	19.4	29.0	24.2	79	
03.3.15	0.0	18.0	30.4	24.2	72	
04.3.15	0.2	18.4	31.0	24.7	73	
05.3.15	0.0	16.7	28.3	22.5	62	
06.3.15	0.0	12.8	28.4	20.6	65	
07.3.15	0.0	13.0	30.0	21.5	68	
08.3.15	0.0	14.3	31.2	22.8	66	
09.3.15	0.0	15.0	31.6	23.3	69	
10.3.15	0.0	16.4	33.8	25.1	61	
11.3.15	0.0	13.8	32.6	23.2	57	
12.3.15	0.0	11.9	32.0	22.0	57	
13.3.15	0.0	14.8	32.5	23.7	64	
14.3.15	0.0	17.0	35.4	26.2	60	
15.3.15	0.0	16.0	34.2	25.1	60	
16.3.15	0.0	17.8	30.7	24.3	68	
17.3.15	0.0	18.0	34.7	26.4	63	
18.3.15	0.0	20.7	33.0	26.9	63	
19.3.15	0.0	18.2	32.3	25.3	56	
20.3.15	0.0	14.8	33.0	23.9	62	
21.3.15	0.0	16.2	34.2	25.2	59	
22.3.15	0.0	16.7	35.2	26.0	59	
23.3.15	0.0	18.4	36.5	27.5	57	
24.3.15	0.0	20.4	37.2	28.8	64	
25.3.15	0.0	19.5	37.2	28.4	67	
26.3.15	0.0	22.9	36.2	29.6	67	
27.3.15	0.0	22.0	35.4	28.7	78	
28.3.15	0.0	22.1	33.7	27.9	76	
29.3.15	0.0	22.9	32.8	27.9	74	
30.3.15	0.0	23.2	35.2	29.2	78	
31.3.15	29.2	21.0	29.0	25.0	80	

Appendix II Mean square values of analysis of variance for tuber yield and yield related characters of thirty two potato genotypes harvested at different maturity stages

Characters	Sources		
	Mean sum of square		
	Replication	Genotypes	Error
Degree of freedom	2	31	62
Days to first shoot emergence	2.167	1.809	1.263
Foliage coverage at 40 DAP (%)	1.125	196.516*	16.673
Foliage coverage at 60 DAP (%)	72.635	95.633*	27.388
Number of stems/plant at 40 DAP	0.063	2.432**	0.056
Number of stem/plant at 60 DAP	0.010	2.071**	0.050
Number of leaves/plant at 40 DAP	0.924	278.997**	2.310
Number of leaves/plant at 60 DAP	8.200	1057.193**	11.816
Plant height at 40 DAP (cm)	3.126	126.979**	1.981
Plant height at 60 DAP (cm)	4.977	167.949**	3.534
Chlorophyll $_a$ content in leaf (mg/g)	0.010	0.081**	0.001
Chlorophyll $_b$ content in leaf (mg/g)	0.001	0.020**	0.0001
Total Chlorophyll content in leaf (mg/g)	0.018	0.143**	0.002
Number of tubers/plant at70 DAP	0.258	155.079**	1.325
Number of tubers/plant at 90 DAP	0.212	179.203**	1.283
Tuber weight/plant at 70 DAP (g)	209.216	8446.720**	152.586
Tuber weight/plant at 90 DAP (g)	250.455	20236.539**	358.830
Single tuber weight at 70 DAP (g)	0.018	770.844***	1.145
Single tuber weight at 90 DAP (g)	25.506	1792.642**	9.517
Tuber yield at 70 DAP (t/ha)	1.002	32.205**	0.567
Tuber yield at 90 DAP (t/ha)	0.761	77.052**	1.434

*, ** and *** indicate significant at 5%, 1% and 0.1% level of significance respectively
DAP= Days after planting

Appendix III Mean square values of analysis of variance for tuber nutritional quality characters of thirty two potato genotypes harvested at different maturity stages

Characters	Source					
	Mean sum of square					
	Replication		Genotypes		Error	
	70 DAP	90 DAP	70 DAP	90 DAP	70 DAP	90 DAP
df	2	2	31	31	62	62
M	0.696	2.369	14.44**	16.90**	0.971	1.071
DM	0.699	2.368	14.45**	16.90**	0.972	1.071
SG	0.0001	0.0001	0.001*	0.001*	0.0001	0.0001
Ash	0.0001	0.0001	0.008**	0.010**	0.0001	0.0001
pH	0.006	0.010	0.043*	0.032*	0.017	0.019
TSS	0.012	0.016	0.44*	0.372*	0.024	0.026
TA	0.0001	0.0001	0.015**	0.008**	0.0001	0.0001
TPC	1.480	4.175	817.74***	212.87***	1.503	0.906
VC	0.095	0.361	9.70**	14.66**	0.117	0.117
SC	0.151	0.139	8.85**	11.89**	0.125	0.182
TS	0.001	0.001	0.33***	0.237***	0.0001	0.0001
RS	0.001	0.001	0.039**	0.025**	0.001	0.0001
NRS	0.001	0.0001	0.160**	0.128**	0.0001	0.0001
SP	0.005	0.0001	0.192***	0.347**	0.0001	0.001
Fe	0.0001	0.003	0.303***	0.392***	0.0001	0.001
P	1.106	0.378	103.11**	93.52**	1.199	1.427
Ca	0.104	0.169	187.05**	241.01**	0.343	0.435
K	103.288	666.036	51694.24**	52456.87**	177.347	171.997
Zn	0.0001	0.0001	0.035**	0.039**	0.0001	0.0001

*, ** and *** Indicate significant at 5%, 1% and 0.1% level of significance respectively

DAP= Days after planting, dF= Degree of freedom, M= Moisture, DM= Dry matter, SG= Specific gravity, TSS= Total soluble solids, TA= Titratable acidity, TPC= Total phenolic content, VC= Vitamin C, SC= Starch content, TS= Total sugar, RS= Reducing sugar, NRS= Non-reducing sugar, SP= Soluble protein, Fe= Iron, P= Phosphorous, Ca= Calcium, K= Potassium and Zn= Zinc