GENETIC VARIABILITY STUDIES IN POTATO (*Solanum tuberosum* L.) GENOTYPES UNDER HILL ZONE OF KARNATAKA

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CERTIFICATE

This is to certify that the thesis entitled **'GENETIC VARIABILITY STUDIES IN POTATO (*Solanum tuberosum* L.) GENOTYPES UNDER HILL ZONE OF KARNATAKA'** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE) in VEGETABLE SCIENCE** to the College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Mr. RAMACHANDRA, M. KULLUR, ID NO. MH2TAE099** (ramachandramkullur@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

Mudigere
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(Mr. Ramachandra. M. Kullur)

GENETIC VARIABILITY STUDIES IN POTATO (*Solanum tuberosum* L.) GENOTYPES UNDER HILL ZONE OF KARNATAKA

(RAMACHANDRA, M. K.)

ABSTRACT

An investigation on genetic variability studies in potato was carried out in the experimental block, Department of Vegetable Science, College of Horticulture, Mudigere during the year 2016-17. The experiment was laid by adopting Randomized Complete Block Design (RBD) with three replications. The experimental material consisting of sixteen genotypes of potato obtained from CPRI, Shimla and CIP, Peru. Data collected on growth, tuber yield and its components and genetic estimation was made for variance, correlation coefficient and path analysis. Analysis of variance revealed that mean sum of squares was significant for the all parameters which indicated the presence of sufficient variability among the genotypes. The phenotypic coefficient of variation (PCV) for all the parameters was found higher magnitude than genotypic coefficient of variation (GCV). Among different yield attributing characters, fresh and dry weight of tuber, tuber volume, marketable and total tuber yield had the highest magnitude of GCV and PCV (>20%). The high heritability (>60%) estimates coupled with high genetic advance (>20%) was recorded for the characters *viz.,* leaf area, fresh weight of tuber, tuber volume, non-reducing sugars, marketable and total tuber yield. Therefore, additive component is predominant here. Thus, there is ample scope for improving these characters through direct selection. Studies on correlation coefficient showed highly significant and positive association of total tuber yield per plot with plant height, number of leaves, number of stems, total fresh weight of plant, total dry weight of plant, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot. Path analysis indicated that out of thirteen characters studied, the direct effects *via* fresh weight of tuber per plant, followed by starch and dry weight of tuber per plant positively contributed towards total tuber yield per plot, indicating the possibility of simultaneous selection for these traits to improve the tuber yield.

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ಕರ್ನಾಟಕದ ಗುಡ್ಡಗಾಡು ಪ್ರದೇಶದಲ್ಲಿ ಆಲೂಗಡ್ಡೆ (*ಸೋಲಾನಮ್ ಟುಬೇರೋಸಮ್* ಲಿ.) ವಂಶವಾಹಿ ರೂಪಗಳ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ ಅಧ್ಯಯನ

(ರಾಮಚಂದ್ರ, ಎಂ. ಕೆ.)

ಸಾರಾಂಶ

ಆಲೂಗಡ್ಡೆಯ ವಂಶವಾಹಿ ರೂಪಗಳ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ ಅಧ್ಯಯನವನ್ನು 2016-17 ಅವಧಿಯಲ್ಲಿ ತರಕಾರಿ ವಿಭಾಗ, ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯ, ಮೂಡಿಗೆರೆಯಲ್ಲಿ ನಡೆಸಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಪ್ರತಿಕೃತಿ ಜೊತೆಗೆ ಯಾದ್ರಚ್ಛಿಕ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ಈ ಪ್ರಯೋಗಕ್ಕೆ ಕೇಂದ್ರೀಯ ಆಲೂಗಡ್ಡೆ ಸಂಶೋಧನಾ ಸಂಸ್ಥೆ, ಶಿಮ್ಲಾ ಮತ್ತು ಅಂತಾರಾಷ್ಟ್ರೀಯ ಆಲೂಗಡ್ಡೆ ಸಂಶೋಧನಾ ಕೇಂದ್ರ, ಪೆರುವಿನಿಂದ ಹದಿನಾರು ತಳಿಗಳನ್ನು ಸಂಗ್ರಹಿಸಲಾಯಿತು. ವಿಶ್ಲೇಷಣೆ ಬದಲಾವಣೆ ಅಧ್ಯಯನದಿಂದ ಎಲ್ಲಾ ವಂಶವಾಹಿ ರೂಪಗಳಲ್ಲಿ, ಬೆಳವಣಿಗೆ ಹಾಗೂ ಇಳುವರಿಗೆ ಸಂಬಧಿಸಿದ ಗುಣಗಳಲ್ಲಿ ವೈವಿಧ್ಯಮಯ ಗಮನಾರ್ಹ ವ್ಯತ್ಯಾಸವಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಆಲೂಗಡ್ಡೆ ಇಳುವರಿಯ ಅಂಕಿ ಅಂಶಗಳನ್ನು ಸಂಗ್ರಹಿಸಿ ವಂಶವಾಹಿಗಳ ವೈವಿಧ್ಯತೆ, ಸಹಯೋಗ ಮತ್ತು ಮಾರ್ಗ ವಿಶ್ಲೇಷಣೆ ಮಾಡಲಾಯಿತು. ಈ ಅಧ್ಯಯನದಲ್ಲಿ ನಿಯತಾಂಕಗಳು ದೈಹಿಕ ವೈವಿಧ್ಯತೆ ಗುಣಾಂಶವು ಅನುವಂಶಿಕ ವೈವಿಧ್ಯತೆ ಗುಣಾಂಶಕ್ಕಿಂತ ಅಧಿಕವಾಗಿ ಕಂಡುಬಂದಿದೆ. ಇಳುವರಿಗೆ ಕಾರಣವಾಗುವ ಬೇರೆ ಬೇರೆ ಗುಣಲಕ್ಷಣಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡಿದಾಗ ತಾಜಾ ಮತ್ತು ಒಣ ಗಡ್ಡೆಯ ತೂಕ, ಗಡ್ಡೆಯ ಘನ ಅಳತೆ, ಮಾರುಕಟ್ಟೆಗೆ ಯೋಗ್ಯವಾದ ಮತ್ತು ಒಟ್ಟು ಗಡ್ಡೆಯ ಇಳುವರಿಯಲ್ಲಿ ಅತ್ಯಧಿಕ ಅನುವಂಶಿಕ ಮತ್ತು ದೈಹಿಕ ವೈವಿಧ್ಯತೆ ಗುಣಾಂಶ (>20%) ಕಂಡುಬಂದಿದೆ. ಅಧಿಕ ಅನುವಂಶಿಕತಿ (>60%) ಜೊತೆಗೆ ಹೆಚ್ಚು ಅನುವಂಶಿಕ ಮುಂಗಡದ ಸರಾಸರಿಯು (>20%) ಎಲೆಯ ವಿಸ್ತೀರ್ಣ, ತಾಜಾಗಡ್ಡೆಯ ತೂಕ, ಗಡ್ಡೆಯ ಘನಅಳತೆ, ಕಡಿಮೆಗೊಳಿಸದ ಸಕ್ಕರೆ, ಮಾರುಕಟ್ಟೆಗೆ ಯೋಗ್ಯವಾದ ಮತ್ತು ಒಟ್ಟು ಗಡ್ಡೆಯ ಇಳುವರಿಯ ಅಂಶಗಳಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಆದ್ದರಿಂದ ಈ ಮೇಲ್ಕಂಡ ಗುಣಲಕ್ಷಣಗಳು ನೇರ ಆಯ್ಕೆಗೆ ಸೂಕ್ತವಾಗಿದೆ. ಪರಸ್ಪರ ಅಧ್ಯಯನದ ಮೂಲಕ ತಿಳಿದು ಬರುವುದೇನೆಂದರೆ ಗಿಡದ ಎತ್ತರ, ಎಲೆ ಮತ್ತು ಕಾಂಡದ ಸಂಖ್ಯೆ, ಗಿಡದ ತಾಜಾ ಮತ್ತು ಒಣ ತೂಕ, ಪ್ರತಿ ತಾಕು ಮತ್ತು ಪ್ರತಿ ಗಿಡದ ಮಾರುಕಟ್ಟೆಗೆ ಯೋಗ್ಯವಾದ ಗಡ್ಡೆಗಳು ಪ್ರತಿ ತಾಕಿನ ಒಟ್ಟು ಇಳುವರಿಯ ಜೊತೆಗೆ ಅತ್ಯಂತ ಗಮನಾರ್ಹ ಮತ್ತು ಗುಣಾತ್ಮಕ ಸಹಯೋಗವನ್ನು ಹೊಂದಿದೆ. ಮಾರ್ಗ ಗುಣಾಂಕದ ಅಧ್ಯಯನದಿಂದ ತಾಜಾ ಮತ್ತು ಒಣ ಗಡ್ಡೆ ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಮತ್ತು ಪಿಷ್ಠ ಪ್ರತಿ ಗಿಡದ ಇಳುವರಿಯ ಮೇಲೆ ನೇರ ಸಕಾರಾತ್ಮಕ ಪರಿಣಾಮ ಬಿರಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಇಂತಹ ಗುಣಗಳನ್ನು ಹೊಂದಿರುವಂತಹ ತಳಿಗಳನ್ನು ಮುಂದಿನ ಅಭಿವೃದ್ಧಿಗೆ ಉಪಯೋಗಿಸಬಹುದು.

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INTRODUCTION

I INTRODUCTION

Potato (*Solanum tuberosum* L.) is popularly known as "Alloo", Batata, belongs to family Solanaceae consisting of 90 genera and 2,800 species. The name "potato" is believed to be derived from the Inca name *"papa" or "patata"'*. The Andes of Peru and Bolivia in South America are regarded as the centre of origin of potato, from where it was first introduced into Europe towards the end of 16th century through Spanish conquerors. Many wild species occurs more specifically in the Anden of Peru and Southern Bolivia (Brown, 1973), out of which, only seven species are cultivated and all the commercial potato cultivars are tetraploids (2n = 48). Different species can grow from sea level up to more than 4000 meters altitude. Most of them produce tubers but there are some which do not. Two tubers forming species namely *Solanum tuberosum* sub species *tuberosum* and to a lesser extent, *Solanum tuberosum* sub species *andigena* have been exploited worldwide for commercial cultivation. Among the wild *Solanum* species, there is a lot of variability in plant type, tuber shape, size, colour, cooking quality, taste, etc. and also in their adaptability to different climatic conditions. The large variability available among the species has not yet been fully exploited. In India firstly introduced Irish potato during early part of 17th century from Europe. Potato has been disseminated throughout the world and is known as "White or Irish Potato". The association with Ireland is thought to be responsible for the name "Irish potato". After its introduction in India, it was initially grown in the Northern and Southern hills and in certain pockets of central plains. It has been cultivated for at least 8,000 years ago (Martins, 1976) where the potato was probably first domesticated and greatest diversity of cultivated forms could be found.

Potato is an annual, herbaceous, dicotyledonous and self pollinated crop. It is vegetatively propagated but can also be propagated through botanical seed known as True Potato Seed (TPS). The potato tuber is a modified stem developed underground on a specialized structure called stolon. It contains all the characteristics of a normal stem such as dormant bud (eye) and scaly leaf (eyebrow). If allowed to flower and fruit, the potato plant bears an inedible fruit in the form of berry resembling a small tomato fruit like appearance and turns yellow on maturity. Normally each fruit contains up to 300 true seeds. All new potato varieties are grown from seeds, also called "true potato seeds" (TPS) to distinguish it from seed tubers.

Potato is popularly known as 'The king of vegetables' owing to its great utility and high yield potential. It is one of the staple food crops and has emerged as fourth most important one after rice, wheat and maize contributing majorly to food and nutritional security in the world. Potato is a highly nutritious, easily digestible, wholesome food containing carbohydrates, proteins, minerals, vitamins and high quality dietary fiber. Potato tuber contains 75-80 per cent water and 20- 25 per cent dry matter which consisting edible protein (2.8 g), starch (16.3 g), total sugar (0.6 g), crude fiber (0.5 g), fat (0.14 g), carbohydrate (22.6 g),vitamin C (25 mg), ash (1-1.5 %), amylose (22-25%) and glycoalkaloids (< 1 mg) per 100 g fresh weight as an antinutritional factor. Potato is low in fat and rich in several micronutrients (Lutaladio and Castaldi, 2009); especially Vitamin C when eaten with its skin. It is a good source of vitamins B_1, B_3 and B_6 and minerals. Potato also contains dietary antioxidants which help in preventing diseases related to ageing. It is second in source of nutrition after egg; it supplies the necessary daily requirements of various substances including macro and microelements. Humans require at least 25 mineral elements for their well being (White and Brown, 2010) and these mineral elements enter the food chain through plants. Tubers contain high concentration of other organic compounds like protein (cytosine), various organic and amino acids that stimulate the absorption of micronutrients by human, accompanied by lower concentration of compounds like phytate (0.11 to 0.27% of dry matter) and oxalate (0.03% of dry matter) that limits absorption of micronutrients, as a result the bioavailability of mineral elements in potatoes is potentially high (Karenlampi and White, 2009).

Starch is the major component of the dry matter accounting for approximately 70 per cent of the total solids. The potato can be distinguished from cereals like rice and wheat for its higher capacity to produce dry matter, which is about 47.6 kg/ hectare/ day. It produces highest dry matter and protein per unit area and time among the major food crops.

The top five potato producing countries in the world are China, India, Russian Federation, Ukraine and United states. One third of world's potato is being harvested from China and India. The major potato growing states in India are Uttar Pradesh, West Bengal, Punjab, Bihar, Haryana, Madhya Pradesh, Gujarat, Maharashtra and Karnataka. More than 90 per cent potato crop is grown in winter season (*Rabi*) under assured irrigation facility from October to March. The rest is being taken up during rainy season (*Kharif*). The area and production of potato in the country is estimated around 20.85 lakh hectares and 480.96 lakh million tonnes respectively and a productivity of 23.07 tonnes per hectare (Anon., 2015). In Karnataka, the crop is grown in an area of 44,160 hectares with an annual production of 698.30 thousand tonnes and productivity of 13.34 tonnes per hectare (Anon., 2015) and mainly grown in Hassan, Belagavi, Chikkaballapur and Kolar. Hassan district alone accounts for more than 41 per cent potato production in the state (Bhajantri, 2011).

In Indian tropics and sub-tropics, it is a short duration crop and thus, fits in very well with intensive cropping system. It can grow in the wide range of climatic conditions, soil types and has wide flexibility in planting time. A potato plant tuberizes only when two specific environmental conditions are met with. These are short day photoperiod (daylight) and cool night temperature. As these conditions are only available during winter in subtropical Indo Gangetic plains, the potatoes are grown in this season and that is the reason why the potato growing conditions in India are entirely different from those in temperate countries of Europe and North America. Nevertheless, temperate potato growing conditions are also available in Indian hills, and there it is cultivated during summer. But this temperate potato production constitutes only about 8-10 per cent of the total production. Therefore, unlike in European countries, 90 per cent of the potato grown in India is under short day conditions and is regarded as a short duration crop with an average cropping stand of 90 to 100 days. It requires 25^0C temperature at the time of sprouting, 20^0C for vegetative growth and 17 to 20^0C for tuber development. In India, potato is cultivated in the vast Indo-Gangetic plains, North-Western and North-Eastern hills and in plateau area in different seasons. Thus, it is possible to see a standing crop of potato in the country round the year in one part or another. Tubers develop best on deep, fertile, sandy to clay loam soils with good water retention capacity. Potato requires frequent irrigation and the irrigation should be stop few days before harvesting. Potato can be grown almost on all types of soils except highly alkaline and saline soils. Therefore, in a country like India with large population to feed, potato is perhaps the only answer to the growing food needs.

Knowledge on the nature of variability and association of yield with its components is of great importance for identification of superior parents in any breeding programme. The proper evaluation and selection provides scope for identifying desirable genes for exploitation either in itself or through hybridization. The effectiveness of selection, in turn depends upon the genetic variability present in the population. The progress of breeding is conditioned by the magnitude, nature and interrelationship of genotypic and environmental variation in different characters. It becomes necessary to partition the observed variability into heritable and non-heritable components with the help of suitable genetic parameters. Study of correlation between different quantitative traits provides an idea of association that could effectively be utilized in selecting a better plant type in potato breeding programme and to identify the role of each individual character towards yield. 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 situation the path coefficient analysis provides an effective means of finding direct and indirect cause of association.

Germplasm can be utilized for development of new varieties suitable for the different region. Development of high yielding cultivar is a continuous process and there is an urgent need to select best variety suitable for growing in hill zone of Karnataka. Considering the past increase in potato area and lack of suitable variety for this State, generation of basic information about the extent of variability, existing diversity with the available materials, association of important yield and its attributes are pre-requisite to breed suitable cultivar for hill zone of Karnataka.

Keeping in view of the above facts, the present investigation on "Genetic variability studies in potato (*Solanum tuberosum* L.) genotypes under hill zone of Karnataka" was undertaken to study the genetic parameters with the following objectives:

1. To determine the nature and extent of genetic variability for growth, yield and quality traits.
2. To assess the character association for growth, yield and quality parameters.
3. To know the direct and indirect effects of path analysis for growth, yield and quality parameters.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The information on both quantitative and qualitative characters is useful in the selecting superior potato genotypes. The knowledge on genetic variability, heritability, character association and path analysis is very useful for crop improvement in potato. Therefore in this chapter attempt has been made to review the information available in the literature pertaining to the study under the following sub chapters.

2.1 Genetic variability

2.2 Heritability and Genetic advance

2.3 Correlation coefficient studies

2.4 Path coefficient analysis

2.1 Genetic variability

The crop improvement programme largely depends on the extent of variability present in the population. The efficiency of selection largely depends on the genetic component of variability as it directly governs the expression of various characters present in the population. On the other hand, the non-genetic component of variability is the result of genetic and environmental interaction which is not much useful to the breeders since it cannot be perpetuated from generation to generation.

The study on genetic variability was made for the first time by great biologist Fisher (1918) and subsequently the estimation of genotypic and phenotypic variations were used to predict the expected genetic behavior. Later number of workers has also discovered several techniques for the estimation of components of variance (Wright, 1921; Lush, 1940 and Warner, 1952).

The information available on genetic variability studies made in potato by many scientists are reviewed here under.

Ahmad *et al.* (2005) studied genetic variability for yield and yield components in fourteen varieties of potato. The highest phenotypic and genotypic variability was found in number of leaves per plant and plant height followed by number of tuber per plant and number of branches per plant.

Basavaraj *et al.* (2005) investigated phenotypic and genotypic variances and coefficient of variation in 100 accessions of during *kharif* 2003 and 2004. Analysis of variance indicating the presence of sufficient genetic variation among the genotypes. The phenotypic coefficient of variation ranged from 25.33 for plant height to 77.09 for tuber yield per plant. Similarly the genotypic coefficient of variation ranged from 10.60 for number of stems per plant to 48.41 for tuber yield. The results revealed that plant height, number of tubers per plant, tuber weight per plant, tuber yield per plant exhibited moderate to higher phenotypic and genotypic coefficient of variation.

Biswas *et al.* (2005) studied genetic variability for eight quantitative traits at 60 and 90 days after planting in 7 parents and 10 hybrids. The highest coefficient of variation was reported for the characters *viz.* plant weight, tuber weight per plant and number of tubers per plant at 60 days after planting.

A significant genotypic difference for all the characters was observed by Kumar *et al.* (2005). The genotype × year interaction was also significant for tuber number per plant, average tuber weight, tuber yield and area under disease progress curve (AUDPC) indicating that expression of these traits may vary from year to year. Variation was very high for AUDPC values while they were moderate to low for other characters studied. The PCV for all characters were higher than their corresponding GCV.

Luthra *et al.* (2005) reported high phenotypic and genotypic coefficient of variations for tuber yield, tuber numbers and average tuber weight.

Mishra *et al.* (2006) evaluated thirty eight genotypes of potato for fifteen characters over two years. The genotypic coefficient of variation (GCV) for most of traits was quite close to estimates of phenotypic coefficient of variations (PCV) indicating negligible environmental effect on expression of the traits for variability studies. GCV and PCV percentages were high for stolon length, plant height, number of shoots per plant, leaf area, tuber volume, shoot girth, tuber yield per plant and specific gravity of tubers.

Roy and Singh (2006) evaluated 18 genotypes of potato for 12 yield attributing characters under four environments. Plant height, tuber weight per plant, total tuber yield, tuber uniformity, 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.

Chandrakar (2007) studied the variability in 43 clonal hybrids of potato during *Rabi* season of 2006-07. Results of variability analysis revealed the presence of sufficient variability in experimental material for almost all the characters.

The GCV and PCV were low in the characters of plant vigour, dry matter content and days to maturity indicating less environmental influence on these characters. Compound leaves per plant had moderate genotypic and phenotypic coefficients of variation which provides practically average chance for selection. On the contrary, dry matter content, days to maturity and average tuber weight had the least phenotypic and genotypic coefficients of variation and these traits provide practically less chance for selection (Sattar *et al.*, 2007).

Birhman and Singh (2008) studied genetic components for field resistance of potatoes to *Phytophthara infestans* using detached leaves from 16 potato cultivars. Inter-genotypic variability was significant for the components and the Area Under

Disease Progress Curve (AUDPC). The resistant cultivars generally had a longer latent period and lower lesion size and spore production than the susceptible cultivars. Lesion size and AUDPC had a high genetic coefficient of variation.

Singh (2008) recorded the presence of sufficient variability in experimental material. The phenotypic variance was in general higher than the genotypic variance for all the characters. Among different yield attributing characters studied, marketable tuber weight per plot (kg) had the highest magnitude of PCV (42.17%) and GCV (39.72%).

Maximum genotypic and phenotypic coefficients of variation was recorded for tuber fresh weight at 80 days after planting (62.748 and 62.564 respectively), while it was minimum for number of leaves per plant (16.271 and 13.859). The PCV was higher than corresponding GCV for most of the characters indicating the influence of environmental factors on their expression (Ara *et al.*, 2009).

Barik *et al.* (2009) evaluated forty four genotypes for thirteen characters, marketable yield, total tuber yield and number of tubers per plant had higher genotypic and phenotypic coefficient of variation, whereas the moderate magnitude of PCV and GCV was observed for per cent emergence, fresh weight of shoots per plant and plant height.

Genetic variability of seventeen potato genotypes comprising of seven parents and their ten crosses were studied by Haydar *et al*. (2009). The high degree of genotypic variance indicated preponderance of additive gene effects. The range of variation was much pronounced for all the characters studied. Maximum genotypic and phenotypic variances were found for plant height and tuber number indicating greater scope of selection for improvement of the characters. The differences between genotypic and phenotypic coefficient of variability were higher for number of leaves, number of branches and number of tuber indicating vulnerability of the three characters to the environmental effects.

Mondal *et al.* (2009) evaluated thirty one genotypes of potato in order to find out genetic variability of tuber yield and its component characters. All the genotypes showed highly significant variation for all the characters studied. High genotypic coefficient of variation (GCV) as well as phenotypic coefficient of variation (PCV) was observed for individual tuber weight per plant, tuber weight loss percentage at 150 days after harvest due to respiration, number of tubers per plant and plant height at 50, 70 and 90 days after planting.

The phenotypic coefficient of variation (PCV) ranged from 1.07 per cent to 74.29 per cent for tuber specific gravity and late blight score, respectively. Similarly, the lowest genotypic coefficient of variation (GCV) was recorded for tuber specific gravity (0.77%) and the highest for late blight score (57.31%). Except for stem number per hill, late blight score and tuber yield, the difference between GCV and PCV for all other traits was lesser indicating that these traits were less influenced by environment (Tekalign, 2009).

Ummyiah *et al.* (2010) evaluated 26 genotypes of potato for seventeen yield and quality traits. The genetic variability analysis revealed that the characters namely tuber yield per plant, leaf area, average tuber weight, stolon length, total soluble solids (TSS), yield per plot and yield per hectare, number of stolons and number of tubers per plant exhibited high phenotypic and genotypic coefficients of variation. The estimates of phenotypic coefficient of variability were slightly higher than corresponding genotypic coefficients of variation for all the characters under study indicating that the genotypic influence was lesser under the influence of the given environment.

Bisognin *et al.* (2012) reported variance and co-variance components of potato tuber shape and fresh weight. Seed and harvested tubers of nine progeny were evaluated for length, larger and smaller diameter and fresh weight. In average, the tubers were lengthy, because the relationship between length with larger diameter was 1.30 and with smaller diameter was 1.51. Also, there were differences among hill variance estimations for individual and ratios of a given trait. The mean square errors among hills were higher than among plots for all evaluated traits.

Fekadu *et al.* (2013) evaluated thirteen potato genotypes for genetic variability in agronomic characters. The analysis of variance showed that the mean square due to genotypes were highly significant ($p<0.01$) for all characters studied, which indicates the existence of sufficient genetic variability and there was less coefficient of variation in all of the characters indicating good precision of the experiment.

Wide range of phenotypic variability for reducing sugars, plant height, average weight of tubers, number of tuber per plant and tuber dry matter content was reported by Patel *et al.* (2013) in twenty four genotypes. The high genotypic coefficient of variation (GCV) was observed for reducing sugar, number of stems per plant, marketable tuber yield and chip color. While high phenotypic coefficient of variation (PCV) observed for marketable tuber yield and number of stems per plant.

Rangare and Rangare (2013) was evaluated 44 genotypes of potato for 13 characters among which marketable yield (kg per plot), total tuber yield (kg per plot) and number of tubers per plant had higher genotypic and phenotypic coefficient of variation, whereas the moderate magnitude of PCV and GCV were observed for per cent emergence, fresh weight of shoots per plant and plant height.

The genetic variability analysis with 11 early and 6 medium maturing advanced potato hybrids was studied by Santhosh *et al.* (2013) during *Kharif* season. Among early maturing advanced potato hybrids, high GCV and PCV were observed for plant height, number of stems, number of tubers per plant, marketable and total tuber yield.

Among medium maturing advanced potato hybrids, high GCV and PCV were observed for plant height, number of stems, number of tubers per plant, marketable and total yield and total sugars.

Singh *et al.* (2013) observed sufficient variability in potato genotypes for tuber yield and other characters. The genotypes Jper96-238, Jper99-242, Jper99-48, Jper95-227 and Kufri Pukhraj were found superior with respect to tuber yield and other characters. The overall values of PCV were higher than those of GCV.

An experiment was conducted to determine genetic variability in yield related characters of some potato (*Solanum tuberosum* L.) varieties. Analysis of variance revealed the presence of significant differences ($p<0.01$) among all varieties for all observed traits. Genotypic and phenotypic coefficients of variation were higher for biological yield, tubers per plant, tuber yield and plant height. The character with high GCV indicates high potential for effective selection. The phenotypic coefficient of variation (PCV) was higher than corresponding genotypic coefficients of variation (GCV) for all characters denoting environmental factors influencing their expression (Lamboro *et al.*, 2014).

Nasiruddin *et al.* (2014) evaluated 31 genotypes of potato and reported that the phenotypic coefficient of variation ranged from 14.48 for main stem number per plant to 14642.4 for canopy size. Similarly, the genotypic coefficient of variation also ranged from 3.28 for main stem number per plant to 13976.6 for canopy size. This indicates the presence of wide range of genetic variation in the test entries. Higher magnitude of both phenotypic as well as genotypic coefficient of variation i.e. PCV and GCV were noted for almost all the traits except for main stem number per plant (14.48 and 3.28, respectively).

Quantitative traits in a potato population comprising 21 genotypes were studied by Ozturk and Yildirim (2014). Based on the combined analysis of variance performed over two years showed that genotypic variance, genotype × year interaction variance and phenotypic variance were significant at the $p\leq0.01$ level. Genetic coefficient of variation was high for plot yield (26.2 %), plant height (21.2 %) and single tuber weight (20.4 %).

Panigrahi *et al.* (2014) studied 19 potato genotypes for yield and yield contributing traits in West Bengal. The study revealed the presence of significant differences among the genotypes in respect of all characters and indicated high genetic variability.

Pradhan *et al.* (2014) reported minimum difference between GCV and PCV for all the characters which suggested presence of least influence of environment on expression of these yield and storage characters.

Significant difference between traits including number of days to tuberisation, plant height, number of main stem per plant, main stem diameter, tuber number per plant, average tuber weight, tuber weight per plant and tuber yield was reported by Zakerhamidi and Hassanpanah (2014).

Hafiz (2015) studied the extent of genetic variation among yield and yield related traits in twenty five genotypes. Analysis of variance indicated significant difference among the 13 trait with respect to all the characters except four traits among the tested genotypes. Wide range of variation was observed among all traits. The phenotypic coefficients of variation values were higher than genotypic coefficients of variation values.

High estimates of coefficients of variability for marketable tuber yield, total yield, dry weight of shoots, number of compound leaves and fresh weight of shoots indicating that these characters are largely controlled by additive gene action and straight selection for them would be effective (Singh *et al.*, 2015).

Genetic variability analysis among forty-eight potato genotypes including four checks and evaluated for nine quantitative traits was studied by Verma and Singh (2015). All the characters showed highly significant differences among varieties which indicate the existence of sufficient variability for various traits *viz.*, emergence percent, plant height, number of shoots, average tuber weight, number of tuber per plant, marketable and unmarketable yield per plot and tuber yield per plant.

Asefa *et al.* (2016) assessed the nature and magnitude of variability for tuber yield, yield related and late blight resistance traits. The genotypes showed highly significant ($P<0.01$) differences for all the characters studied. High genotypic (GCV) and phenotypic (PCV) coefficient of variations computed which ranged from 22.7 to 51.9 per cent and 32.8 to 56.7 per cent, respectively. They revealed that the presence of considerable variability in tested genotypes for economic importance traits and the higher chance of selecting genotypes with high yield and moderately resistant to late blight.

Tripura *et al.* (2016) reported that the estimates of phenotypic and genotypic variances were found to be very high for weight of tuber per plant, tuber number, tuber breadth, and single tuber weight and comparatively high in plant height at 60. The magnitude of PCV was either substantially or marginally higher than GCV for most of the characters.

Verma and Singh (2016) investigated the level of variability in 44 potato germplasm and reported high genotypic and phenotypic variance for plant height, average tuber weight and tuber yield per plant, number of shoots per plant, number of tubers per plant and tuber yield per plot.

Investigation was undertaken to estimate genetic variability for important yield component characters in potato. The analysis of variance indicated the existence of sufficient amount of variability among genotypes for all the characters .The phenotypic variance was in general higher than the genotypic variance. Among different yield attributing characters studied, number of compound leaves per plant had the highest magnitude of PCV (30.96 %) and GCV (27.94 %) (Mishra *et al*., 2017).

2.2 Heritability and genetic advance

Heritability is the quantitative statement of the relative importance of heredity and environment. The partitioning of phenotypic variation into genetic and environmental variation was first done by Fisher (1918). However, different methods have been revised by several workers for the estimation of heritability.

The ratio of the genotypic variance to the phenotypic variance or total variance is known as heritability. It is a good index of transmission of character from parents to their offspring. The estimate of heritability helps the breeders in selecting elite genotypes from diverse genetic populations. The amount of progress expected through selection for obtaining the best individual cannot be made on the basis of heritability alone. The genetic progress would be enhanced with an increase in heritability estimate. Hence, the heritability estimate could be best utilized in conjugation with genetic advance in predicting genetic gain. Genetic advance denotes the improvement in the genotype values of the new population. So, the knowledge of genetic advance, to be expected by applying selection pressure to a segregating and variable population, is useful in designing an effective breeding programme.

Lush (1940) defined the broad sense heritability as the ratio of genotypic variance to total variance. Different methods of estimating heritability have also been suggested by Kaul (1967) and Reddy and Heyne (1968).

Basavaraj *et al*. (2005) investigated heritability and genetic advance in 100 accessions during *kharif* 2003 and 2004. The results revealed that plant height, number of tubers per plant, tuber weight per plant and tuber yield per plant exhibited moderate to higher heritability coupled with higher genetic advance as per cent of the mean. Finally it could be concluded that there exists a lot of genetic variation among the entries and improvement could be brought through simple selection. Biswas *et al*. (2005) studied genetic variability for eight quantitative traits at 60 and 90 days after planting in seven parents and ten hybrids. Results revealed that high heritability observed for plant weight, tuber weight per plant and number of tubers per plant.

Kumar *et al*. (2005) studied on heritability and genetic advance for all the characters *viz.,* tuber number per plant, average tuber weight, tuber yield and area under disease progress curve (AUDPC). High heritability coupled with high genetic advance for AUDPC and tuber yield indicated that the direct selection would be highly effective for the improvement of these traits. On the other hand, little improvement would be possible for tuber number per plant.

Mishra *et al*. (2006) investigated thirty eight genotypes of potato for fifteen characters over two years. The traits *viz*., stolon length, plant height, leaf area, number of shoots per plant, tuber volume, tuber dry matter content, specific gravity of tubers, shoot girth and tuber yield per plant had high heritability and genetic advance as per cent of mean. High heritability and genetic advance for per cent emergence, total tuber yield, harvest index, dry matter percentage, total sugar and total starch percent was recorded by Roy and Singh (2006). Results revealed that the genotypic coefficient of variation, high heritability and genetic advance may be exploited in further breeding programme.

Chandrakar (2007) recorded high heritability coupled with high genetic advance as per cent of mean for number of tubers per plant and tuber weight per plant.

The characters with high heritability were effective for selection as observed by Sattar *et al.* (2007). Yield of tubers per plant, number of leaves per plant, plant vigour and plant height had high heritability values and these characters are very much important to be considered by a breeder for selection. In addition, the characters like number of leaves per plant and yield had high genetic advance along with high heritability.

Birhman and Singh (2008) studied genetic parameters for field resistance of potatoes to *Phytophthara infestans* using detached leaves from 16 potato cultivars. Inter-genotypic variability was significant for components and Area Under Disease Progress Curve (AUDPC). The resistant cultivars generally had a longer latent period and lower lesion size and spore production than the susceptible cultivars. Lesion size and AUDPC had a high heritability and genetic advance.

High heritability coupled with high genetic advance as percentage of mean was estimated for marketable tuber weight per plot, total tuber weight per plot, weight of tubers per plant, number of marketable tubers per plant, number of leaves per plant and number of tubers per plant (Singh, 2008). Ara *et al.* (2009) reported that the heritability ranged from 72.558 to 99.414. High heritability was observed for tuber fresh weight at 90 days (99.414) and plant height at 50 days 99.253), whereas main shoot number, fresh weight at 50 days, plant height and tuber fresh weight at 90 days had high heritability and genetic advance which indicated that these characters were most vital in the selection for yield improvement.

Barik *et al.* (2009) evaluated forty four genotypes for thirteen characters. High heritability estimates for the characters *viz.*, fresh weight of shoots per plant, harvest index, dry weight of tubers per plant, per cent emergence, total number of leaves per plant, fresh weight of tubers per plant total tuber yield per plot, plant height and dry weight of shoots per plant. High genetic advance as percentage of mean was obtained for characters namely dry weight tubers per plant and total tuber yield per plot. High heritability coupled with high genetic advance was recorded for the traits *viz.*, dry weight of tubers and total tuber yield per plot. Results revealed that the high heritability and genetic advance may be exploited in further breeding programme.

High heritability as well as high genetic advance as percentage of mean were observed for plant height, branches number, tubers number and tuber yield indicated that these traits controlled by additive gene action (Haydar *et al*., 2009).

Mondal *et al.* (2009) evaluated thirty one genotypes of potato in order to find out genetic variability of tuber yield and its component characters. All the genotypes showed highly significant variation for all the characters studied and revealed that heritability was found high for plant height, tuber weight per plant, tuber number per plant, individual tuber weight per plant and tuber weight loss percentage at 150 days after harvest.

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 indicate dominance of additive gene effect. Pradhan *et al.* (2011) recorded the high heritability and genetic advance for plant height at 60 DAP followed by number of leaves and sprouting percentage.

Bisognin *et al*. (2012) reported heritability components for potato tuber shape and fresh weight. Seed and harvested tubers of nine progeny were evaluated for length, larger and smaller diameter and fresh weight. High heritability was observed for progeny selection and low heritability for clone selection in the progeny. Patel *et al.* (2013) reported high heritability (99.98 and 99.96 %) value for reducing sugars in 75 days and 95 days of harvest, respectively. The highest value of genetic advance (95.34 and 97.24 %) observed for reducing sugars in 75 days and 95 days of harvest, respectively.

Rangare and Rangare (2013) reported high heritability estimates for the characters such as fresh weight of shoots per plant, harvest index, dry weight of tubers per plant, per cent emergence, total number of leaves per plant, fresh weight of tubers per plant, total tuber yield per plot, plant height and dry weight of shoots per plant. High genetic advance as percentage of mean was obtained for characters namely dry weight of tubers per plant and total tuber yield per plot. Results revealed that high heritability coupled with high genetic advance was recorded for the traits *viz.*, dry weight of tubers and total tuber yield per plot.

Santhosh *et al*. (2013) conducted biometrical studies with 11 early and 6 medium maturing advanced potato hybrids during *Kharif* season. Among early maturing advanced potato hybrids, high heritability coupled with high GAM were observed for plant height, number of tubers per plant, marketable and total tuber yield, tuber diameter, non-reducing sugars, potato leaf roll virus and Spodoptera. Among medium maturing advanced potato hybrids, high heritability coupled with high to moderate GAM were observed for all the characters except chlorophyll content. Genotypes 200/P-26, MS/99-1871 and Kufri Pukhraj performed well under southern transitional zone of Karnataka.

Singh *et al.* (2013) recorded the high heritability for reducing sugar content, volume of tuber, weight of tuber and length of tuber. High heritability along with high genetic advance as per cent of mean was estimated for reducing sugar content, volume of tuber and weight of tuber. Lamboro *et al.* (2014) reported days to maturity, plant height, days to flowering, tubers per plant, biological yield, tuber yield and stems per plant were found to be the most heritable traits studied in the potato varieties. They observed that relatively higher heritability associated with higher predicted genetic advance was observed for tubers per plant, biological yield and medium tuber percentage. These traits therefore, deserve greater attention in future breeding programmes for developing better potato varieties.

Nasiruddin *et al.* (2014) evaluated 31 genotypes of potato and reported that high heritability estimates were noticed for all the traits except main stem number per plant and secondary stem number per plant (22.67 per cent and 31.98 per cent, respectively). Moreover, higher heritability estimates were coupled with high genetic advance as per cent of the mean for all the characters except main stem number per plant, secondary stem number per plant (10.41 per cent and 18.28 per cent respectively) and dry matter (%) per plant (18.28 per cent).

Broad-sense heritability values for some quantitative traits in a potato population comprising 21 genotypes were reported during the 2013 and 2014. Based on the combined analysis of variance performed over two years, moderate to high level heritability values were found for plant height (0.77), leaf width (0.69), leaf length (0.71), single tuber weight (0.74), plant yield (0.60) and starch content (0.87) (Ozturk and Yildirim, 2014).

Pradhan *et al.* (2014) noticed that heritability of all yield and storage characters were found to be high. High heritability coupled with high genetic advance as per cent of mean was observed for characters like number of non-marketable tubers, weight of non-marketable tubers, number of marketable tubers and weight of marketable tubers, desiccation loss, sprouting loss, rotting loss as well as total storage loss and these characters may be considered predominantly controlled by additive gene action and selection should be in positive direction for all these characters.

Hafiz (2015) investigated biometrical analysis among yield and related traits in twenty five genotypes. Analysis of variance indicated significant difference among the

13 traits with respect to all the characters except four traits among the tested genotypes. Higher heritability coupled with higher genetic advance as per cent of the mean was noticed for weight of tuber per hectare, date of flowering, plant height, tuber diameter and leaf width. Singh *et al.* (2015) recorded high estimates of heritability and genetic gain (GA) for marketable tuber yield, total yield, dry weight of shoots, number of compound leaves and fresh weight of shoots indicating that these characters were largely controlled by additive gene action.

Asefa *et al.* (2016) assessed the nature and magnitude of variability for tuber yield, yield related and late blight resistance traits. Heritability in broad sense and genetic advance as per cent of the mean ranged from 44.5 to 89.5 per cent and 14 to 98.1 per cent, respectively. Both h^2 and GAM high for total tuber yield, marketable tuber yield, average tuber weight, marketable tuber number per hill, per cent severity index, days to flowering and area under disease progress curve. Tripura *et al.* (2016) observed that heritability estimates were high for weight of tuber per plant, tuber number, tuber breadth, plant height 60 days, tuber length and stem girth. High heritability coupled with high genetic advance was noted in weight of tuber per plant, single tuber weight and tuber breadth which indicated the influence of additive gene effect on these characters.

Mishra *et al.* (2017) estimated heritability and genetic advance for important yield component characters in potato. High heritability was recorded for the traits namely dry weight of tubers per plant, marketable tuber yield per plot, total tuber yield per plot and fresh weight of tubers per plant were recorded with high heritability. The highest genetic advance as percentage of mean was recorded for number of compound leaves per plant, dry weight of tubers per plant, marketable tuber yield per plot, total tuber yield per plot and fresh weight of shoots per plant. High heritability coupled with high genetic advance was recorded for the traits *viz.*, number of compound leaves per plant, dry weight of tubers per plant, marketable tuber yield per plot and total tuber yield per plot.

2.3 Correlation coefficient studies

Information on genetic association among various characters under particular environmental condition helps to formulate the most effective method of breeding to achieve certain objectives and to simplify the approach to selection. The study of the association of component characters with a complex trait like yield is prerequisite for any of the breeding programme.

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. Later, the formula for its quantitative estimation was developed by Pearson (1904), Fisher (1918) and Wright (1921). Thereafter, Searle

(1961) described the mathematical implications of correlation coefficient at phenotypic, genotypic and environmental levels.

Kumar *et al*. (2005) studied on correlation coefficient for all the characters *viz.*, tuber number per plant, average tuber weight, tuber yield and area under disease progress curve (AUDPC). Average tuber weight had significantly positive correlation with tuber yield. Non-significant correlation was observed between yield and late blight and also advocated selection of average tuber weight for achieving higher yield in potato.

Experiment was conducted to study the correlation involving eighteen genotypes of potato under four different environments during *Rabi* season in Bihar, India. The results indicated that positive significant association of total tuber yield with plant height, number of tubers per plant and tuber yield per plant (Roy and Singh, 2006).

Shashikamal (2006) revealed that maximum and significantly positive genotypic and phenotypic correlation of tuber yield was recorded with average tuber weight and number of tubers per hill, whereas shoot girth exhibited negative correlation with tuber yield. Protein content showed negative correlation with all growth and quality characters except number of tubers per hill.

Barik (2007) recorded the positive and highly significant association of tuber yield with marketable tuber yield per plant, whereas total tuber yield per plant was positively correlated with per cent plant emergence, number of tubers per plant and fresh weight of tubers per plant. Chandrakar (2007) observed that tuber yield was positively correlated with number of shoots per plant, number of leaves per plant, number of compound leaves per plant, number of tubers per plant, tuber weight per plant and harvest index per cent.

An investigation was conducted using the five check cultivars Agria, Marfona, Draga, Agata and Arinda and 120 potato clones obtained from TPS. Correlation coefficient analysis showed that tuber yield had significant positive association with number of tubers per plant, average weight per tuber (tuber size), plant height, diameter of main stem and number of main and secondary stems per plant, whereas its correlation with tuber dry-matter content was significantly negative (Rasool *et al.*, 2007).

Regassa and Basavaraj (2007) investigated character association in 100 accessions during *kharif* 2003 and 2004. The results revealed that tuber yield was highly and positively correlated both at phenotypic and genotypic levels with plant height, plant spread, weight of medium size tubers, weight of large size tubers, total tuber weight, number of medium size tubers, number of large size tubers and total number of tubers per plant. The correlation coefficients were highly significant ($p=0.01$) indicating the presence of strong association and it could be possible to improve the tuber yield by considering these traits. Highly significant and negative correlation was found between yield and days to flowering both at phenotypic and genotypic levels. There was a positive association between number of main stems per plant and tuber weight, tuber number, plant height and plant spread which in turn highly correlated with yield.

Sattar *et al.* (2007) found that plant vigour, number of compound leaves per plant, number of tubers per plant, average weight of a tuber and dry matter content of tuber had high degree of positive association with tuber yield per plant.

Amadi *et al.* (2008) reported the estimates of phenotypic correlation coefficients and revealed that a significant positive correlation between tuber yield and each of five attributes namely average tuber weight per plant (r = 0.632), number of tubers per plant (r = 0.486), early blight severity (r = 0.123), days to tuber initiation (r = 0.128), and days to maturity (r = 0.147). These findings, indicated that average tuber weight per plant and number of tuber per plant were the critical attributes of utmost importance which can be used successfully as indices of selection for yield improvement in potato.

Birhman and Singh (2008) studied correlation coefficient analysis for field resistance of potatoes to *Phytophthara infestans* using detached leaves from 16 potato cultivars. The correlation between AUDPC (Area Under Disease Progress Curve) and infection efficiency and between AUDPC and spore density were not significant. However latent period, lesion size and sporulation correlate significantly with AUDPC. Singh (2008) reported that number of leaves per plant, number of tubers per plant, weight of tubers per plant, marketable tuber weight per plot and total tuber weight per plot exhibited a significant and positive correlation with marketable tuber weight per plot.

Yenagi *et al.* (2008) conducted an experiment to study the correlation between yield and yield components of potato variety Kufri Chandarmuki. The results revealed that positive and significant correlation between tuber yield and growth attributes namely plant height(r=0.977) and total dry matter production per plant (r=0.797) but negative and significant correlation between dry matter production in tubers per plant (r=0.782). Number of tubers per plant (r=0.818) and weight of tubers per plant (r=0.782) were positively and significantly correlated with tuber yield. Ara *et al.* (2009) suggested that the characters like plant height, fresh weight per plant and number of leaves per plant showed positive association with fresh weight of tuber at 80 days after planting.

Gaur *et al.* (2009) reported phenotypic, genotypic and environmental correlation coefficients for 13 morphological and tuber quality characters. 17 out of 78 possible combinations were found to be significant. Tuber yield was positively associated with average tuber weight and total tuber dry matter per plant. Average tuber weight was negatively associated with number of tubers per plant and most of the quality characters. Among the tuber quality characters, percentage tuber dry matter showed significant positive association with the percentage alcohol-insoluble solids (AIS), percentage of starch in fresh tubers and a negative association with the percentage of protein in tuber dry matter.

Thirty one genotypes of potato were evaluated to find out character association among tuber yield and its component characters. Tuber weight per plant was found to be positively and significantly associated at genotypic as well as phenotypic levels with plant height (50, 70 and 90 DAP), tuber number per plant, individual tuber weight per plant and tuber weight loss percentage at 150 days after harvest (Mondal *et al.*, 2009).

Lopez *et al.* (2010) recorded the positive and significant correlation of yield with weight, diameter and length of tuber per plant. The results suggest that potato genotypes considered in this study could be improved efficiently by means of yield itself or considering tuber quality characteristics.

Felenji *et al*. (2011) studied the correlation coefficient among different traits *viz.,* Tuber yield, tuber weight, stolon length, number of tubers per plant, dry matter per cent number of stems per plant, plant height, harvest index, stem diagonal and biological yield. Correlation coefficient showed that tuber weight and harvest index have positive and significant correlation with tuber yield. Khayatnezhad *et al.* (2011) found stronger positive and significant correlation between starch content and dry matter content (r=1). Similarly, tuber yield exhibited strong positive correlation with number of main stems per plant (r=0.925), plant tuber weight(r=0.992) and plant height (r=0.843).

Bisognin *et al.* (2012) observed higher and direct character association of potato tuber shape and fresh weight in the early generations of selection. The smallest correlation (0.348) was between length and smaller diameter, which is also important. The breeding gain can be maximized combining the selection among and within progeny to early discard undesirable clones.

Genotypic correlation coefficient was found to be higher in magnitude than that of phenotypic correlation coefficients which clearly indicated the presence of inherent association among various characters. Tuber yield was positively correlated with plant height, biological yield, harvest index and big tuber percentage at both the phenotypic and genotypic levels. In contrast, it was negatively correlated with small and medium tuber percentage at both levels (Fekadu *et al*., 2013).

Panghal *et al.* (2013) reported negative and significant correlation for dry weight and number of weeds with the total tuber yield, whereas total tuber yield was highly significant and positive relationship with total tuber number.

The characters such as marketable yield, number of tubers per plant and number of stems per plant showed significant positive correlation with total tuber yield at both genotypic and phenotypic levels, while average weight of tuber and reducing sugar showed significant positive correlation with total tuber yield at genotypic level. At both genotypic and phenotypic levels, this character showed positive and significant correlation with total tuber yield (Patel *et al.*, 2013).

Rangare and Rangare (2013) observed that the tuber yield showed significant positive correlation with marketable tuber yield both at the genotypic and phenotypic levels. The tuber yield also positive and significant correlation both at phenotypic and genotypic levels with per cent plant emergence, number of tubers per plant and fresh weight of tubers per plant. Association of component characters revealed positive and highly significant correlation of marketable tuber yield with per cent plant emergence, fresh weight of tubers per plant and number of compound leaves per plant at phenotypic and genotypic levels. Dry matter content of tubers per plant exhibited positive and highly significant correlation both at phenotypic and genotypic levels with fresh weight of tubers per plant and harvest index. Similarly number of tubers per plant exhibited significant and positive correlation with the number of shoots per plant at genotypic level. Fresh weight of tubers per plant showed positive and highly significant correlation for number of compound leaves per plant and number of shoots per plant at genotypic level.

Rangare *et al.* (2014) studied that the marketable tuber yield per plot had significant and positive correlation on total tuber yield both at genotypic (0.979) and phenotypic (0.926) levels. Similarly, the total tuber yield exhibited the positive and significant association both at phenotypic and genotypic levels with per cent emergence (0.663 and 0.757 respectively), number of tubers per plant (0.930 and 0.365 respectively) and fresh weight of tubers per plant (0.512 and 0.607, respectively). However, in case of number of compound leaves per plant, it had positive and significant correlation with tuber yield per plant at genotypic (0.784) level. Similarly tuber yield exhibited positive and significant association at genotypic level with unmarketable tuber yield per plant (0.313) and number of shoots per plant (0.303). While the tuber yield per plant exhibited significant but negative correlation with the number of branches per plant (-0.440).

Santhosh *et al*. (2013) conducted an experiment for correlation coefficient analysis with 11 early and 6 medium maturing advanced potato hybrids during *Kharif* season. Number of leaves, tuber weight per plant and marketable tuber yield per plot were shown significant positive correlation with tuber yield per plot in both genotypic and phenotypic levels. The results in case of medium maturing potato hybrids indicated that tuber yield was positively and significantly correlated both at phenotypic and genotypic levels with number of tubers per plant and marketable yield per plot.

Ummyiah *et al.* (2013) studied genotypic and phenotypic correlations and reported that tuber yield per plant had positive and significant correlation with number of stems per hill, leaf area, plant height, plant spread, number of stolons per plant, stolon length, number of tubers per plant, average tuber weight and yield per hectare.

Darabad (2014) reported that tuber yield had a significant positive correlation with leaf area index, edible tubers percentage, plant cover percentage, plant height, main stem diameter, weight of tubers per plant and number of tubers per plant. The number of tubers per plant had a significant positive correlation with the traits of emergence percentage, plant height, number of main stem, weight of tubers per plant and tuber dry matter percentage.

Correlation coefficient among different characters in all possible combination. The results revealed that tuber yield witnessed positive significant correlation with average tuber weight per plant (0.967), average tuber weight (0.575), number of stolon per hill (0.403) and ascorbic acid (0.460). Selection for these traits would be effective to improve tuber yield in potato reported by Datta *et al*. (2014).

Nasiruddin *et al.* (2014) evaluated 31 genotypes of potato and reported that tuber yield per plant had a significant positive correlation with plant height, main stem number per plant, canopy size, leaf area per plant and dry matter (%) per plant. They depicted that these characters have high and positive correlation with tuber yield per plant.

Lamboro *et al.* (2014) observed high positive significant correlation between tuber yield and biological yield, plant height and tuber yield, tuber yield per plant and small tuber percentage, stems per plant and tuber yield per plant. Days to maturity and plant height had high significant positive correlation with biological yield, whereas tuber yield was positively associated with plant height.

Zakerhamidi and Hassanpanah (2014) indicated that there was a significant and positive correlation between tuber weight per plant and tuber number per plant (r=0.74) at 1 per cent probable level. There was a significant and positive correlation between tuber yield and tuber number per plant (r = 0.742**) at 1 per cent probable level. The correlation between tuber yield and tuber weight per plant (r=0.999**) was significant and positive at 1 per cent probable level. Tuber yield was of the highest correlation with tuber weight per plant (0.999**) among all these traits.

Hafiz (2015) investigated biometrical analysis among yield and related traits in twenty five genotypes. The results revealed that genotypic correlation coefficients were higher than corresponding phenotypic correlation coefficients. Weight of tuber per hectare was positively and significantly correlated with total tuber per plant and marketable tuber per plant at genotypic as well as phenotypic level.

Singh *et al.* (2015) reported that total tuber yield per hectare showed a significant and positive association with marketable tuber yield per hectare (0.999 & 0.997), fresh weight of tubers per plant (0.925 & 0.833), number of shoots per plant

(0.891 & 0.519), number of tuber per plant (0.806 & 0.353) and plant emergence per cent (0.800 & 0.444).

Verma and Singh (2015) studied on correlation coefficient analysis among forty-eight potato genotypes including four checks. They revealed that significant and positive correlation of total tuber yield was recorded with plant height (r= 0.411), number of shoots (0.449), tuber yield per plant (r=0.757), marketable yield per plot (r=0.995) and average tuber weight (r=0.594) and non significant correlation with emergence per cent (0.284) and number of tuber per plant (0.153).

The tuber yield was positively and significantly correlated with lateral leaflet length at 30 days, terminal leaflet length at 30 days and tuber number per plot at genotypic as well as phenotypic levels. Tuber number was found to have positive and significant association with tuber breadth and total tuber yield. Number of tubers per plot and plant height showed positive correlations with maximum direct effect on yield and these characters can be considered for selection of high yielding genotypes on the basis of their phenotypic data because these characters were least influenced by environment (Tripura *et al.*, 2016).

Verma and Singh (2016) investigated the level of character association in 44 potato germplasm among ten different quantitative characters. Positive and significant correlation of tuber yield observed for plant height followed by number of shoots per plant, average weight of tuber, tuber yield per plant and marketable yield per plot.

Correlation coefficient analysis showed a significant and positive correlation between yield (weight of tubers per plant) and number of compound leaves (0.336), terminal leaf area (0.487) and length of primary stolon (0.606). Among the three parameters, length of primary stolon exerted the maximal direct positive effect on yield (Yerima, 2016).

Mishra *et al*. (2017) studied on correlation coefficient for important yield component characters in potato and showed that total tuber yield was positively correlated with fresh weight of tuber , number of tubers, number of leaves, dry weight of tubers, number of compound leaves and harvest index percentage.

2.4 Path Coefficient analysis

The concept of path analysis was originally developed by Wright in 1921, but the technique was first used for better selection by Deway and Lu in 1959. Path coefficient analysis allows a detailed examination of specific force acting to produce a given correlation and measures the relative importance of such casual factor. It has been widely employed in selection work of many crop plants. Path coefficient analysis is used as an effective tool in finding out the direct and indirect effects of different contributing characters towards yield. Each component possesses a large direct effect on yield and its important indirect effects (Fonseca and Peterson, 1968).

Roy and Singh (2006) observed that tuber yield per plant had the highest direct effect towards total tuber yield followed by number of tubers per plant and per cent marketable yield.

Shashikamal (2006) revealed that tuber weight, plant height, number of tubers per hill, number of stolons per hill, number of leaves haulms-1 and number of haulms per hill have positive effect on tuber yield. Keeping in view high negative direct effect of total soluble solids, phosphorus content, specific gravity of tuber and total chlorophyll content on tuber yield, it is suggested that important yield determining traits *viz.*, tuber weight, plant height and number of tubers per hill should be given due importance during selection for improvement of yield in potato.

Chandrakar (2007) noticed that there is no common causal factor that directly influenced the tuber yield. The direct selection for the traits namely tuber weight per plant, harvest index per cent and number of shoots per plant could be useful for improvement of tuber yield.

An investigation was conducted using the five check cultivars Agria, Marfona, Draga, Agata, and Arinda and 120 potato clones obtained from TPS. Path coefficient analysis showed that number of tubers per plant, tuber size and plant height had significant standardized partial regression coefficients with very small tolerance and large variance inflation factor (VIF) values. These were considered as the first-order variables in path analysis (Rasool *et al.*, 2007).

Regassa and Basavaraj (2007) investigated path coefficient analysis in 100 accessions during *kharif* 2003 and 2004. The results revealed that seven out of eight genotypes had a positive direct influence on the yield. However, plant spread and weight of small tubers per plant had negative direct influence only at genotypic level. Plant height has been observed to exert negative direct effect both at phenotypic and genotypic levels regardless of its positive and higher correlation with the yield both at phenotypic and genotypic levels. Weight of large size tubers per plant exerted the maximum positive direct effect on tuber yield at both phenotypic and genotypic levels followed by weight of medium size tubers per plant. The maximum positive indirect effect was exerted on yield by number of main stems per plant through weight of large size tubers per plant at genotypic level. This was followed by plant height and plant spread through weight of large size tubers per plant both at phenotypic and genotypic levels.

Sattar *et al.* (2007) observed that average weight of tuber and total number of tubers per per plant contributed maximum direct effect to tuber yield indicating their importance as selection index for yield improvement.

Amadi *et al.* (2008) reported that partitioning observed phenotypic correlation into their direct and indirect effects using path analysis. The results showed that average tuber weight followed by the number of tubers per plant exerted the highest direct influence on tuber yield per plant. Other attributes exerted minimal direct influence on tuber yield. These findings, indicate that average tuber weight per plant and number of tuber per plant were the critical attributes of utmost importance which can be used successfully as indices of selection for yield improvement in potato.

Birhman and Singh (2008) studied phenotypic and genetic path analyses for field resistance of potatoes to *Phytophthara infestans* using detached leaves from 16 potato cultivars. Genotypic and phenotypic path-coefficient analysis indicated lesion size to be the most important component of field resistance.

Singh (2008) revealed that direct selection for the characters namely total tuber weight per plot, number of marketable tubers per plant, number of leaflets per leaf, number of unmarketable tubers per plant, plant height, number of leaves per plant and plant emergence percentage were beneficial in improving the marketable tuber weight in potato.

Ara *et al.* (2009) revealed that number of shoots showed highest (0.716) positive direct effect on tuber yield followed by fresh weight of plant at 80 days after planting (0.464) and number of leaves per plant (0.341).

Mondal *et al.* (2009) evaluated thirty one genotypes of potato in order to find out path coefficient of tuber yield and its component characters. They revealed that plant height at 50, 70 and 90 days after planting, number of stems per plant, individual tuber weight per plant and tuber weight loss percentage at 150 days after harvest have direct positive influence on tuber weight per plant.

Khayatnezhad *et al.* (2011) demonstrated that plant height, medium tuber weight and large tuber weight had the highest direct influence (2.19, 0.867 and 0.656, respectively) on the total tuber yield. So, to increase the performance of the genotypes these traits can be used.

Path coefficient analysis at the phenotypic level revealed that days to flowering, plant height, tuber diameter, biological yield, harvest index and medium tuber percentage showed positive direct effects on tuber yield. The genotypic path analysis also indicated that biological yield and harvest index showed positive and significant correlation. Therefore, these characters are more important than other traits for the genetic improvement of potato (Fekadu *et al*., 2013).

Patel *et al*. (2013) conducted path coefficient analysis for plant height, number of stem per plant, number of tubers per plant, average weight of tubers, tubers dry matter, total tuber yield and marketable yield. Results revealed that higher positive direct effect on total tuber yield for marketable yield.

Santhosh *et al*. (2013) conducted experiment on path coefficient analysis with 11 early and 6 medium maturing advanced potato hybrids during *Kharif* season. Path coefficient analysis revealed that plant height, number of leaves, number of tubers per plant, tuber weight per plant and marketable tuber yield at both genotypic and phenotypic level had a positive direct influence on the yield. Genotypes J/97-168 and Kufri Pukhraj performed well under southern transitional zone of Karnataka.

High heritability for reducing sugar content, volume of tuber, weight of tuber and length of tuber. High heritability along with high genetic advance as per cent of mean was estimated for reducing sugars content, volume of tuber and weight of tuber reported by Singh *et al.* (2013).

Ummyiah *et al.* (2013) conducted path coefficient analysis for yield and its contributing characters. The average tuber weight exerted highest positive direct effect on tuber yield per plant followed by number of tubers per plant, stolon length and plant height suggesting that these traits were the strongest forces influencing tuber yield in potato.

Darabad (2014) reported green plant percentage, tubers weight per plant and percentage of tubers between 35-45 mm direct and indirect effect on tuber yield. Results revealed that the most important traits as the independent variable to develop the tuber yield as the dependent variable.

Lamboro *et al.* (2014) revealed that days to emergence, stems per plant, biological yield, and harvest index exerted positive highest phenotypic direct influence on tuber yield. However, days to flowering, days to maturity, small, medium and big tuber percentage exerted high negative direct influence on tuber yield. Conversely, tubers per plant and plant height had positive and low direct effect on tuber yield. The stems per plant had the maximum direct effect on tuber yield followed by days to emergence.

Hafiz (2015) reported path coefficient analysis among yield and related traits in twenty five genotypes. As per path analysis, the maximum positive direct effect on tuber yield per hectare was exhibited by unmarketable tuber number per plant followed by average tuber number, days to flowering which have high and direct contribution towards final tuber weight per plant.

Singh *et al.* (2015) revealed that marketable tuber yield per hectare (1.583), number of shoots per plant (0.717), dry weight of shoots per plant (0.545), plant height (0.499), number of leaflets per plant (0.186), number of tubers shoots per plant (0.095) had high positive and direct influence on total tuber yield.

Verma and Singh (2015) studied on path coefficient analysis among forty-eight potato genotypes including four checks and evaluated for nine quantitative traits in an augmented block design during winter season. Results found that marketable yield per plot, number of tuber per plant, plant height and tuber yield per plant had highest positive direct effect on total tuber yield. This analysis showed that plant height, number of tuber per plant, marketable yield per plot and tuber yield per plant were main characters for tuber yield.

Direct effects of independent characters *viz.*, total number of tubers followed by plant height at 30 days, number of branches, stem girth, tuber length, lateral leaflet length at 30 days, terminal leaflet breadth at 30 days, weight of tuber per plant showed positive effect on yield. Number of leaves, length of the leaves, terminal leaflet length, plant height at 60 days, number of tubers per plant, single tuber weight and tuber breadth incurred negative direct effect towards tuber yield per plant. Total tuber number imparted the maximum positive direct effect (2.10) on tuber yield per plant followed by plant height at 30 days, branch number at 30 days, stem girth at 60 days and tuber length (Tripura *et al*., 2016).

Verma and Singh (2016) investigated the level of characters effect in 44 potato germplasm among ten different quantitative characters. Path analysis revealed that marketable yield per plot, tuber yield per plant, number of tuber per plant and plant height had highest positive direct effect on tuber yield.

Path coefficient analysis showed a significant effect between yield and number of compound leaves (0.336), terminal leaf area (0.487) and length of primary stolon (0.606). The path way to yield as caused by length of primary stolon was negligibly influenced by indirect effect via other parameters like number of stems per plant, number of primary stolons per plant and stem height per plant (Yerima, 2016).

Mishra *et al*. (2017) studied on path coefficient analysis for important yield component characters in potato. Results revealed that positive and direct effect of fresh weight of tubers, followed by plant canopy cover percentage, number of tubers, dry weight of shoots and number of leaves on total tuber yield.

MATERIAL AND METHODS

III MATERIAL AND METHODS

Present investigation on “Genetic variability studies in potato (*Solanum tuberosum* L.) genotypes under hill zone of Karnataka” was carried out during 2016 *Kharif* season. The materials used, methodology followed and statistical analysis adopted during the course of investigation are described in this chapter.

3.1 Location of experimental site

The experiment was conducted at experimental block of the Department of Vegetable Science, College of Horticulture, Mudigere which is situated in the Western Ghats at 13°7’ North latitude and 74°37’ East longitude with an altitude of 980 m above mean sea level.

3.2 Climatic conditions

Mudigere lies in zone-9 of agro climatic zones of Karnataka. The average rainfall of area was 123.47 mm and distributed over a period of six to eight months (April - December) with peaks during June to September. The meteorological data for the period of experimentation was recorded at the meteorological observatory of Zonal Agricultural and Horticultural Research Station (ZAHRS), Mudigere and the same was presented in Appendix-I.

3.3 Soil characteristics

The experiment was conducted in medium sandy loam soil having pH of 5.98 and physical and chemical properties of soil are presented in Appendix-II.

3.4 Experimental details

3.4.1 Cultivars and their salient features

Sixteen genotypes of potato were procured from international potato centre (CIP) Peru and central potato research institute (CPRI), Shimla and the details are furnished in table 1.

3.4.2 Design and experimental layout

The experiment was laid out by adopting randomized complete block design (RCBD) with four replications. The treatments in each replication were allotted randomly using random number table. The plan and layout of the experiment is given in figure 1 and general view of experimental plot represented in plate 1.

Table 1. List of genotypes used for the study with their salient features

Sl. No.	Genotypes	Flower colour	Tuber colour	Tuber shape	Tuber size	Depth of eyes
1	TT 7003	White	White	Oblong	Medium	Fleet
2	TT 7010	White	Yellow	Oblong	Medium	Fleet
3	TT 7016	White	Yellow	Oblong	Medium	Fleet
4	TT 7008	Purple	Red	Oval	Medium	Fleet
5	TT 7011	Purple	Yellow	Oblong	Medium	Fleet
6	TT 7015	Purple	Red	Round	Medium	Fleet
7	TT 7005	Purple	Red	Oval	Medium	Fleet
8	TT 7007	Purple	Red	Round	Medium	Fleet
9	TT 7006	Purple	Red	Oval	Medium	Fleet
10	Kufri Jyoti	White	White	Oval	Medium	Fleet
11	C-28	Purple	Yellow	Round	Medium	Fleet
12	FC-3	White	Yellow	Oblong	Medium	Fleet
13	FC-5	White	Yellow	Round	Medium	Fleet
14	FL-1533	Purple	White	Oblong	Medium	Fleet
15	Kufri Surya	White	White	Oblong	Medium	Shallow
16	Kufri Himalini	White	Yellow	Oblong	Medium	Shallow

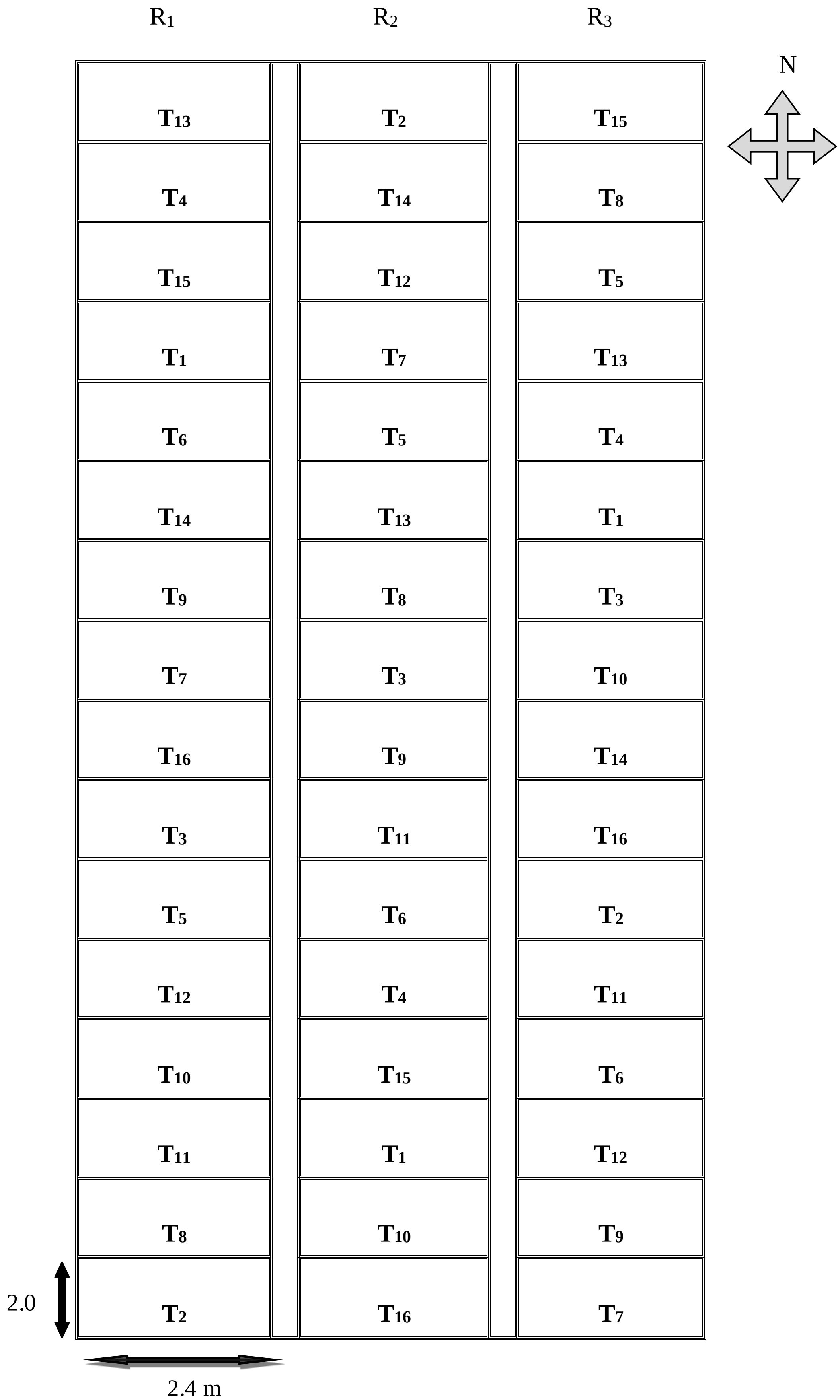

Fig.1. Plan and layout of the experimental plot

Plate. 1. General view of experimental plot

3.4.2.1 The experimental details are as follows

Location	: College of Horticulture, Mudigere, Karnataka.
Season	: *Kharif*
Statistical design	: RCBD
Number of genotypes	: Sixteen
Number of replications	: Three
Plot size	: 2.4 m × 2 m
Spacing	: 60 cm × 20 cm
Number of plants per plot	: 40

3.4.2.2 Treatments details

T_1 - TT 7003	T_9 - TT 7006
T_2 - TT 7010	T_{10} - Kufri Jyoti
T_3 - TT 7016	T_{11} - C-28
T_4 - TT 7008	T_{12} - FC-3
T_5 - TT 7011	T_{13} - FC-5
T_6 - TT 7015	T_{14} - FL-1533
T_7 - TT 7005	T_{15} - Kufri Surya
T_8 - TT 7007	T_{16} - Kufri Himalini

3.5 Cultural operations

3.5.1 Preparation of experimental plot

The land was brought to a fine tilth by repeated ploughing and harrowing. The plot of requisite dimension was prepared as per the plan. A gap of 0.5 m between two replications was provided for laying out irrigation channels and working space.

3.5.2 Planting

Tubers collected from international potato centre (CIP), Peru and central potato research institute (CPRI), Shimla were used for planting. The ridges and furrows were opened at 60 cm and planted one tuber per hill on one side of the ridge at 20 cm. The planting was done on 18^{th}, June 2016 during *Kharif* season.

3.5.3 Application of manures and fertilizers

Well decomposed FYM at 25 tonnes per hectare was applied at the time of final land preparation along with recommended dose of NPK (75:75:100 kg/ha). Half dose of the nitrogen, full dose of phosphorus and potassium were applied as basal dose before planting of tubers and remaining half dose nitrogen was applied at the time of earthing up.

3.5.4 Weeding and irrigation

The plots were kept weed free by 3-4 hand weedings at an interval of 15-20 days. Depending on the soil moisture status and climatic conditions, irrigation was given at an interval of 6-7 days during the entire experiment. Irrigation was stopped 10 days before the harvesting to allow tuber skin to become dry and firm.

3.5.5 Earthing up

Earthing up was done at 30-35 days after planting to improve tuber number and avoid greening.

3.5.6 Plant protection

Incidence of cut worm was noticed at 30 days after planting and it was controlled by hand picking and destroyed the larvae. At the end of the crop period, late blight and bacterial wilt infestations were noticed. Which were managed by spraying of Curzate (CymoXanil+Mancozeb) (3g/l) and Agrimycin 100 (0.5g/l). Aphids and caterpillars were managed by spraying of imidacloprid (0.5g/l).

3.5.7 Harvesting

Dehaulming practiced 10-12 days before harvesting of tubers and harvesting was done manually using spade.

3.6 Observations on growth, yield and quality attributes

3.6.1 Sampling procedure

Five tagged plants per treatment were selected randomly and observations were recorded on selected plants for different characters in each replication. The data recorded on five plants per treatment was averaged and subjected to statistical analysis.

3.6.2 Morphological parameters

3.6.2.1 Germination percentage

The germination percentage was worked out after 20 and 30 days after planting. It was calculated by using the formula;

$$\text{Germination (\%)} = \frac{\text{Total number of tubers germinated}}{\text{Total number of tubers planted}} \times 100$$

3.6.2.2 Plant height

Height of the plant was measured from ground level to the tip of the plant at 45 and 60 days after planting (DAP) and expressed in centimeter.

3.6.2.3 Number of leaves per plant

The total number of leaves produced in the tagged plants were counted at 60 and 90 DAP and average was worked out and expressed in numbers.

3.6.2.4 Plant spread

It was measured by recording the plant spread from North- South to East- West directions in tagged plants at 60 DAP. Average was worked out and expressed in centimeters.

3.6.2.5 Leaf area

The leaves from five selected plants from each treatment were used for estimation of leaf area. Leaf area was computed by using leaf area meter (LAM 211) and was expressed as cm^2 per plant.

3.6.2.6 Number of stems per plant

The total number of stems produced in the tagged five plants were counted at 60 DAP and average was worked out.

3.6.2.7 Fresh weight of leaves

Fresh weight of leaves of randomly selected five plants from each plot was recorded at the time of 60 DAP and haulm cutting. Portion of the leaves above ground level, was separated from the plants with the help of sickle and it was weighed to obtain the fresh weight of leaves per plant and is expressed in grams per plant.

3.6.2.8 Dry weight of leaves

After recording the fresh weight of leaves per plant, leaves of the tagged plants were dried in oven at 80^0C for 72 hours till constant weight was achieved and their average dry weight was expressed in grams per plant.

3.6.2.9 Fresh weight of stem

The fresh weight of stem was taken from each of tagged plants in each replication and the average fresh weight of stem was expressed in grams per plant.

3.6.2.10 Dry weight of stem

After recording the fresh weight of stem per plant, the stem of the tagged plants were collected at two intervals 60 DAP and 90 DAP and dried in oven at 80^0C for 72 hours till constant weight was achieved and their average dry weight was expressed in grams per plant.

3.6.2.11 Fresh weight of tuber

This observation was recorded from already tagged and uprooted five plants at the time of harvesting with the help of physical balance and averaged.

3.6.2.12 Dry weight of tuber

After recording the fresh weight of tubers per plant, the tubers were sliced into chips and left for natural sun drying for five days. The samples were finally kept in the hot air oven for 12 hours at 60^0 C till constant weight was achieved and weighed on digital balance. The data of five individual plants was then averaged.

3.6.2.13 Total fresh weight of plant

Fresh biomass production of different plant parts at 60 and 90 days after planting and at harvesting was estimated by uprooting the five plants randomly in each treatment. Then leaves, stem and root were separated and recorded the fresh weight. The total fresh biomass production was calculated by adding fresh weight of leaves, stem and roots and the mean value is expressed in grams per plant.

3.6.2.14 Total dry weight of plant

Five plants were sampled randomly at 60 and 90 days after planting and at harvest and which were separated into leaf, stem and roots. The same were dried in hot air oven at 80^0 C until a constant weight was attained. The total dry biomass production was calculated by adding dry weight of leaves, stem and root and expressed as grams per plant.

3.6.3 Growth parameters

3.6.3.1 Leaf area index

Leaf area index was calculated by dividing the leaf area per plant by the land area occupied by the plant using the formula suggested by Sestak *et al.* (1971).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Ground area covered by plant or spacing}} \times 100$$

3.6.3.2 Absolute growth rate (AGR)

It is the dry matter production per unit time and was calculated by using the formula suggested by Briggs *et al.* (1920) and expressed in grams per day.

$$\text{AGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are the total dry weight of the plant at time t_1 and t_2 respectively

t_1 and t_2 - time interval between two stages

3.6.3.3 Crop growth rate (CGR)

The crop growth rate indicates the increase in the dry matter per unit land area per unit time (Watson, 1952). It was calculated by using the following formula and expressed in grams per square meter per day (g/m^2/day).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A}$$

Where,

W_1 and W_2 - dry weight of the plant at time t_1 and t_2 respectively.

t_1 and t_2 – time interval between two stages

A- Land area in cm^2

3.6.3.4 Net assimilation rate (NAR)

It is the rate of increase in dry weight per unit leaf area per unit time. It was calculated by following the formula of Gregory (1926) and expressed as $g/dm^2/day$.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Where,

L_1 and L_2 – Leaf area at time t_1 and t_2 respectively

W_1 and W_2- Dry weight of the plants at time t_1 and t_2 respectively

t_1 and t_2 – time interval between two stages.

3.6.4 Yield parameters

3.6.4.1 Number of tubers per plant

The numbers of tubers in each of five plants were counted. The mean was recorded as number of tubers per plant.

3.6.4.2 Number of tubers per plot

The numbers of tubers per plot (tagged + non tagged plants) were counted. The mean was recorded as number of tubers per plot.

3.6.4.3 Tuber length

Tuber length was recorded from the tagged five plants and expressed in centimeters.

3.6.4.4 Tuber circumference

Tuber circumference was measured in the middle of the tuber using thread after harvesting and expressed in centimeters.

3.6.4.5 Tuber volume

The volume of the tuber was recorded by water displacement method and expressed in Cubic Centimeter (cc) per tuber.

3.6.4.6 Tuber weight

The weight of tubers in each grade was recorded in grams per plant during harvesting using sensitive balance and the average was recorded.

3.6.4.7 Total tuber yield per plant

Total tuber yield of the each five tagged plants were recorded and expressed in grams.

3.6.4.8 Total tuber yield per plot

Total tuber yield of the each five tagged plants and non tagged plants were recorded and expressed in kilograms.

3.6.4.9 Total tuber yield per hectare

The total tuber yield per plot was computed by summing up all the harvested tubers of each treatment, converted to tuber yield per hectare and expressed in tonnes per hectare.

$$\text{Tuber yield (t/ha)} = \frac{\text{Plot yield}}{\text{Plot area}} \times \frac{10{,}000}{1000}$$

3.6.4.10 Marketable yield per plant

Tubers weighing more than 20 grams from each five tagged plants were recorded and expressed in grams.

3.6.4.11 Marketable yield per plot

Tubers weighing more than 20 grams from each plot were recorded and expressed in kilo grams.

3.6.4.12 Marketable yield per hectare

The total tuber yield per plot was computed by summing up all the harvested tubers of each treatment converted to tuber yield per hectare and expressed in tonnes per hectare.

3.6.5 Quality parameters

3.6.5.1 Tuber colour

The colour of the tuber skin was carefully examined and recorded on the basis of visual observation. Where, white, yellow and red coloured once were found.

3.6.5.2 Tuber shape

The shape of tubers was recorded on the basis of visual observation for all the treatments. Where, oval, round and oblong were observed.

3.6.5.3 Tuber size

The tuber size of all the varieties recorded by weighing and recorded the readings by big, medium and small size.

3.6.5.4 Tuber dry matter content

Step 1: Chop five tubers (about 500 g) into small 1-2 cm cubes, mix thoroughly and take two sub-samples of 200 g each. It is important to sample all parts of the tubers, because dry matter content is not uniform throughout the tuber. Determine the exact weight of each sub-sample and record it as fresh weight.

Step 2: Place each sub-sample in an open container or paper bag and put in an oven at 80˚C for 72 hours or after checking sample weight at regular intervals, until constant dry weight is reached. Weigh each sub-sample immediately and record as dry weight (Anon, 1960).

Step 3: Calculate the per cent dry matter content for each sub-sample with the following formula:

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

3.6.5.5 TSS (^{0}Brix)

TSS was estimated by using hand refractometer and recorded the readings.

3.6.5.6 Number of eyes per tuber

Total numbers of eyes were counted for each tuber under storage regimes at 60 days of storage and the mean was calculated.

3.6.5.7 Depth of eyes (shallow or deep)

The depth of tuber eyes in each treatment was recorded as shallow, fleet (medium deep) and deep by visual observation during storage period.

3.6.6 Biochemical parameters

3.6.6.1 Total chlorophyll content (mg/g)

The total chlorophyll content in leaves were measured at 45 days after planting by using dimethyl sulfoxide (DMSO) method given by Shof and Lilum (1976).

Procedure:

Fresh and fully matured leaves from the plant were brought to laboratory in ice box from the field and were cut into small pieces. Known weight of sample (100 mg) was incubated in 7.0 ml of dimethyl sulfoxide at 65^0 C for 120 minutes. After the incubation, supernatant was collected by decanting and leaf tissue was discarded, then the volume of the supernatant was made up to 10 ml using dimethyl sulfoxide (DMSO). The absorbance of the extract was measured at 645 nm and 663 nm using dimethyl sulfoxide as blank in spectrophotometer. The total chlorophyll content was calculated by using formulae given below.

$$\text{Total chlorophyll} = 20.2\ (A_{645}) + 8.02\ (A_{663})\} \times \frac{V}{1000 \times W \times a}$$

Where,

A = Absorbance at specific wave length (645 nm and 663 nm)

V = Final volume of the chlorophyll extract (10 ml)

W = Fresh weight of the sample (100 mg)

a = Path length of light in cuvette (1 cm)

3.6.6.2 Reducing and non reducing sugars

i. Reducing sugars

Reagents:

(i) Dissolve 2.5 g anhydrous sodium carbonate, 2 g sodium bicarbonate, 2.5 g potassium sodium tartrate and 20 g anhydrous sodium sulphate in 80 ml water and make up to 100 ml.

(ii) Dissolve 15 g copper sulphate in a small volume of distilled water. Add one drop of sulphuric acid and make up to 100 ml.

Mix 4 ml of B and 96 ml of solution A before use.

Arsenomolybdate reagent: Dissolve 2.5 g ammonium molybdate in 45 ml water. Add 2.5 ml sulphuric acid and mix well. Then add 0.3 g disodium hydrogen arsenate dissolved in 25 ml water. Mix well and incubate at 37°C for 24–48 hours.

Standard glucose solution: Stock: 100 mg in 100 ml distilled water.

Working standard: 10 ml of stock diluted to 100 ml with distilled water [100 µg/ml]. Procedure:

1. Weigh 100 mg of the sample and extract the sugars with hot 80% ethanol twice (5 ml each time).

2. Collect the supernatant and evaporate it by keeping it on a water bath at 80°C.

3. Add 10 ml water and dissolve the sugars.

4. Pipette out aliquots of 0.1 or 0.2 ml to separate test tubes.

5. Pipette out 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard solution into a series of test tubes.

6. Make up the volume in both sample and standard tubes to 2 ml with distilled water.

7. Pipette out 2 ml distilled water in a separate tube to set a blank.

8. Add 1 ml of alkaline copper tartrate reagent to each tube.

9. Place the tubes in boiling water for 10 minutes.

10. Cool the tubes and add 1 ml of arsenomolybolic acid reagent to all the tubes.

11. Make up the volume in each tube to 10 ml with water.

12. Read the absorbance of blue colour at 620 nm after 10 min.

13. From the graph drawn, calculate the amount of reducing sugars present in the sample.

Estimation method: Nelson-Somogyi method (Ranganna, 1977).

ii. Non-reducing sugars

Non-reducing sugars is estimated by subtracting the reducing sugar from total sugar content of the sample. Total sugars content was estimated as follows.

iii. Total sugars

Materials:

- 2.5 N HCl
- Anthrone reagent: Dissolve 200 mg anthrone in 100 ml of ice-cold 95% H2SO4. Prepare fresh before use.
- Standard glucose: Stock—Dissolve 100 mg in 100 ml water. Working standard—10 ml of stock diluted to 100 ml with distilled water. Store refrigerated after adding a few drops of toluene.

Procedure:

1. Weigh 100 mg of the sample into a boiling tube.

2. Hydrolyse by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N HCl and cool to room temperature.

3. Neutralise it with solid sodium carbonate until the effervescence ceases.

4. Make up the volume to 100 ml and centrifuge.

5. Collect the supernatant and take 0.5 and 1 ml aliquots for analysis.

6. Prepare the standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard. '0' serves as blank.

7. Make up the volume to 1 ml in all the tubes including the sample tubes by adding distilled water.

8. Then add 4 ml of anthrone reagent.

9. Heat for eight minutes in a boiling water bath.

10. Cool rapidly and read the green to dark green colour at 630 nm.

11. Draw a standard graph by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis.

12. From the graph calculate the amount of total sugars present in the sample tube.

Total sugars content in the sample is estimated by hydrolyzing the non-reducing sugars Anthrone method (Ranganna, 1977).

Formula:

$$\text{Reducing sugars (\%)} = \frac{A}{B} \times \frac{C}{D} \times \frac{E}{F} \times 100$$

$$\text{Total sugars (\%)} = \frac{A}{B} \times \frac{X}{Y} \times \frac{Y}{D} \times \frac{G}{H} \times 100$$

Where,

A=Glucose in sample from standard curve (mg)

B= Aliquot taken for test (ml)

C= Volume made after alcohol evaporation (ml)

D= Volume taken for alcohol evaporation (ml)

E= Volume made after sample extraction (ml)

F= Sample taken for extraction (mg)

X= Volume made after hydrolysis (ml)

Y= Volume taken for hydrolysis (ml)

Non reducing sugars (%) = Total sugars – Reducing sugars

3.6.6.3 Starch estimation

The residue left was dried after reducing sugar extraction in an oven at 80^{0} C for starch extraction. To this residue, 5 ml of distilled water was added and the tube was putting in a boiling water bath for 15 minutes with occasional stirring. Then after cooling 6.5 ml of 50 per cent $HClO_4$ (Perchloric acid) was added to it. The tube was kept as such for 15 minutes with occasional stirring followed by centrifugation for 15 minutes. The supernatant was collected in 50 ml volumetric flask. The residue was extracted with 50 per cent $HClO_4$ using the same procedure. The combined supernatant was made to 50 ml distilled water. A quantity of 5 ml of this solution was diluted to 25 ml with distilled water and starch was analysed from this extract.

Properly diluted starch extract of 0.2 ml was taken in Pyrex tube along with blank containing distilled water only. The volume of the extract was made to 1 ml by adding water; 4 ml of anthrone reagent was added to test tube slowly and mixed thoroughly. The tube was put into boiling water bath for 10 minutes after which that was immediately cooled in ice and the absorbance was read at 630 nm.

The amount of starch was estimated from the standard curve which was prepared using a series of five standard glucose solutions (20-100 micro gram/ml).

Method used: Anthrone reagent method (Ranganna, 1977).

3.6.7 Pest and disease incidence

The incidence of potato diseases and pest *viz*., late blight, early blight incidence and aphids damage were recorded during the growing season as follows and express in percentage.

3.6.7.1 Late blight

The number of plants showing the symptom of the late blight disease incidence was counted and recorded. The percentage of plants showing the symptom per plot was then calculated using the following formula.

$$\text{Percentage of affected plants per plot} = \frac{\text{Number of plants showing the symptom}}{\text{Total number of plants in the plot}} \times 100$$

3.6.7.2 Early blight incidence

The number of plants showing the symptom of the early blight incidence was counted and recorded. The percentage of plants showing the symptom per plot was then calculated using the following formula.

$$\text{Percentage of affected plants per plot} = \frac{\text{Number of plants showing the symptom}}{\text{Total number of plants in the plot}} \times 100$$

3.6.7.3 Aphid damage

The number of plants showing the symptom of the aphid damage was counted and recorded. The percentage of plants showing the symptom per plot was then calculated using the following formula.

$$\text{Percentage of infested plants per plot} = \frac{\text{Number of plants infested}}{\text{Total number of plants in the plot}} \times 100$$

3.7 Statistical analysis of experimental data

The data of the experiment was subjected to statistical analysis by using RCBD as described by Sundar *et al*. (1972). The level of significance used in 'F' test was P = 0.05. Critical difference was calculated whenever the 'F' test was found significant.

3.7.1 Biometrical parameters

Source of Variation	**Degrees of Freedom (d.f)**	**Sum of Square (SS)**	**Mean sum of square (MSS)**	**'F' cal**
Replications	r-1	RSS	RMSS	
Genotypes	t-1	TrSS	TrMSS	$\frac{TrMSS}{EMSS}$
Error	(r-1) (t-1)	ESS	EMSS	
Total	(rt-1)	TSS		

3.7.1.1 Analysis of variance (ANOVA)

The mean values of the genotypes were used for analysis of variance. Replication wise mean values were subjected to RCBD analysis. The significance of difference among all genotypes was tested using 'F' test**.** The model of analysis of variance is given previous page.

Where,

t = Number of treatments (genotypes)

r = Number of replications

SS = Sum of square

MSS = Mean sum of square

DF = Degrees of freedom

The standard error was calculated as,

$$\text{S. Em}\pm = \sqrt{\text{EMSS}}/\text{r}$$

The significance of treatment mean squares and replication mean squares were tested by comparing with error mean squares referring to 'F' table values at 5 and 1 per cent level of probabilities.

Critical difference, CD = $\sqrt{2 \times \text{S.Em} \times \text{t}\ (\alpha, \text{df})}$

Where,

α – level of significance (5 and 1 per cent)

Edf – Error degrees of freedom.

The calculated F value is compared with the table F value for respective degrees of freedom (treatment df, error df) at 5 or 1 per cent level of significance.

Mean, Range and Variance

The mean, range and variance values of each character were calculated for each genotype.

$$\text{Mean} = \frac{\text{Sum of observations of all the plants}}{\text{Number of plants}}$$

Range = The minimum and maximum values for each trait.

$$\text{Variance} = \frac{1}{(n-1)} [\Sigma (Xi\text{-}X)^2]$$

Where,

Xi = Individual value

$\bar{X}$= Population mean

n = Number of observations

$$\text{Standard deviation (SD)} = \sqrt{\text{Variance}}$$

3.7.2 Estimation of genetic parameters

3.7.2.1 Genotypic, phenotypic and environmental variances

Variance due to genotype, phenotype and environment were computed as follows.

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{Treatment MSS} - \text{Error MSS}}{r}$$

Environmental variance (σ^2e) = Error mean sum of squares

Phenotypic variance (σ^2p) = σ^2g + σ^2e

Where, ‘r’ is number of replications.

3.7.2.2 Genotypic and phenotypic coefficient of variation

Genotypic and phenotypic coefficients of variance were estimated according to Burton and Devane (1953) based on estimate of genotypic and phenotypic variance.

Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sigma g}{\bar{x}} \times 100$$

Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sigma p}{\bar{x}} \times 100$$

Where,

$\bar{x}$ = Grand mean

r = Number of replications

σg = Genotypic standard deviation

σp = Phenotypic standard deviation

PCV and GCV were classified (Subramaniyan and Memon, 1973) as mentioned below

0 - 10% = Low

10 - 20% = Moderate

20% and above = High

3.7.2.3 Heritability

The broad sense heritability (h^2) was estimated by following the procedure suggested by Weber and Moorthy (1952) as indicated here below.

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

h^2 (%) = Heritability (Broad sense)

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

Heritability was categorized (Robinson *et al*., 1949) as mentioned below

0 - 30% = Low

30 - 60% = Moderate

60% and above = High

3.7.2.4 Expected genetic advance

Genetic advance for each character was predicted by the formula given by Johnson *et al*. (1955).

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

Where,

k = selection differential at 5 per cent selection intensity

h^2 = Heritability in broad sense

σp = Phenotypic standard deviation

3.7.2.5 Genetic advance as per cent of mean (GAM)

Genetic advance as per cent over mean was worked out as suggested by Johnson *et al*. (1955).

Genetic advance as per cent over mean (GAM) = $\frac{GA}{\bar{x}} \times 100$

Where,

GA = Genetic advance

$\bar{x}$ = General mean

The Genetic advances as per cent of mean (GAM) was categorized as suggested by Johnson et al. (1955) and is mentioned below:

0 - 10% = Low

10 - 20% = Moderate

20% and above = High

3.7.2.6 Correlation co-efficient analysis

The correlation coefficient among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated employing formula (Al-Jibouri *et al.*, 1958).

Phenotypic correlation = r_{xy} (p) = $\frac{Cov_{xy}(p)}{\sqrt{V_x(p) \times V_x(p)}}$

Genotypic correlation = r_{xy} (g) = $\frac{Cov_{xy}(g)}{\sqrt{V_x(g) \times V_x(g)}}$

Where,

Cov_{xy} (g) = Genotypic covariance between x and y

Cov_{xy} (p) = Phenotypic covariance between x and y

V_x (g) = Genotypic variance of character 'x'

V_x (p) = Phenotypic variance of character 'x'

V_y (g) = Genotypic variance of character 'y'

V_y (p) = Phenotypic variance of character 'y'

The test of significance for association between characters was done by comparing table 'r' values at (n-2) error degrees of freedom for phenotypic and genotypic correlations with estimated values, respectively.

3.7.2.7 Path coefficient analysis

Path coefficient analysis suggested by Wright (1921) and Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on plant yield. The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$r_{1y} = a + r_{12}b + r_{13}c + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{1Ii}$

$r_{2y} = a + r_{21}a + b + r_{23}c + \ldots\ldots\ldots\ldots\ldots\ldots + r_{2Ii}$

$r_{3y} = r_{31}a + r_{32}b + c + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{3Ii}$

$r_{1y} = r_{11}a + r_{12}b + r_{13}c + \ldots\ldots\ldots\ldots\ldots\ldots + I$

Where,

r_{1y} to I_{1y} = Coefficient of correlation between causal factors 1 to I with dependent characters y.

r_{12} to r_1I = Coefficient of correlation among causal factors

a, b, c…….i = Direct effects of characters 'a' to 'I' on the dependent character 'y'

Residual effect (R) was computed as follows.

Residual effect (R) = $1- \sqrt{} \; a_2 + b_2 + c_2 + \ldots\ldots\ldots\ldots i_2 + 2abc_{12} + 2acr_{13}\ldots\ldots\ldots\ldots$

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The present investigation was carried out with 16 genotypes of potato (*Solanum tuberosum* L.) at College of Horticulture, Mudigere (Karnataka) to assess the genetic variability for growth, yield and quality parameters, correlation and path analysis. The results of the experiment are presented in this chapter.

4.1 Analysis of variance

4.2 Genetic components of variation

4.3 Character association studies

4.4 Path coefficient analysis

4.1 Analysis of variance

The analysis of variance indicated significantly higher amount of variability among the genotypes for all the characters studied *viz*., emergence percentage, plant height, number of leaves, plant spread from North to South and East to West, leaf area, number of stem per plant, fresh weight of leaves, dry weight of leaves, fresh weight of stem, dry weight of stem, fresh weight of root, dry weight of root, total fresh weight of plant, total dry weight of plant, fresh weight of tuber, dry weight of tuber, leaf area index, absolute growth rate, crop growth rate, net assimilation rate, number of tubers per plant, number of tubers per plot, tuber length, tuber circumference, tuber volume, tuber weight, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot, marketable yield per hectare, tuber dry matter content, total soluble solids, number of eyes per tuber, total chlorophyll content, reducing sugars, non-reducing sugars, total sugars and starch (Table 2 and 3).

4.2 Genetic components of variation

4.2.1 Genetic variability, heritability and genetic advance for growth and yield parameters

The estimates of mean, range, genotypic and phenotypic variance, genotypic and phenotypic coefficients of variation, heritability, genetic advance and genetic advance as per cent of mean for all the characters were studied and the results are presented in table 4a, 4b, 5a, 5b, 6, 7,8 and 9.

4.2.1.1 Plant emergence per cent

Mean performance of genotypes for plant emergence percentage at 20 DAP ranged from 78.33 per cent (TT 7008 and C-28) to 70.0 per cent (FC-5) with an overall average of 74.58 per cent. The maximum percentage of emergence was found in genotype TT 7008 (78.33 per cent) which was *at par* with the performance of

Table 2. Analysis of variance for morphological parameters in potato genotypes

Sl. No.	Source of variation/ characters	Replication	Treatments (genotypes)	Error	S. Em±	CD @ 5%
	Degrees of freedom	2	15	30		
	Morphological parameters					
1	Per cent emergence at 20 DAP	0.52	20.00**	13.85	2.15	6.21
2	Per cent emergence at 30 DAP	0.02	4.96**	4.91	1.28	3.69
3	Plant height (cm) at 45 DAP	25.20	117.83**	41.02	3.70	10.68
4	Plant height (cm) at 60 DAP	6.53	75.54**	9.35	1.77	5.10
5	Number of leaves at 60 DAP	213.47	777.97**	218.25	8.53	24.63
6	Number of leaves at 90 DAP	1033.79	1035.42**	209.66	8.36	24.14
7	Plant spread from North to South (cm) at 60 DAP	60.38	47.55**	17.44	2.41	6.96
8	Plant spread from East to West (cm) at 60 DAP	14.69	33.73**	11.83	1.99	5.73
9	Leaf area (cm^2) at 60 DAP	295786.92	782946.58**	89497.70	172.72	498.85
10	Leaf area (cm^2) at 90 DAP	1565103.10	2045866.90**	132406.00	210.00	606.70
11	Number of stems per plant at 60 DAP	4.44	0.73**	0.16	0.23	0.66
12	Fresh weight of leaves (g) at 60 DAP	43.44	29.79**	10.35	1.86	5.36
13	Fresh weight of leaves (g) at 90 DAP	27.05	35.14**	12.93	2.08	6.00
14	Dry weight of leaves (g) at 60 DAP	2.15	2.10**	0.77	0.51	1.47
15	Dry weight of leaves (g) at 90 DAP	0.78	1.52**	0.56	0.43	1.25
16	Fresh weight of stem (g) at 60 DAP	734.70	103.36**	35.30	3.44	9.94
17	Fresh weight of stem (g) at 90 DAP	777.90	123.40**	45.40	3.89	11.24
18	Dry weight of stem (g) at 60 DAP	16.56	2.73**	0.98	0.57	1.65
19	Dry weight of stem (g) at 90 DAP	17.59	3.39**	1.24	0.64	1.86
20	Fresh weight of root (g) at 60 DAP	1.29	1.88**	0.83	0.53	1.52
21	Fresh weight of root (g) at 90 DAP	1.31	4.06**	1.88	0.79	2.28
22	Dry weight of root (g) at 60 DAP	0.01	0.20**	0.10	0.18	0.52
23	Dry weight of root (g) at 90 DAP	0.08	0.46**	0.21	0.26	0.76
24	Total fresh weight of plant (g) at 60 DAP	1097.70	223.74**	37.00	3.51	10.14
25	Total fresh weight of plant (g) at 90 DAP	1110.10	262.20**	47.30	3.97	11.47
26	Total dry weight of plant (g) at 60 DAP	26.69	9.40**	1.65	0.74	2.14
27	Total dry weight of plant (g) at 90 DAP	23.47	8.72**	1.50	0.70	2.03
28	Fresh weight of tuber (g)	5459.40	14222.20**	2034.40	26.04	75.20
29	Dry weight of tuber (g)	118.70	466.50**	120.80	6.35	18.33

** Significant @ 1 %   DAP: Days After Planting

Table 3. Analysis of variance for growth, yield and quality parameters in potato genotypes

Sl. No.	Source of variation/ characters	Replication	Treatments (genotypes)	Error	S. Em±	CD @ 5%
	Degrees of freedom	2	15	30		
	Growth parameters					
1	Leaf Area Index (LAI)	1.09	1.42**	0.09	0.18	0.51
2	Absolute Growth Rate (AGR) (g/plant/day)	0.0005	0.0030**	0.0008	0.02	0.05
3	Crop Growth Rate (CGR)(g/m^2/day)	0.01	0.07**	0.03	0.10	0.28
4	Net Assimilation Rate (NAR) (g/cm^2/day)	0.000003	0.000014**	0.000004	0.0012	0.0035
	Yield parameters					
5	Number of tubers per plant	2.04	1.26**	0.43	0.38	1.09
6	Number of tubers per plot	3699.00	2289.30**	589.80	14.00	40.50
7	Tuber length (cm)	12.10	2.11**	0.66	0.47	1.35
8	Tuber circumference (cm)	6.70	5.57**	2.26	0.87	2.51
9	Tuber volume (CC)	12832.00	2352.80**	311.00	10.10	29.40
10	Tuber weight (g)	117.50	205.10**	72.20	4.90	14.10
11	Total tuber yield per plant (g)	5459.40	14222.20**	2034.40	26.04	75.20
12	Total tuber yield per plot (kg)	9.55	19.70**	2.37	0.90	2.57
13	Total tuber yield per hectare (tonnes)	45.40	87.80**	10.90	1.91	5.51
14	Marketable yield per plant (g)	1565.90	17508.20**	1276.70	20.63	59.50
15	Marketable yield per plot (kg)	1.52	23.20**	1.60	0.75	2.16
16	Marketable yield per hectare (tonnes)	6.60	101.00**	7.29	1.56	4.50
	Quality parameters					
17	Tuber dry matter content	11.30	16.00**	6.09	1.43	4.12
18	TSS (^{0} Brix)	0.13	0.93**	0.33	0.33	0.96
19	Number of eyes per tuber	1.70	3.80**	0.99	0.57	1.66
20	Total chlorophyll (mg/g)	0.13	0.01**	0.00	0.03	0.08
21	Reducing sugars (%)	0.02	0.04**	0.02	0.04	0.11
22	Non-reducing sugars (%)	0.02	0.04**	0.01	0.03	0.09
23	Total sugars (%)	0.01	0.13**	0.01	0.07	0.19
24	Starch (%)	0.09	6.00**	0.07	0.15	0.44

** Significant @ 1 % DAP: Days After Planting genotype C-28 (78.33 per cent) followed by TT 7016 (77.50 per cent) whereas, the minimum plant emergence per cent was recorded in genotype FC-5 (70.0 per cent).

Plant emergence percentage ranged from per cent 95.0 (C-28) to 90.33 per cent (FL-1533) with an overall average of 92.51 per cent at 30 DAP. The highest percentage of emergence was found in genotype C-28 (95.0 per cent) which was followed by TT 7010 (94.50 per cent) whereas, the minimum plant emergence per cent was recorded in genotype FL-1533 (90.33 per cent). Plant emergence per cent trait represented in the table 5a.

4.2.1.2 Plant height

Plant height at 45 DAP, ranged from 35.13 cm (TT 7005) to 59.07 cm (TT 7003) with an average mean of 49.64 cm. The GV and PV were 25.60 and 66.62 respectively. Moderate estimate of GCV (10.19 %) and PCV (16.44 %) were observed. Moderate heritability (38.43 %) was observed along with moderate genetic advance as per cent of mean (13.02 %) and genetic advance (6.46) for this trait (Table 4a and 5a).

At 60 DAP, the plant height ranged from 47.74 cm (TT 7005) to 66.72 cm (TT 7003) with grand mean of 57.73 cm. The GV and PV were 22.06 and 31.42 respectively. Low estimate of GCV (8.14 %) and PCV (9.71 %) were observed. High heritability (70.23 %) was observed along with moderate genetic advance as per cent of mean (14.05 %) and genetic advance (8.11) for this trait (Table 4a and 5a).

4.2.1.3 Number of leaves

Number of leaves at 60 DAP, varied from 192.67 (TT 7006) to 252.53 (Kufri Jyoti) with an overall average of 223.03. The GV and PV were 186.57 and 404.83 respectively. Low estimate of GCV (6.12 %) and PCV (9.02 %) were observed. Moderate heritability (46.09 %) was observed along with low genetic advance as per cent of mean (8.56 %) and genetic advance (19.10) for this trait (Table 4a and 5a).

At 90 DAP, the number of leaves varied from 251.73 (TT 7006) to 321.13 (C-28) with grand mean of 276.28 cm. The GV and PV were 275.25 and 484.91 respectively. Low estimates of GCV (6.00 %) and PCV (7.97 %) were observed. Moderate heritability (56.76 %) was observed along with low genetic advance as per cent of mean (9.32 %) and genetic advance (25.75) for this trait (Table 4a and 5a).

4.2.1.4 Plant spread from North to South

Plant spread at 60 DAP, varied in between 38.12 cm (TT 7006) to 52.31 cm (Kufri Jyoti) with an average mean of 43.03 cm. The GV and PV were 10.04 and 27.48 respectively. Low estimate of GCV (7.36 %) and moderate was PCV (12.18 %) were observed. Moderate heritability (36.52 %) was observed along with low genetic

Table 4a. Estimates of genetic parameters for morphological parameters in potato genotypes

Sl. No.	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
1	Plant height (cm) at 45 DAP	49.64±3.71	35.13-59.07	25.60	66.62	10.19	16.44	38.43	6.46	13.02
2	Plant height (cm) at 60 DAP	57.73±1.77	47.74-66.72	22.06	31.42	8.14	9.71	70.23	8.11	14.05
3	Number of leaves at 60 DAP	223.03±8.53	192.67-252.53	186.57	404.83	6.12	9.02	46.09	19.10	8.56
4	Number of leaves at 90 DAP	276.28±8.36	251.73-321.13	275.25	484.91	6.00	7.97	56.76	25.75	9.32
5	Plant spread from North to South (cm) at 60 DAP	43.03±2.41	38.12-52.31	10.04	27.48	7.36	12.18	36.52	3.94	9.17
6	Plant spread from East to West (cm) at 60 DAP	41.31±1.99	35.72-47.57	7.30	19.13	6.54	10.59	38.17	3.44	8.33
7	Leaf area (cm^2) at 60 DAP	3798.06±172.72	3116.79-4785.84	231149.60	320647.30	12.66	14.91	72.09	840.90	22.14
8	Leaf area (cm^2) at 90 DAP	5276.20±210	4390.60-7023.48	637820.30	770226.30	15.14	16.63	82.81	1497.12	28.37
9	Number of stems per plant at 60 DAP	3.49±0.23	2.87-4.73	0.19	0.35	12.55	16.94	54.86	0.67	19.15
10	Fresh weight of leaves (g) at 60 DAP	31.90±1.86	26.73-37.93	6.48	16.83	7.98	12.86	38.52	33.26	10.21
11	Fresh weight of leaves (g) at 90 DAP	38.70±2.08	33.20-45.80	7.41	20.33	7.03	11.65	36.42	3.38	8.74
12	Dry weight of leaves (g) at 60 DAP	6.83±0.51	5.31-8.57	0.44	1.22	9.73	16.14	36.30	0.82	12.07
13	Dry weight of leaves (g) at 90 DAP	7.63±0.43	6.52-9.20	0.32	0.88	7.41	12.32	36.20	0.70	9.18

DAP- Days After Planting GV- Genotypic Variance PV- Phenotypic Variance

GCV- Genotypic Coefficient of Variation PCV- Phenotypic Coefficient of Variation

h^2- Broad sense heritability GA- Genetic Advance GAM- Genetic Advance as Per cent of Mean

Table 4b. Estimates of genetic parameters for morphological parameters in potato genotypes

Sl. No.	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
14	Fresh weight of stem (g) at 60 DAP	59.26±3.44	48.13-69.27	22.61	58.10	8.02	12.87	38.89	6.11	10.31
15	Fresh weight of stem (g) at 90 DAP	69.65±3.89	57.33-81.40	25.90	71.40	7.32	12.13	36.30	6.30	9.10
16	Dry weight of stem (g) at 60 DAP	9.10±0.57	7.52-10.88	0.58	1.56	8.31	13.61	37.29	0.96	10.45
17	Dry weight of stem (g) at 90 DAP	10.71±0.64	8.94-12.68	0.72	1.96	7.85	12.90	36.61	1.06	9.78
18	Fresh weight of root (g) at 60 DAP	11.12±0.53	9.83-12.67	0.35	1.18	5.31	9.73	29.72	0.67	5.96
19	Fresh weight of root (g) at 90 DAP	15.60±0.79	14.37-17.83	0.73	2.60	5.47	10.34	27.90	0.93	5.96
20	Dry weight of root (g) at 60 DAP	3.70±0.18	3.26-4.19	0.03	0.13	5.01	9.85	25.90	0.19	5.25
21	Dry weight of root (g) at 90 DAP	5.13±0.26	4.66-5.89	0.09	0.29	5.69	10.51	29.35	0.33	6.35
22	Total fresh weight of plant (g) at 60 DAP	102.33±3.51	85.20-118.28	62.20	99.20	7.70	9.70	62.70	12.80	12.50
23	Total fresh weight of plant (g) at 90 DAP	123.92±3.97	105.40-145.15	71.60	119.00	6.83	8.80	60.20	13.50	10.90
24	Total dry weight of plant (g) at 60 DAP	19.70±0.74	16.32-23.02	2.58	4.24	8.16	10.40	61.00	2.60	13.10
25	Total dry weight of plant (g) at 90 DAP	23.52±0.71	20.30-26.79	2.41	3.90	6.60	8.38	61.90	2.52	10.69
26	Fresh weight of tuber (g)	260.50±26.04	161.33-365.40	4062.00	6097.00	24.46	29.90	66.60	107.10	41.40
27	Dry weight of tuber (g)	43.42±6.35	16.57-65.75	115.20	236.10	24.70	35.30	48.80	15.40	35.50

DAP- Days After Planting   GV- Genotypic Variance   PV- Phenotypic Variance

GCV- Genotypic Coefficient of Variation   PCV- Phenotypic Coefficient of Variation

h^2- Broad sense heritability   GA- Genetic Advance   GAM- Genetic Advance as Per cent of Mean

Table 5a. Mean performance of potato genotypes for morphological parameters

Sl. No.	Genotypes	1		2		3		4	5	6		7	8	
		20 DAP	**30 DAP**	**45 DAP**	**60 DAP**	**60 DAP**	**90 DAP**	**60 DAP**	**60 DAP**	**60 DAP**	**90 DAP**	**60 DAP**	**60 DAP**	**90 DAP**
1	TT 7003	75.83	91.83	59.07	66.72	231.47	284.07	40.53	35.72	3506.71	4866.45	3.47	28.10	34.02
2	TT 7010	73.33	94.50	46.33	53.53	225.40	269.20	40.85	38.14	3406.70	4593.05	3.67	33.47	40.71
3	TT 7016	77.50	92.00	43.47	53.87	230.07	282.40	40.20	38.08	3546.91	4918.74	3.60	34.80	41.01
4	TT 7008	78.33	92.00	50.40	55.47	216.20	265.80	45.02	40.03	4368.03	5900.28	3.39	30.67	37.93
5	TT 7011	71.67	92.67	54.43	60.00	226.47	277.87	38.82	41.11	4785.84	5423.12	3.42	32.07	39.33
6	TT 7015	72.50	92.00	54.13	62.00	198.40	258.13	42.93	40.06	3863.21	4513.51	3.40	34.40	41.73
7	TT 7005	75.00	91.67	35.13	47.74	216.40	267.80	38.91	40.13	3116.79	4390.60	3.13	26.87	34.13
8	TT 7007	75.83	92.00	52.73	57.20	209.27	260.67	43.00	43.03	3403.76	4757.82	3.33	30.67	37.93
9	TT 7006	74.17	91.00	45.73	53.20	192.67	251.73	38.12	39.77	3199.59	4684.98	2.93	26.73	33.20
10	Kufri Jyoti	70.82	93.83	55.07	62.80	252.53	303.93	52.31	46.55	4424.32	7023.48	4.40	34.53	41.33
11	C-28	78.33	95.00	57.67	60.20	242.80	321.13	41.53	39.27	3751.60	6893.71	4.73	37.93	45.80
12	FC-3	77.50	92.33	44.33	64.60	240.87	292.27	49.05	47.57	3976.04	5407.40	3.73	29.53	36.80
13	FC-5	70.00	91.67	44.13	55.27	211.47	262.87	48.05	47.28	4181.11	5724.47	2.87	30.05	37.27
14	FL-1533	73.33	90.33	48.53	59.07	226.93	279.80	41.86	41.24	3135.57	4415.77	3.53	33.60	40.87
15	Kufri Surya	75.00	94.00	53.93	59.27	213.47	257.33	42.25	40.98	3742.32	5016.28	3.00	34.03	41.27
16	Kufri Himalini	74.17	93.33	49.20	52.67	234.13	285.53	45.06	41.89	4360.43	5889.60	3.20	33.07	35.87
	Mean	**74.58**	**92.51**	**49.64**	**57.73**	**223.03**	**276.28**	**43.03**	**41.31**	**3798.06**	**5276.20**	**3.49**	**31.90**	**38.70**
	S.Em±	2.15	1.28	3.70	1.77	8.53	8.36	2.41	1.99	172.72	210.00	0.23	1.86	2.08
	CD @ 5%	6.21	3.69	10.68	5.10	24.63	24.14	6.96	5.73	498.85	606.70	0.66	5.36	6.00

DAP: Days After planting

1. Emergence (%)
2. Plant height (cm)
3. Number of leaves
4. Plant spread from North to South (cm)
5. Plant spread from East to West (cm)
6. Leaf area (cm^2)
7. Number of stems per plant
8. Fresh weight of leaves (g)

Table 5b. Mean performance of potato genotypes for morphological parameters

Sl. No.	Genotypes	1		2		3		4		5		6		7		8	9
		60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	60 DAP	90 DAP	90 DAP	90 DAP
1	TT 7003	5.87	6.67	60.18	70.98	9.35	10.99	11.38	17.32	3.75	5.66	99.57	122.31	18.85	23.32	311.13	47.50
2	TT 7010	7.53	8.04	59.16	69.96	9.01	10.71	11.72	16.75	3.83	5.56	104.35	127.45	20.35	24.31	322.47	59.53
3	TT 7016	7.41	8.09	55.42	66.22	8.62	10.26	12.15	16.90	3.93	5.72	102.37	124.12	19.74	24.07	265.13	42.28
4	TT 7008	6.82	7.70	56.37	67.17	8.76	10.40	12.67	17.83	4.19	5.89	99.68	122.93	19.78	24.02	248.60	39.28
5	TT 7011	7.02	7.89	62.99	73.79	9.64	11.28	12.40	16.48	4.18	5.27	107.46	129.61	20.81	24.44	356.87	65.75
6	TT 7015	7.31	8.16	66.95	77.75	10.40	12.04	11.58	16.67	3.83	5.32	113.02	136.15	21.74	25.52	213.87	44.88
7	TT 7005	5.65	6.63	51.25	62.05	7.89	9.53	10.23	14.75	3.34	4.89	88.35	110.93	16.93	21.05	162.8	26.77
8	TT 7007	6.07	7.40	53.30	64.10	8.16	9.81	10.58	14.37	3.52	4.66	94.55	116.40	17.95	21.86	176.27	29.96
9	TT 7006	5.31	6.52	48.13	57.33	7.52	8.94	10.33	14.87	3.47	4.84	85.20	105.40	16.32	20.30	161.33	16.57
10	Kufri Jyoti	7.42	8.03	68.06	78.81	10.88	12.52	9.83	14.97	3.26	4.85	112.37	135.08	21.87	25.38	365.40	51.60
11	C-28	8.57	9.20	69.27	81.40	10.77	12.68	11.08	14.95	3.76	4.91	118.28	142.15	23.02	26.79	360.01	56.95
12	FC-3	6.31	7.23	60.02	70.80	9.31	10.95	10.60	14.53	3.49	4.75	100.13	122.13	19.13	22.93	249.2	45.54
13	FC-5	6.45	7.36	56.98	67.78	8.83	10.48	11.03	15.15	3.68	5.07	98.01	120.20	18.61	22.90	203.07	38.24
14	FL-1533	7.13	7.99	59.50	64.03	9.07	9.72	10.87	14.95	3.67	5.03	103.97	119.85	19.85	22.75	221.20	37.49
15	Kufri Surya	7.33	8.18	62.75	73.55	9.75	11.71	10.98	14.67	3.65	4.86	107.73	129.48	20.70	24.75	287.33	49.82
16	Kufri Himalini	7.06	7.01	57.93	68.73	8.87	10.52	11.16	14.50	3.66	4.76	102.20	119.09	19.58	22.32	264.14	42.51
	Mean	**6.83**	**7.63**	**59.26**	**69.65**	**9.10**	**10.71**	**11.12**	**15.60**	**3.70**	**5.13**	**102.33**	**123.92**	**19.70**	**23.52**	**260.50**	**43.42**
	S.Em±	0.51	0.43	3.44	3.89	0.57	0.64	0.53	0.79	0.18	0.26	3.51	3.97	0.74	0.7	26.04	6.35
	CD @ 5%	1.47	1.25	9.94	11.24	1.65	1.86	1.52	2.28	0.52	0.76	10.14	11.47	2.14	2.03	75.2	18.33

DAP: Days After planting

1. Dry weight of leaves (g)
2. Fresh weight of stem (g)
3. Dry weight of stem (g)
4. Fresh weight of root (g)
5. Dry weight of root (g)
6. Total Fresh weight of plant (g)
7. Total dry weight of plant (g)
8. Fresh weight of tuber (g)
9. Dry weight of tuber (g)

advance as per cent of mean (9.17 %) and genetic advance (3.94) for this trait (Table 4a and 5a).

4.2.1.5 Plant spread from East to West

At 60 DAP, Plant spread ranged from 35.72 cm (TT 7003) to 47.57 cm (FC-3) with grand mean of 41.31 cm. The GV and PV were 7.30 and 19.13 respectively. Low estimate of GCV (6.54 %) and moderate was PCV (10.59 %) were observed. Moderate heritability (38.17 %) was observed along with low genetic advance as per cent of mean (8.33 %) and genetic advance (3.44) for this trait (Table 4a and 5a).

4.2.1.6 Leaf area

Leaf area at 60 DAP, varied from 3116.79 cm^2 (TT 7005) to 4785.84 cm^2 (TT 7011) with an average mean of 3798.06 cm^2. The GV and PV were 231149.60 and 320647.30 respectively. Moderate estimate of GCV (12.66 %) and PCV (14.91 %) were observed. High heritability (72.09 %) was observed along with high genetic advance as per cent of mean (22.14 %) and genetic advance (840.90) for this trait (Table 4a and 5a).

The leaf area was found between 4390.60 cm^2 (TT 7005) to 7023.48 cm^2 (Kufri Jyoti) with grand mean of 5276.20 cm^2 at 90 DAP. The GV and PV were 637820.30 and 770226.30 respectively. Moderate estimate of GCV (15.14 %) and PCV (16.63 %) were observed. High heritability (82.81 %) was observed along with high genetic advance as per cent of mean (28.37 %) and genetic advance (1497.12) for this trait (Table 4a and 5a).

4.2.1.7 Number of stems per plant

Number of stems per plant at 60 DAP, varied in between 2.87 (FC-5) to 4.73 (C-28) with an overall mean of 3.49. The GV and PV were 0.19 and 0.35 respectively. Moderate estimate of GCV (12.55 %) and PCV (16.94 %) were observed. Moderate heritability (54.86 %) was observed along with moderate genetic advance as per cent of mean (19.15 %) and genetic advance (0.67) for this trait (Table 4a and 5a).

4.2.1.8 Fresh weight of leaves

Fresh weight of leaves at 60 DAP, ranged from 26.73 g (TT 7006) to 37.93 g (C-28) with an average mean of 31.90 g. The GV and PV were 6.48 and 16.83 respectively. Low estimate of GCV (7.98 %) and moderate PCV (12.86 %) were observed. Moderate heritability (38.52 %) was observed along with moderate genetic advance as per cent of mean (10.21 %) and genetic advance (33.26) for this trait (Table 4a and 5a).

At 90 DAP, the fresh weight of leaves was found between 33.20 g (TT 7006) to 45.80 g (C-28) with grand mean of 38.70 g. The GV and PV were 7.41 and 20.33 respectively. Low estimate of GCV (7.03 %) and moderate PCV (11.65 %) were observed. Moderate heritability (36.42 %) was observed along with low genetic advance as per cent of mean (8.74 %) and genetic advance (3.38) for this trait (Table 4a and 5a).

4.2.1.9 Dry weight of leaves

The dry weight of leaves varied in between 5.31 g (TT 7006) to 8.57 g (C-28) with an average mean of 6.83 g at 60 DAP. The GV and PV were 0.44 and 1.22 respectively. Low estimate of GCV (9.73 %) and moderate PCV (16.14 %) were observed. Moderate heritability (36.30 %) was observed along with moderate genetic advance as per cent of mean (12.07 %) and genetic advance (0.82) for this trait (Table 4a and 5b).

At 90 DAP, the dry weight of leaves varied from 6.52 g (TT 7006) to 9.20 g (C-28) with grand mean of 7.63 g. The GV and PV were 0.32 and 0.88 respectively. Low estimate of GCV (7.41 %) and moderate PCV (12.32 %) were observed. Moderate heritability (36.20 %) was observed along with low genetic advance as per cent of mean (9.18 %) and genetic advance (0.70) for this trait (Table 4a and 5b).

4.2.1.10 Fresh weight of stem

Fresh weight of stem at 60 DAP, ranged from 48.13 g (TT 7006) to 69.27 g (C-28) with an average mean of 59.26 g. The GV and PV were 22.61and 58.10 respectively. Low estimate of GCV (8.02 %) and moderate PCV (12.87 %) were observed. Moderate heritability (38.89 %) was observed along with moderate genetic advance as per cent of mean (10.31 %) and genetic advance (6.11) for this trait (Table 4b and 5b).

At 90 DAP, the fresh weight of stem varied from 57.33 g (TT 7006) to 81.40 g (C-28) with grand mean of 69.65 g. The GV and PV were 25.90 and 71.40 respectively. Low estimate of GCV (7.32 %) and moderate PCV (12.13 %) were observed. Moderate heritability (36.30 %) was observed along with low genetic advance as per cent of mean (9.10 %) and genetic advance (6.30) for this trait (Table 4b and 5b).

4.2.1.11 Dry weight of stem

At 60 DAP, dry weight of stem ranged from 7.52 g (TT 7006) to 10.88 g (Kufri Jyoti) with an average mean of 9.10 g. The GV and PV were 0.58 and 1.56 respectively. Low estimate of GCV (8.31 %) and moderate PCV (13.61 %) were observed. Moderate heritability (37.29 %) was observed along with moderate genetic advance as per cent of mean (10.45%) and genetic advance (0.96) for this trait (Table 4b and 5b).

The dry weight of stem varied from 8.94 g (TT 7006) to 12.68 g (C-28) with mean of 10.71 g at 90 DAP. The GV and PV were 0.72 and 1.96 respectively. Low estimate of GCV (7.85 %) and moderate PCV (12.90 %) were observed. Moderate heritability (36.61 %) was observed along with low genetic advance as per cent of mean (9.78 %) and genetic advance (1.06) for this trait (Table 4b and 5b).

4.2.1.12 Fresh weight of root

Fresh weight of root at 60 DAP, varied in between 9.83 g (Kufri Jyoti) to 12.67 g (TT 7008) with an average mean of 11.12 g. The GV and PV were 0.35 and 1.18 respectively. Low estimate of GCV (5.31 %) and PCV (9.73 %) were observed. Low heritability (29.72 %) was observed along with low genetic advance as per cent of mean (5.96 %) and genetic advance (0.67) for this trait (Table 4b and 5b).

At 90 DAP, the fresh weight of root was found between 14.37 g (TT 7007) to 17.83 g (TT 7008) with grand mean of 15.60 g. The GV and PV were 0.73 and 2.60 respectively. Low estimate of GCV (2.60 %) and PCV (5.47 %) were observed. Low heritability (27.90%) was observed along with low genetic advance as per cent of mean (5.96%) and genetic advance (0.93) for this trait (Table 4b and 5b).

4.2.1.13 Dry weight of root

Dry weight of root varied from 3.26 g (Kufri Jyoti) to 4.19 g (TT 7008) with an overall mean of 3.70 g at 60 DAP. The GV and PV were 0.03 and 0.13 respectively. Low estimate of GCV (5.01 %) and PCV (9.85 %) were observed. Low heritability (25.90 %) was observed along with low genetic advance as per cent of mean (5.25 %) and genetic advance (0.19) for this trait (Table 4b and 5b).

The dry weight of root at 90 DAP, ranged from 4.66 g (TT 7007) to 5.89 g (TT 7008) with mean of 5.13 g. The GV and PV were 0.09 and 0.29 respectively. Low estimate of GCV (5.69 %) and moderate PCV (10.51 %) were observed. Low heritability (29.35 %) was observed along with low genetic advance as per cent of mean (6.35 %) and genetic advance (0.33) for this trait (Table 4b and 5b).

4.2.1.14 Total Fresh weight of plant

The total fresh weight of plant at 60 DAP, ranged from 85.20 g (TT 7006) to 118.28 g (C-28) with an average mean of 102.33 g. The GV and PV were 62.20 and 99.20 respectively. Low estimate of GCV (7.70 %) and PCV (9.70 %) were observed. High heritability (62.70 %) was observed along with moderate genetic advance as per cent of mean (12.50 %) and genetic advance (12.80) for this trait (Table 4b and 5b).

At 90 DAP, the total fresh weight of plant varied from 105.40 g (TT 7006) to 145.15 g (C-28) with grand mean of 123.92 g. The GV and PV were 71.60 and 119.0 respectively. Low estimate of GCV (6.83 %) and PCV (8.80 %) were observed. High heritability (60.20 %) was observed along with moderate genetic advance as per cent of mean (10.90 %) and genetic advance (13.50) for this trait (Table 4b and 5b).

4.2.1.15 Total dry weight of plant

The total dry weight of plant at 60 DAP, was found between 16.32 g (TT 7006) to 23.02 g (C-28) with mean of 19.70 g. The GV and PV were 2.58 and 4.24 respectively. Low estimate of GCV (8.16 %) and moderate PCV (10.40 %) were observed. High heritability (61.0 %) was observed along with moderate genetic advance as per cent of mean (13.10 %) and genetic advance (2.60) for this trait (Table 4b and 5b).

At 90 DAP, the total dry weight of plant ranged from 20.30 g (TT 7006) to 26.79 g (C-28) with average mean of 23.52 g. The GV and PV were 2.41 and 3.90 respectively. Low estimate of GCV (6.60 %) and PCV (8.38 %) were observed. High heritability (61.90 %) was observed along with moderate genetic advance as per cent of mean (10.69 %) and genetic advance (2.52) for this trait (Table 4b and 5b).

4.2.1.16 Fresh weight of tuber

Fresh weight of tuber was maximum in Kufri Jyoti (365.40 g) followed by C-28 (360.0 g) and it was minimum in TT 7006 (161.33 g) with a mean of 260.50 g. The GV and PV were 4062.0 and 6097.0, respectively. The estimates of GCV and PCV were high (24.46 % and 29.90 %, respectively). High heritability (66.60 %) was observed along with high genetic advance as per cent of mean (41.40 %) and GA (107.10) (Tables 4b and 5b).

4.2.1.17 Dry weight of tuber

Dry weight of tuber was maximum in TT 7011(65.75 g) followed by TT 7010 (59.53 g) and it was minimum in TT 7006 (16.57 g) with an average mean of 43.42 g. The GV and PV were 115.20 and 236.10 respectively. The estimates of GCV and PCV were high (24.70 % and 35.30 % respectively). Moderate heritability (48.80 %) was observed along with high genetic advance as per cent of mean (35.30 %) and GA (15.40) (Tables 4b and 5b).

4.2.1.18 Number of tubers per plant

TT 7011 (4.72) followed by TT 7010 (4.54) genotypes were showed maximum number of tubers per plant and the minimum was observed in TT 7006 (2.63). Average mean of 3.68 tubers per plant was recorded. The GV and PV were 0.28 and 0.71 respectively. The estimates of GCV and PCV were moderate and high (14.30 % and 22.83 %, respectively). Moderate heritability (39.20 %) was observed along with moderate genetic advance as per cent of mean (18.46 %) and GA was 0.68 (Tables 6 and 7).

4.2.1.19 Number of tubers per plot

TT 7011 (178.0) followed by C-28 (170.22) genotypes were showed maximum number of tubers per plot and the least was observed in TT 7006 (89.78).

Table 6. Estimates of genetic parameters for yield parameters in potato genotypes

Sl. No.	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
1	Number of tubers per plant	3.68±0.38	2.63-4.72	0.28	0.71	14.30	22.83	39.20	0.68	18.46
2	Number of tubers per plot	132.50±14.1	89.78-178.00	566.50	1156.30	17.90	25.60	49.00	34.30	25.80
3	Tuber length (cm)	6.87±0.47	5.25-8.27	0.48	1.14	10.10	15.50	42.30	0.93	13.60
4	Tuber circumference (cm)	14.61±0.87	11.83-16.8	1.21	3.46	7.50	12.74	34.79	1.33	9.13
5	Tuber volume (CC)	113.25±10.12	66.44-162.56	680.50	991.00	23.00	27.80	68.60	44.50	39.30
6	Tuber weight (g)	71.90±4.90	56.32-85.36	44.20	116.50	9.26	15.00	38.00	8.45	11.76
7	Total tuber yield per plant (g)	260.50±26.04	161.33-365.40	4062.00	6097.00	24.46	29.90	66.60	107.10	41.40
8	Total tuber yield per plot (kg)	9.35±0.90	5.70-13.15	5.80	8.10	25.75	30.50	71.00	4.10	44.70
9	Total tuber yield per hectare (tonnes)	19.37±1.91	11.87-27.40	25.60	36.56	26.14	31.20	70.00	8.70	45.00
10	Marketable yield per plant (g)	236.70±20.63	124.33-363.47	5410.00	6687.00	31.00	34.50	80.90	136.30	57.50
11	Marketable yield per plot (kg)	8.50±0.75	4.29-13.01	7.20	8.80	31.50	35.00	81.00	5.00	58.50
12	Marketable yield per hectare (tonnes)	17.70±1.56	8.93-27.10	31.20	38.50	31.56	35.00	81.00	10.30	58.50

DAP- Days After Planting
GV- Genotypic Variance
PV- Phenotypic Variance
GCV- Genotypic Coefficient of Variation
PCV- Phenotypic Coefficient of Variation
h^2- Broad sense heritability
GA- Genetic Advance
GAM- Genetic Advance as Per cent of Mean

Table 7. Mean performance of potato genotypes for yield parameters

Sl. No.	Genotypes	1	2	3	4	5	6	7	8	9	10	11	12
1	TT 7003	4.14	145.11	7.62	16.11	135.11	76.04	311.13	11.36	23.68	300.20	10.79	22.48
2	TT 7010	4.54	169.78	8.27	15.22	140.56	71.71	322.47	11.83	24.65	261.87	9.60	20.00
3	TT 7016	3.99	142.22	6.88	15.50	128.89	68.82	265.13	9.47	19.74	229.73	8.36	17.43
4	TT 7008	3.51	128.22	6.91	13.33	106.11	72.09	248.60	8.97	18.69	232.27	8.33	17.35
5	TT 7011	4.72	178.00	7.72	12.78	89.78	78.24	356.87	12.97	27.01	331.33	12.02	25.05
6	TT 7015	3.45	117.78	5.39	11.83	66.44	66.35	213.87	7.70	16.04	178.87	6.44	13.42
7	TT 7005	2.77	91.11	6.84	14.20	95.00	60.63	162.80	5.82	12.13	140.33	4.99	10.39
8	TT 7007	3.16	112.89	6.38	16.33	118.89	56.32	176.27	6.25	13.01	129.27	4.56	9.50
9	TT 7006	2.63	89.78	6.70	13.78	98.00	63.52	161.33	5.70	11.87	124.33	4.29	8.93
10	Kufri Jyoti	4.29	159.56	7.34	14.02	97.33	82.23	365.40	13.15	27.40	363.47	13.01	27.10
11	C-28	4.35	170.22	7.99	14.22	154.22	81.97	360.00	13.03	27.14	355.87	12.76	26.57
12	FC-3	3.53	118.67	5.25	14.33	74.78	78.13	249.20	8.91	18.56	239.93	8.56	17.82
13	FC-5	3.09	112.44	5.69	13.56	92.44	68.29	203.07	7.30	15.21	187.27	6.79	14.15
14	FL-1533	3.01	110.00	7.02	16.80	162.56	74.93	221.20	7.88	16.41	193.13	6.86	14.28
15	Kufri Surya	3.52	129.21	6.96	15.56	112.50	85.36	287.33	10.78	22.47	285.93	10.37	21.60
16	Kufri Himalini	4.17	150.22	6.81	16.15	123.56	65.75	264.20	8.53	15.86	234.25	8.32	17.33
	Mean	**3.68**	**132.50**	**6.87**	**14.61**	**113.25**	**71.90**	**260.50**	**9.35**	**19.37**	**236.70**	**8.50**	**17.70**
	S.Em±	0.38	14.00	0.47	0.87	10.10	4.90	26.04	0.90	1.91	20.63	0.75	1.56
	CD @ 5%	1.09	40.50	1.35	2.51	29.40	14.10	75.20	2.57	5.51	59.50	2.16	4.50

1. Number of tubers/ plant 2.Number of tubers/ plot 3. Tuber length (cm) 4. Tuber circumference (cm)

5. Tuber volume (CC) 6. Tuber weight (g) 7. Total tuber yield/ plant (g) 8. Total tuber yield/ plot (kg)

9. Total tuber yield/ hectare (tonnes) 10. Marketable yield/ plant (g) 11. Marketable yield/ plot (kg) 12. Marketable yield/ hectare (tonnes)

Average mean of 132.50 tubers per plot was recorded. The GV and PV were 566.50 and 1156.30 respectively. The estimates of GCV and PCV were moderate and high (17.90 % and 25.60 %, respectively). Moderate heritability (49.0 %) was observed along with high genetic advance as per cent of mean (25.80 %) and GA was 34.30 (Tables 6 and 7).

4.2.1.20 Tuber length

Tuber length varied in between 5.25 (FC-3) to 8.27 cm (TT 7010) with a mean value of 6.87 cm. The GV and PV were 0.48 and 1.14 respectively. The estimates of GCV and PCV were moderate (10.10 % and 15.50 % respectively). Moderate heritability (42.30 %) was observed along with moderate genetic advance as per cent of mean (13.60 %) and GA was 0.93 (Tables 6 and 7).

4.2.1.21 Tuber circumference

Tuber circumference ranged from 11.83 (TT 7015) to 16.8 cm (FL-1533) with an average mean of 14.61 cm. The GV and PV were 1.21 and 3.46 respectively. The estimates of GCV and PCV were low and moderate (7.50 % and 12.74 % respectively). Moderate heritability (34.79 %) was observed along with low genetic advance as per cent of mean (9.13 %) and GA was 1.33 (Tables 6 and 7).

4.2.1.22 Tuber volume

Tuber volume varied from 66.44 (TT 7015) to 162.56 cc (C-28) with an overall mean of 113.25 cm. The GV and PV were 680.50 and 991.0 respectively. The estimates of GCV and PCV were high (23.0 % and 27.80 % respectively). High heritability (68.60 %) was observed along with high genetic advance as per cent of mean (39.30 %) and GA was 44.50 (Tables 6 and 7).

4.2.1.23 Tuber weight

Tuber weight ranged from 56.32 (TT 7007) to 85.36 cm (Kufri Surya) with a mean value of 71.90 cm. The GV and PV were 44.20 and 116.50 respectively. The estimates of GCV and PCV were low and moderate (9.26 % and 15.0 %, respectively). Moderate heritability (38.0 %) was observed along with moderate genetic advance as per cent of mean (11.76 %) and GA was 8.45 (Tables 6 and 7).

4.2.1.24 Total tuber yield per plant

Kufri Jyoti (365.40 g) followed by C-28 (360.0 g) genotypes was maximum for total tuber yield per plant and it was minimum in TT 7006 (161.33 g) genotype. Mean yield per plant was 260.5 g. The GV and PV were 4062.0 and 6097.0 respectively. The estimates of GCV and PCV were high (24.46 % and 29.90 %, respectively). High heritability (66.60 %) was observed along with high genetic advance as per cent of mean (41.40 %) and GA was 107.10 (Tables 6 and 7).

4.2.1.25 Total tuber yield per plot

Total tuber yield per plot was maximum in Kufri Jyoti (13.15 kg) followed by C-28 (13.03 kg) and it was minimum in TT 7006 (5.70 kg). Mean yield per plant was 9.35 kg. The GV and PV were 5.80 and 8.10 respectively. The estimates of GCV and PCV were high (25.75 % and 30.50 % respectively). High heritability (71.0 %) was observed along with high genetic advance as per cent of mean (44.70 %) and GA was 4.10 (Tables 6 and 7).

4.2.1.26 Total tuber yield per hectare

The maximum total tuber yield per hectare was observed in genotype Kufri Jyoti (27.40 t) followed by C-28 (27.14 t), TT 7011 (27.01 t), TT 7010 (24.65 t) and the minimum yield was observed in TT 7006 (11.87). Yield per hectare ranged from 11.87 to 27.40 tonnes per hectare with a mean value of 19.37 tonnes per hectare. The GV and PV were 25.60 and 36.56 respectively. The estimates of GCV and PCV were high (26.14 % and 31.20 %, respectively). High heritability (70.0 %) was observed along with high genetic advance as per cent of mean (45.0 %) and GA (8.70) (Tables 6 and 7).

4.2.1.27 Marketable yield per plant

Marketable yield per plant was maximum in Kufri Jyoti (363.47 g) followed by C-28 (355.87 g) and it was minimum in TT 7006 (124.33 g). Mean yield per plant was 236.7 g. The GV and PV were 5410.0 and 6687.0 respectively. The estimates of GCV and PCV were high (31.0 % and 34.50 % respectively). High heritability (80.90 %) was observed along with high genetic advance as per cent of mean (57.50 %) and GA was 136.30 (Tables 6 and 7).

4.2.1.28 Marketable yield per plot

Marketable yield per plot was maximum in Kufri Jyoti (13.01 kg) followed by C-28 (12.76 kg) and it was minimum in TT 7006 (4.29 kg). Mean yield per plant was 8.50 kg. The GV and PV were 7.20 and 8.80 respectively. The estimates of GCV and PCV were high (31.50 % and 35.0 % respectively). High heritability (81.0 %) was observed along with high genetic advance as per cent of mean (58.50 %) and GA was 5.0 (Tables 6 and 7).

4.2.1.29 Marketable yield per hectare

The maximum Marketable yield per hectare was observed in genotype Kufri Jyoti (27.10 t) followed by C-28 (26.57 t), TT 7011 (25.05 t), TT 7003 (22.48 t) and the minimum yield was observed in TT 7006 (8.93 t). Yield per hectare ranged from 8.93 to 27.10 tonnes per hectare with a mean value of 17.70 tonnes per hectare. The GV and PV were 31.20 and 38.50 respectively. The estimates of GCV and PCV were high

(31.56 % and 35.0 % respectively). High heritability (81.0 %) was observed along with high genetic advance as per cent of mean (58.50 %) and GA (10.30) (Tables 6 and 7).

4.2.1.30 Dry matter

TT 7015 (19.78 %) followed by TT 7011 (19.11 %) genotypes were showed maximum in tuber dry matter content and it was minimum in TT 7006 (9.61 %) with an overall mean of 16.32 per cent. The GV and PV were 3.30 and 9.40 respectively. The estimates of GCV and PCV were moderate (11.10 % and 18.70 % respectively). Moderate heritability (35.10 %) was observed along with moderate genetic advance as per cent of mean (13.60 %) and GA (2.20) (Table 8 and Fig. 2).

4.2.1.31 Total Soluble Solids

Total Soluble Solids was maximum in TT 7007 (6.20 ^{0}Brix) followed by FC-3 (6.16 ^{0}Brix) and it was minimum in Kufri Surya (4.37 ^{0}Brix) with a mean of 5.68 ^{0}Brix. The GV and PV were 0.20 and 0.53 respectively. The estimates of GCV and PCV were low and moderate (7.83 % and 12.80 %, respectively). Moderate heritability (37.20 %) was observed along with low genetic advance as per cent of mean (9.85 %) and GA (0.56) (Tables 8 and 9).

4.2.1.32 Number of eyes per tuber

Kufri jyoti (10.67) followed by TT 7003 (10.33) genotypes were maximum in number of eyes per tuber and it was minimum in TT 7006 (6.11) with an average mean of 8.99. The GV and PV were 0.93 and 1.90 respectively. The estimates of GCV and PCV were moderate (10.70 % and 15.40 %, respectively). Moderate heritability (48.50 %) was observed along with moderate genetic advance as per cent of mean (15.40 %) and GA (1.39) (Table 8 and Fig. 2).

4.2.1.33 Total chlorophyll

Total chlorophyll content was maximum in FL-1533 (1.34 mg/g) and minimum in Kufri Himalini (1.19 mg/g) with an overall mean of 1.18 mg/g. The GV and PV were 0.01 and 0.02 respectively. The estimates of GCV and PCV were low and moderate (9.65 % and 11.25 %, respectively). High heritability (73.60 %) was observed along with moderate genetic advance as per cent of mean (17.06 %) and GA (0.20) (Tables 8 and 9).

4.2.1.34 Reducing sugars

Reducing sugars was maximum in TT 7015 (1.45 %) followed by FC-5 (1.34 %) and it was minimum in TT 7003 (1.03 %) with a mean of 1.27 %. The GV and PV were 0.01 and 0.02 respectively. The estimates of GCV and PCV were high (2.71 % and 4.52 %, respectively). High heritability (35.81 %) was observed along with high genetic advance as per cent of mean (3.34 %) and GA (0.04) (Tables 8 and 9).

Table 8. Estimates of genetic parameters for quality parameters in potato genotypes

Sl. No.	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
1	Tuber dry matter content	16.32±1.43	9.61-19.78	3.30	9.40	11.10	18.70	35.10	2.20	13.60
2	TSS (^{0} Brix)	5.68±0.33	4.37-6.20	0.20	0.53	7.83	12.80	37.20	0.56	9.85
3	Number of eyes per tuber	8.99±0.57	6.11-10.67	0.93	1.90	10.70	15.40	48.50	1.39	15.40
4	Total chlorophyll (mg/g)	1.18±0.04	1.19-1.34	0.01	0.02	9.65	11.25	73.60	0.20	17.06
5	Reducing sugars (%)	1.27±0.03	1.03-1.45	0.01	0.02	2.71	4.52	35.81	0.04	3.34
6	Non reducing sugars (%)	0.84±0.03	0.62-1.07	0.01	0.01	12.90	14.45	80.50	0.20	23.90
7	Total sugars (%)	2.02±0.07	1.66-2.39	0.04	0.05	9.73	11.20	74.70	0.35	17.30
8	Starch (%)	20.90±0.15	19.19-23.00	1.97	2.04	6.70	6.80	96.50	2.84	13.60

DAP- Days After Planting
GV- Genotypic Variance
PV- Phenotypic Variance
GCV- Genotypic Coefficient of Variation
PCV- Phenotypic Coefficient of Variation
h^2- Broad sense heritability
GA- Genetic Advance
GAM- Genetic Advance as Per cent of Mean

Table 9. Mean performance of potato genotypes for quality parameters

Sl. No.	Genotypes	TSS (^{0} Brix)	Total Chlorophyll (mg/g)	Reducing sugars (%)	Non reducing sugars (%)
1	TT 7003	5.40	1.28	1.03	0.68
2	TT 7010	5.53	1.25	1.08	0.72
3	TT 7016	5.67	1.27	1.04	0.85
4	TT 7008	5.95	1.30	1.23	0.78
5	TT 7011	6.10	1.25	1.05	0.62
6	TT 7015	5.56	1.32	1.45	0.94
7	TT 7005	5.83	1.24	1.23	0.91
8	TT 7007	6.20	1.28	1.20	0.90
9	TT 7006	6.13	1.33	1.21	0.81
10	Kufri Jyoti	5.96	1.21	1.30	1.07
11	C-28	5.95	1.27	1.20	0.95
12	FC-3	6.16	1.23	1.22	0.90
13	FC-5	6.08	1.28	1.34	0.75
14	FL-1533	5.59	1.34	1.22	0.91
15	Kufri Surya	4.37	1.33	1.07	0.81
16	Kufri Himalini	4.46	1.19	1.07	0.83
	Mean	**5.68**	**1.27**	**1.18**	**0.84**
	S.Em±	0.33	0.03	0.04	0.03
	CD @ 5%	0.96	0.08	0.11	0.09

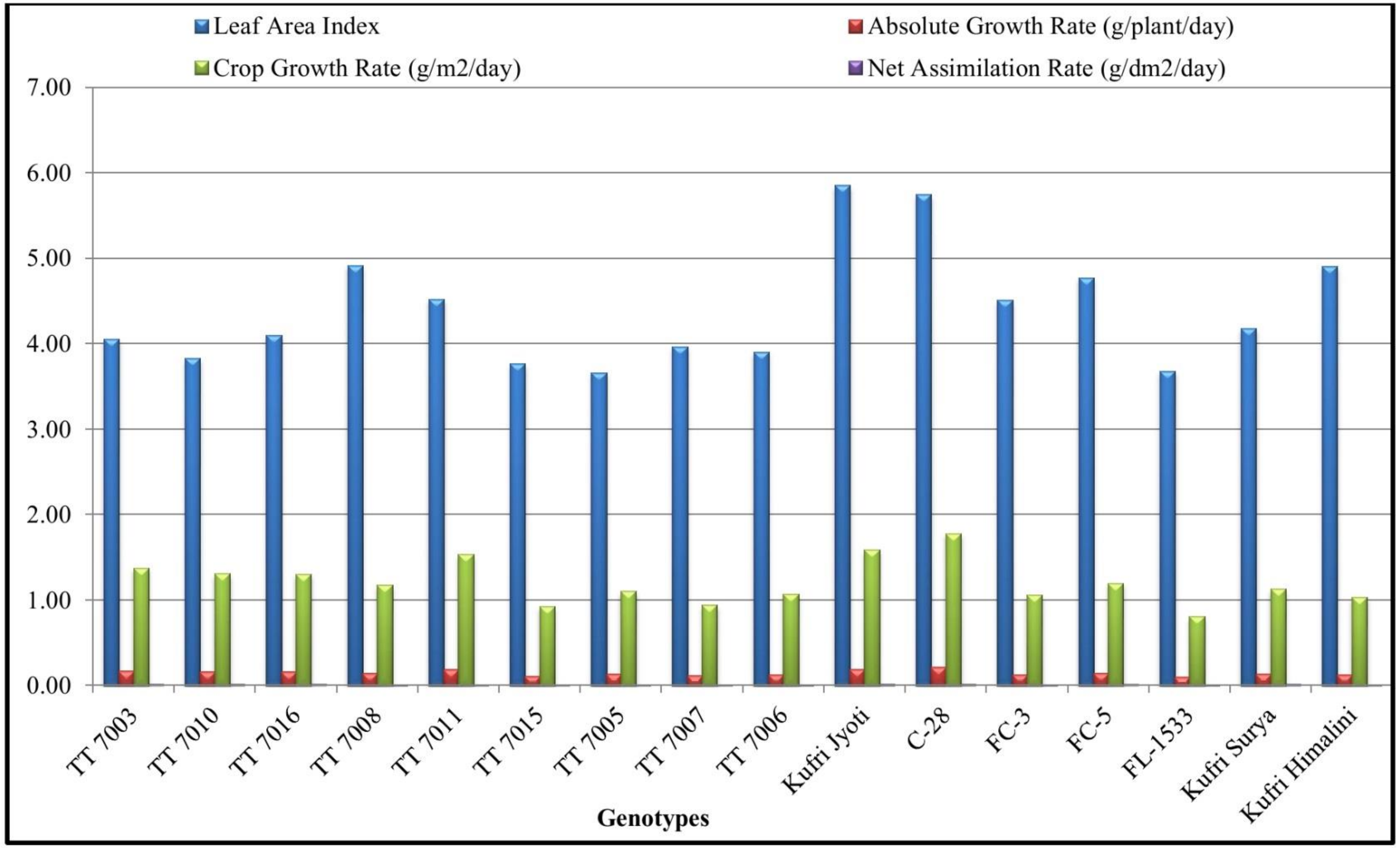

Fig. 2. Mean performance of potato genotypes for growth parameters

4.2.1.35 Non-reducing sugars

Non-reducing sugars was maximum in Kufri Jyoti (1.07 %) followed by C-28 (0.95 %) and it was minimum in TT 7011 (0.62 %) with a mean of 0.84 per cent. The GV and PV were 0.01 and 0.01 respectively. The estimates of GCV and PCV were moderate (12.90 % and 14.45 %, respectively). High heritability (80.50 %) was observed along with high genetic advance as per cent of mean (23.90 %) and GA (0.20) (Tables 8 and 9).

4.2.1.36 Total sugars

TT 7015 (2.39 %) followed by Kufri Jyoti (2.36 %) genotypes were maximum in total sugars and it was minimum in TT 7011 (1.66 %) with grand mean of 2.02 per cent. The GV and PV were 0.04 and 0.05 respectively. The estimates of GCV and PCV were low and moderate (9.73 % and 11.20 %, respectively). High heritability (74.70 %) was observed along with moderate genetic advance as per cent of mean (17.30 %) and GA (0.35) (Table 8 and Fig. 2).

4.2.1.37 Starch

Starch content was observed maximum in TT 7008 (23.0 %) followed by Kufri Jyoti (22.70 %) and it was minimum in Kufri Himalini (19.19 %) with an average mean of 20.90 %. The GV and PV were 1.97 and 2.04 respectively. The estimates of GCV and PCV were low (6.70 % and 6.80 %, respectively). High heritability (96.50 %) was observed along with moderate genetic advance as per cent of mean (13.60 %) (Table 8 and Fig. 2).

4.2.1.38 Leaf area index (LAI)

The data on leaf area index in different genotypes of potato are presented in Fig. 3. Leaf area index differed significantly among the genotypes from 3.66 to 5.85. At 60-90 DAP, significantly maximum leaf area index in genotype Kufri Jyoti (5.85) followed by C-28 (5.74) and TT 7008 (4.92). The minimum leaf area index recorded in TT 7005 (3.66) and TT 7015 (3.76).

4.2.1.39 Absolute growth rate (g/plant/day)

The genotypes differed significantly for absolute growth rate varied in between 0.097 to 0.213. At 60-90 DAP, significantly maximum absolute growth rate index in genotype C-28 (0.213) followed by Kufri Jyoti (0.190) and TT 7011 (0.183). The minimum absolute growth rate recorded in FL-1533 (0.097) and TT 7015 (0.110) (Fig. 3).

4.2.1.40 Crop growth rate (g/m^2/day)

The genotypes differed significantly for crop growth rate ranged from 0.80 to 1.78. At 60-90 DAP, significantly maximum crop growth rate in genotype C-28 (1.78)

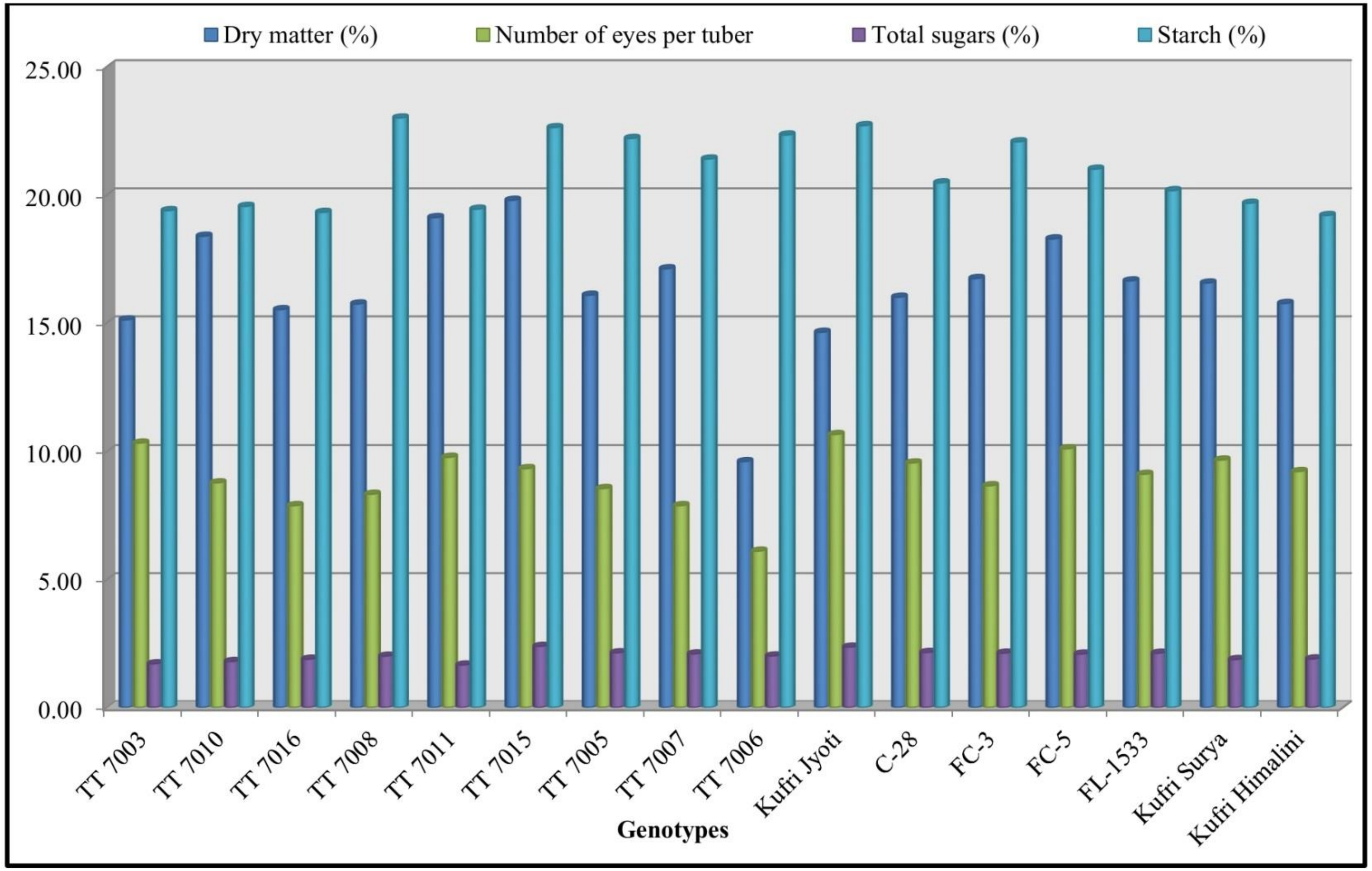

Fig. 3. Qualitative traits in potato genotypes

followed by Kufri Jyoti (1.58). The minimum crop growth rate recorded in FL-1533 (0.80) and TT 7015 (0.92) (Fig. 3).

4.2.1.41 Net assimilation rate (g/dm^2/day)

Net assimilation rate differed significantly among the genotypes was found between 0.0080 to 0.0160. At 60-90 DAP, significantly maximum net assimilation rate in genotype Kufri Jyoti (0.0160) followed by C-28 (0.0146). The minimum net assimilation rate recorded in TT 7005 (0.0080) and TT 7015 (0.0093) (Fig. 3).

4.2.1.42 Disease incidence

4.2.1.43.1 Incidence of early, late blight and aphids

The results on incidence of early blight, late blight and aphid in different genotypes of potato are presented in the Table 10. The crop recorded to a lesser extent to an incidence of pest and diseases. Early blight incidence was found non-significant in different genotypes which ranged from 0.93 per cent to 1.85 per cent. It was minimum 0.93 per cent in genotypes FL-1533, Kufri Himalini, TT 7003 and TT 7003 and maximum 1.85 per cent in genotype FC-3 and in other genotypes the damage was nil. Similarly, the incidence of late blight and aphids was found non-significant in different genotypes (0.93 to 1.85 and 0.93 to 2.78, respectively). Incidence of late blight maximum (1.85 %) in both genotypes (Kufri Surya and TT 7003) and minimum (0.93 %) in genotypes (TT 7016, TT 7011, TT 7007, FC-3, FC-5 and Kufri Himalini) and in other genotypes the damage was nil. Whereas, aphid infestation maximum (2.78 per cent) in genotypes (TT 7015, TT 7011, TT 7008 and C-28) and minimum (0.93 per cent) in genotypes (TT 7016, Kufri Jyoti, Kufri Surya and FL-1533).

4.3 Character association studies

The genotypic and phenotypic correlation studies were carried out to know the nature of relationship existing between total tuber yield and its component characters. Higher genotypic correlation coefficient were noticed than phenotypic correlation coefficients for all the 14 characters studied (Table 11 and 12).

4.3.1 Genotypic correlation

Genotypic correlation coefficients among growth, yield and quality attributes are studied (Table 11).

At genotypic level, plant height at 60 DAP was positively and significantly correlated with dry weight of tuber per plant (0.614), marketable yield per plant (0.609), marketable yield per plot (0.604) and total tuber yield per plot (0.597), total fresh weight of plant (0.590), fresh weight of tuber per plant (0.571), total dry weight of plant (0.551), number of stems at 60 DAP (0.522), number of tubers per plant

Table 10. Per cent incidence of pest and diseases in potato genotypes

Sl. No.	Genotypes	Late blight (%)	Early blight (%)	Aphids (%)
1	TT 7003	0.93	1.85	1.85
2	TT 7010	0.00	0.00	1.85
3	TT 7016	0.00	0.93	0.93
4	TT 7008	0.93	0.00	2.78
5	TT 7011	0.93	0.93	2.78
6	TT 7015	0.00	0.00	2.78
7	TT 7005	0.00	0.00	1.85
8	TT 7007	0.00	0.93	1.85
9	TT 7006	0.00	0.00	1.85
10	Kufri Jyoti	0.00	0.00	0.93
11	C-28	0.00	0.00	2.78
12	FC-3	1.85	0.93	1.85
13	FC-5	0.00	0.93	1.85
14	FL-1533	0.93	0.00	0.93
15	Kufri Surya	0.00	1.85	0.93
16	Kufri Himalini	0.93	0.93	1.85
Mean		**0.41**	**0.58**	**1.85**
S.Em±		0.56	0.57	0.81
CD @ 5%		1.63	1.65	2.35

Table 11. Estimates of genotypic correlation coefficients for yield and its component characters in potato genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	0.463**	0.281	0.522**	0.590**	0.551**	0.319*	0.008	0.476**	0.571**	0.641**	0.609**	0.604**	0.597**
2		1.000	0.696**	0.986**	0.708**	0.694**	0.002	-0.196	0.778**	0.782**	0.684**	0.814**	0.799**	0.758**
3			1.000	0.783**	0.635**	0.639**	-0.090	0.130	0.596**	0.647**	0.495**	0.712**	0.698**	0.613**
4				1.000	0.761**	0.748**	-0.137	0.064	0.718**	0.796**	0.586**	0.793**	0.781**	0.778**
5					1.000	0.999**	0.702**	-0.121	0.929**	0.914**	0.997**	0.858**	0.869**	0.919**
6						1.000	0.628**	-0.136	0.925**	0.920**	0.993**	0.859**	0.872**	0.927**
7							1.000	0.291*	0.236	0.196	0.496**	0.143	0.170	0.194
8								1.000	-0.642**	-0.451**	0.301*	-0.355*	-0.369*	-0.426**
9									1.000	0.981**	0.928**	0.941**	0.946**	0.947**
10										1.000	0.951**	0.995**	0.998**	0.998**
11											1.000	0.924**	0.935**	0.944**
12												1.000	0.991**	0.991**
13													1.000	0.993**
14														1.000

Critical r value 1% = 0.368 5%= 0.284

* & ** indicates Significant @ 5 % and 1 % level respectively.

1. Plant height (cm) 60 DAP
2. Number of leaves at 60 DAP
3. Leaf area (cm^2) at 60DAP
4. Number of stems at 60 DAP
5. Total fresh weight of plant (g)
6. Total dry weight of plant (g)
7. Dry matter (%)
8. Starch (%)
9. Number of tubers per plant
10. Fresh weight of tuber per plant (g)
11. Dry weight of tuber per plant (g)
12. Marketable yield per plant (g)
13. Marketable yield per plot (kg)
14. Total tuber yield per plot (kg)

(0.476), number of leaves at 60 DAP (0.463) and dry matter (0.319). But it was non-significantly associated with leaf area at 60 DAP (0.281) and starch (0.008).

Number of leaves at 60 DAP was positively and significantly correlated with number of stems at 60 DAP (0.986), marketable yield per plant (0.814), marketable yield per plot (0.799), fresh weight of tuber per plant (0.782), number of tubers per plant (0.778), total tuber yield per plot (0.758), total fresh weight of plant (0.708), leaf area at 60 DAP (0.696), total dry weight of plant (0.694) and dry weight of tuber per plant (0.684). But it was non-significantly associated with dry matter (0.002) and starch (-0.196).

The character leaf area at 60 DAP had positively and significantly correlated with number of stems at 60 DAP (0.783), marketable yield per plant (0.712), marketable yield per plot (0.698), fresh weight of tuber per plant (0.647), total dry weight of plant (0.639), total fresh weight of plant (0.635), total tuber yield per plot (0.613), number of tubers per plant (0.596) and dry weight of tuber per plant (0.495). But it was non-significantly associated with starch (0.130) and dry matter (-0.090).

Number of stems at 60 DAP exhibited positive and significant correlated with fresh weight of tuber per plant (0.796), marketable yield per plant (0.793), marketable yield per plot (0.781), total tuber yield per plot (0.778), total fresh weight of plant (0.761), total dry weight of plant (0.748), number of tubers per plant (0.718) and dry weight of tuber per plant (0.586). But it was non-significantly associated with starch (0.064) and dry matter (-0.137).

Total fresh weight of plant had positive and significant correlation with total dry weight of plant (0.999), dry weight of tuber per plant (0.997), number of tubers per plant (0.929), total tuber yield per plot (0.919), fresh weight of tuber per plant (0.914), marketable yield per plot (0.869), marketable yield per plant (0.858) and dry matter (0.702). But it was non-significantly associated with starch (-0.121).

The character total dry weight of plant exhibited positive and significant correlation with dry weight of tuber per plant (0.993), total tuber yield per plot (0.927), number of tubers per plant (0.925), fresh weight of tuber per plant (0.920), marketable yield per plot (0.872), marketable yield per plant (0.859) and dry matter (0.628). But it was non-significantly associated with starch (-0.136).

Dry matter was positively and significantly correlated with dry weight of tuber per plant (0.496) and starch (0.291). But it was non-significantly associated with number of tubers per plant (0.236), fresh weight of tuber per plant (0.196), total tuber yield per plot (0.194), marketable yield per plot (0.170) and marketable yield per plant (0.143).

Starch had positive and significant correlation with dry weight of tuber per plant (0.301). But it was negatively and significantly associated with number of tubers per plant (-0.642), fresh weight of tuber per plant (-0.451), total tuber yield per plot (-0.426), marketable yield per plot (-0.369) and marketable yield per plant (-0.355).

Number of tubers per plant was positively and significantly correlated with fresh weight of tuber per plant (0.981), total tuber yield per plot (0.947), marketable yield per plot (0.946), marketable yield per plant (0.941) and dry weight of tuber per plant (0.928).

Fresh weight of tuber per plant was exhibited positive and significant correlation with marketable yield per plot (0.998), total tuber yield per plot (0.998), marketable yield per plant (0.995) and dry weight of tuber per plant (0.951). Dry weight of tuber per plant was positively and significantly correlated with total tuber yield per plot (0.944), marketable yield per plot (0.935) and marketable yield per plant (0.924).

The character marketable yield per plant had positive and significant correlation with marketable yield per plot (0.991) and total tuber yield per plot (0.991). Marketable yield per plot was positively and significantly correlated with total tuber yield per plot (0.993).

4.3.2 Phenotypic correlations

Phenotypic correlation coefficients among growth, yield and quality attributes are studied (Table 12).

At genotypic level, plant height at 60 DAP was positively and significantly correlated with total fresh weight of plant (0.479), total dry weight of plant (0.441), marketable yield per plant (0.439), marketable yield per plot (0.429), total tuber yield per plot (0.372), fresh weight of tuber per plant (0.364), number of leaves at 60 DAP (0.336) and number of stems at 60 DAP (0.311). But it was non-significantly associated with dry weight of tuber per plant (0.279), number of tubers per plant (0.223), leaf area at 60 DAP (0.221), dry matter (0.043) and starch (-0.025).

Number of leaves at 60 DAP was positively and significantly correlated with leaf area at 60 DAP (0.717), marketable yield per plant (0.586), marketable yield per plot (0.576), number of stems at 60 DAP (0.569), fresh weight of tuber per plant (0.552), total tuber yield per plot (0.490), number of tubers per plant (0.414), total fresh weight of plant (0.358), dry weight of tuber per plant (0.318) and total dry weight of plant (0.299). But it was non-significantly associated with starch (-0.150) and dry matter (-0.049).

The character leaf area at 60 DAP had positive and significant correlation with marketable yield per plant (0.610), marketable yield per plot (0.599), fresh weight of tuber per plant (0.534), total tuber yield per plot (0.485), number of stems at 60 DAP (0.439), total fresh weight of plant (0.388), total dry weight of plant (0.358), number

Table 12. Estimates of phenotypic correlation coefficients for yield and its component characters in potato genotypes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	0.336*	0.221	0.311*	0.479**	0.441**	0.043	-0.025	0.223	0.364*	0.279	0.439**	0.429**	0.372**
2		1.000	0.717**	0.569**	0.358*	0.299*	-0.049	-0.150	0.414**	0.552**	0.318*	0.586**	0.576**	0.490**
3			1.000	0.439**	0.388**	0.358*	-0.099	0.114	0.353*	0.534**	0.287*	0.610**	0.599**	0.485**
4				1.000	0.626**	0.602**	0.170	0.043	0.426**	0.532**	0.459**	0.524**	0.518**	0.529**
5					1.000	0.972**	0.309*	-0.132	0.437**	0.573**	0.565**	0.637**	0.633**	0.586**
6						1.000	0.289*	-0.134	0.433**	0.575**	0.567**	0.645**	0.643**	0.599**
7							1.000	0.286*	0.355*	0.205	0.637**	0.165	0.178	0.238
8								1.000	-0.391**	-0.365*	0.3012*	-0.319*	-0.330*	-0.352*
9									1.000	0.877**	0.858**	0.766**	0.776**	0.859**
10										1.000	0.853**	0.945**	0.951**	0.985**
11											1.000	0.791**	0.804**	0.872**
12												1.000	0.981**	0.951**
13													1.000	0.959**
14														1.000

Critical r value 1% = 0.368   5%= 0.284

* & ** indicates Significant @ 5 % and 1 % level respectively.

1. Plant height (cm) 60 DAP   2. Number of leaves at 60 DAP   3.Leaf area (cm^2) at 60DAP   4.Number of stems at 60 DAP

5.Total fresh weight of plant (g)   6.Total dry weight of plant (g)   7. Dry matter (%)   8. Starch (%)

9. Number of tubers per plant   10. Fresh weight of tuber per plant (g)   11. Dry weight of tuber per plant (g)   12. Marketable yield per plant (g)

13. Marketable yield per plot (kg)   14. Total tuber yield per plot (kg)

of tubers per plant (0.353) and dry weight of tuber per plant (0.287). But it was non-significantly associated with starch (0.114) and dry matter (-0.099).

Number of stems at 60 DAP exhibited positive and significant correlation with total fresh weight of plant (0.626), total dry weight of plant (0.602), fresh weight of tuber per plant (0.532), total tuber yield per plot (0.529), marketable yield per plant (0.524), marketable yield per plot (0.518), dry weight of tuber per plant (0.459) and number of tubers per plant (0.426). But it was non-significantly associated with dry matter (0.170) and starch (0.043).

Total fresh weight of plant had positive and significant correlated with total dry weight of plant (0.972), marketable yield per plant (0.637), marketable yield per plot (0.633), total tuber yield per plot (0.586), fresh weight of tuber per plant (0.573), dry weight of tuber per plant (0.565), number of tubers per plant (0.437) and dry matter (0.309). But it was non-significantly associated with starch (-0.132)

Total dry weight of plant was positively and significantly correlated with marketable yield per plant (0.645), marketable yield per plot (0.643), total tuber yield per plot (0.599), fresh weight of tuber per plant (0.575), dry weight of tuber per plant (0.567), number of tubers per plant (0.433) and dry matter (0.289). But it was non-significantly associated with starch (-0.134).

The character dry matter exhibited positive and significant correlation with dry weight of tuber per plant (0.637), number of tubers per plant (0.355) and starch (0.286). But it was non-significantly associated with total tuber yield per plot (0.238), fresh weight of tuber per plant (0.205), marketable yield per plot (0.178) and marketable yield per plant (0.165).

Starch was positively and significantly correlated with dry weight of tuber per plant (0.301). But it was negatively and significantly associated with number of tubers per plant (-0.391), fresh weight of tuber per plant (-0.365), total tuber yield per plot (-0.352), marketable yield per plot (-0.330) and marketable yield per plant (-0.319).

Number of tubers per plant exhibited positive and significant correlation with fresh weight of tuber per plant (0.877), total tuber yield per plot (0.859), dry weight of tuber per plant (0.858), marketable yield per plot (0.776) and marketable yield per plant (0.766).

Fresh weight of tuber per plant had positive and significant correlation with total tuber yield per plot (0.985), marketable yield per plot (0.951), marketable yield per plant (0.945) and dry weight of tuber per plant (0.853). Dry weight of tuber per plant was positively and significantly correlated with marketable and total tuber yield per plot (0.872), marketable yield per plot (0.804), and yield per plant (0.791).

The character marketable yield per plant was positive and significant correlation with marketable yield per plot (0.981) and total tuber yield per plot (0.951). Marketable yield per plot was positively and significantly correlated with total tuber yield per plot (0.959).

4.4 Path coefficient analysis

The correlation would only indicate the relationship of independent variable with the dependent variable without specifying causes and effects relationship. Using path coefficient analysis, it is resolve the correlation which will provide direct and indirect contribution of different quantitative traits.

4.4.1 Genotypic path coefficient analysis

The path coefficient analysis for total tuber yield per plot was performed with a set of thirteen independent characters, *viz.*, plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, starch, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant, marketable yield per plot (Table 13).

4.4.1.1 Direct effect of yield contributing characters on total tuber yield

The direct effects *via* marketable yield per plant (1.6491), total fresh weight of plant (1.3171), fresh weight of tuber per plant (0.5117), number of tubers per plant (0.5002), starch (0.3193) and dry weight of tuber per plant (0.1229) contributed positively. While, total dry weight of plant (-1.2894), marketable yield per plot (-1.1792), leaf area (-0.3064), plant height (-0.1464), dry matter (-0.1360), number of stems per plant (-0.1126) and number of leaves (-0.0839) was negatively contributed towards total tuber yield per plot.

4.4.1.2 Indirect effect of yield contributing characters on total tuber yield

4.4.1.2.1 Plant height at 60 DAP

It was observed that the indirect effect of plant height *via* dry weight of tuber per plant (-0.0940), marketable yield per plant (-0.0892), marketable yield per plot (-0.0884), total fresh weight of plant (-0.0864), fresh weight of tuber per plant (-0.0836), total dry weight of plant (-0.0808), number of stems (-0.0765), number of tubers per plant (-0.0697), number of leaves (-0.0649), leaf area (-0.0413), dry matter (-0.0468) and starch (-0.0012) contributed negatively.

4.4.1.2.3 Number of leaves at 60 DAP

The results of path coefficient revealed that, the starch (0.0165) had positive effect. Whereas, it’s indirect contribution towards yield *via* number of stems (-0.0958), marketable yield per plant (-0.0684), marketable yield per plot (-0.0671),

Table 13. Genotypic path coefficient showing direct and indirect effects of different characters on tuber yield in potato

	1	2	3	4	5	6	7	8	9	10	11	12	13	rG
1	**-0.1464**	-0.0649	-0.0413	-0.0765	-0.0864	-0.0808	-0.0468	-0.0012	-0.0697	-0.0836	-0.0940	-0.0892	-0.0884	0.597**
2	-0.0372	**-0.0839**	-0.0585	-0.0958	-0.0595	-0.0583	-0.0002	0.0165	-0.0653	-0.0657	-0.0575	-0.0684	-0.0671	0.758**
3	-0.0863	-0.2135	**-0.3064**	-0.2402	-0.1947	-0.1961	0.0277	-0.0399	-0.1826	-0.1983	-0.1519	-0.2184	-0.2140	0.613**
4	-0.0589	-0.1285	-0.0883	**-0.1126**	-0.0857	-0.0843	0.0155	-0.0072	-0.0809	-0.0898	-0.0660	-0.0894	-0.0880	0.778**
5	0.7772	0.9337	0.8368	1.0026	**1.3171**	1.3167	0.9258	-0.1600	1.2236	1.2044	1.3872	1.1309	1.1458	0.919**
6	-0.7111	-0.8957	-0.8251	-0.9653	-1.2889	**-1.2894**	-0.8108	0.1764	-1.1933	-1.1870	-1.3252	-1.1087	-1.1253	0.927**
7	-0.0434	-0.0003	0.0123	0.0187	-0.0956	-0.0855	**-0.1360**	0.0410	-0.0321	-0.0267	-0.0676	-0.0195	-0.0231	0.194
8	0.0026	-0.0628	0.0416	0.0204	-0.0388	-0.0437	0.0962	**0.3193**	-0.2052	-0.1442	-0.1763	-0.1135	-0.1179	-0.426**
9	0.2381	0.3892	0.2981	0.3594	0.4647	0.4629	0.1181	-0.3214	**0.5002**	0.4909	0.4644	0.4711	0.4735	0.947**
10	0.2922	0.4003	0.3312	0.4078	0.4679	0.4711	0.1005	-0.2311	0.5022	**0.5117**	0.4870	0.5133	0.5132	0.998**
11	0.0789	0.0842	0.0609	0.0720	0.1294	0.1263	0.0610	-0.0678	0.1141	0.1170	**0.1229**	0.1136	0.1150	0.944**
12	1.0043	1.3438	1.1756	1.3088	1.4160	1.4181	0.2362	-0.5861	1.5533	1.6543	1.5250	**1.6491**	1.6490	0.991**
13	-0.7123	-0.9432	-0.8235	-0.9210	-1.0258	-1.0292	-0.2005	0.4354	-1.1163	-1.1828	-1.1036	-1.1792	**-1.1792**	**0.993****

Residual effect = 0.0907 Diagonal value indicates direct effect; Above and below the diagonal value indicates indirect effect.

* & ** Significant at 5% and 1% respectively. rG- Genotypic correlation with total tuber yield per plot (kg)

1. Plant height (cm) 60 DAP 2. Number of leaves at 60 DAP 3.Leaf area (cm^2) at 60 DAP 4.Number of stems at 60 DAP

5. Total fresh weight of plant (g) 6.Total dry weight of plant (g) 7. Dry matter (%) 8. Starch (%) 9. Number of tubers per plant

10. Fresh weight of tuber per plant (g) 11. Dry weight of tuber per plant (g) 12. Marketable yield per plant (g) 13. Marketable yield per plot (kg)

fresh weight of tuber per plant (-0.0657), number of tubers per plant (-0.0653), total fresh weight of plant (-0.0595), leaf area (-0.0585), total dry weight of plant (-0.0583), dry weight of tuber per plant (-0.0575), plant height (-0.0372) and dry matter (-0.0002) was negative.

4.4.1.2.3 Leaf area at 60 DAP

The results of path coefficient revealed that, the dry matter (0.0277) had positive effect. Whereas, it's indirect contribution towards yield *via* number of stems (-0.2402), marketable yield per plant (-0.2184), marketable yield per plot (-0.2140), number of leaves (-0.2135), fresh weight of tuber per plant (-0.1983), total dry weight of plant (-0.1961), total fresh weight of plant (-0.1947), number of tubers per plant (-0.1826), dry weight of tuber per plant (-0.1519), plant height (-0.0863) and starch (-0.0399) was negative.

4.4.1.2.4 Number of stems at 60 DAP

The indirect contribution of number of stems per plant to total tuber yield per plot was positive through dry matter (0.0155). Whereas, it's negative contribution towards yield *via* number of leaves (-0.1285), fresh weight of tuber per plant (-0.0898), marketable yield per plant (-0.0894), leaf area (-0.0883), marketable yield per plot (-0.0880), total fresh weight of plant (-0.0857), total dry weight of plant (-0.0843), number of tubers per plant (-0.0809), dry weight of tuber per plant (-0.0660), plant height (-0.0589) and starch (-0.0072).

4.4.1.2.5 Total fresh weight of plant

The results revealed that the starch (-0.1600) had negative effect. Whereas, it's indirect contribution towards yield *via* dry weight of tuber per plant (1.3872), total dry weight of plant (1.3167), number of tubers per plant (1.2236), fresh weight of tuber per plant (1.2044), marketable yield per plot (1.1458), marketable yield per plant (1.1309), number of stems (1.0026), number of leaves (0.9337), dry matter (0.9258), leaf area (0.8368) and plant height (0.7772) was positive.

4.4.1.2.6 Total dry weight of plant

The results revealed that starch (0.1764) had positive effect. Whereas it's indirect contribution towards yield *via* dry weight of tuber per plant (-1.3252), total fresh weight of plant (-1.2889), number of tubers per plant (-1.1933), fresh weight of tuber per plant (-1.1870), marketable yield per plot (-1.1253), marketable yield per plant (-1.1087), number of stems (-0.9653), number of leaves (-0.8957), leaf area (-0.8251), dry matter (-0.8108) and plant height (-0.7111) was negative.

4.4.1.2.7 Dry matter

The indirect contribution of dry matter to total tuber yield per plot was positive through starch (0.0410), number of stems (0.0187) and leaf area (0.0123). Whereas it exerted negative contribution indirectly through total fresh weight of plant (-0.0956), total dry weight of plant (-0.0855), dry weight of tuber per plant (-0.0676), plant height (-0.0434), number of tubers per plant (-0.0321), fresh weight of tuber per plant (-0.0267), marketable yield per plot (-0.0231), marketable yield per plant (-0.0195) and number of leaves (-0.0003).

4.4.1.2.8 Starch

The results showed the indirect effect of starch through dry matter (0.0962), leaf area (0.0416), number of stems (0.0204) and plant height (0.0026) was positive. Whereas it exerted negative contribution indirectly through number of tubers per plant (-0.2052), dry weight of tuber per plant (-0.1763), fresh weight of tuber per plant (-0.1442), marketable yield per plot (-0.1179).marketable yield per plant (-0.1135), number of leaves (-0.0628), total dry weight of plant (-0.0437) and total fresh weight of plant (-0.0388).

4.4.1.2.9 Number of tubers per plant

The indirect contribution of number of tubers per plant to total tuber yield per plot was positive through *via* fresh weight of tuber per plant (0.4909), marketable yield per plot (0.4735), marketable yield per plant (0.4711), total fresh weight of plant (0.4647), dry weight of tuber per plant (0.4644), total dry weight of plant (0.4629), number of leaves (0.3892), number of stems (0.3594), leaf area (0.2981), plant height (0.2381) and dry matter (0.1181). While it exerted negative effect through starch (-0.3214).

4.4.1.2.10 Fresh weight of tuber per plant

The results showed the indirect effect of fresh weight of tuber per plant to total tuber yield per plot was positive through marketable yield per plant (0.5133), marketable yield per plot (0.5132), number of tubers per plant (0.5022), dry weight of tuber per plant (0.4870), total dry weight of plant (0.4711), total fresh weight of plant (0.4679), number of stems (0.4078), number of leaves (0.4003), leaf area (0.3312), plant height (0.2922) and dry matter (0.1005). But it is negatively contributed through starch (-0.2311).

4.4.1.2.11 Dry weight of tuber per plant

The indirect contribution of dry weight of tuber per plant to total tuber yield per plot was positive through total fresh weight of plant (0.1294), total dry weight of plant (0.1263), fresh weight of tuber per plant (0.1170), marketable yield per plot (0.1150), number of tubers per plant (0.1141), marketable yield per plant (0.1136), number of leaves (0.0842), plant height (0.0789), number of stems (0.0720), dry matter (0.0610) and leaf area (0.0609). But it is negatively contributed through starch (-0.0678).

4.4.1.2.12 Marketable yield per plant

The results revealed that marketable tuber yield per plant had positive indirect effect through fresh weight of tuber per plant (1.6543), marketable yield per plot (1.6490), number of tubers per plant (1.5533), dry weight of tuber per plant (1.5250), total dry weight of plant (1.4181), total fresh weight of plant (1.4160), number of leaves (1.3438), number of stems (1.3088), leaf area (1.1756), plant height (1.0043) and dry matter (0.2362). But it is negatively contributed through starch (-0.5861).

4.4.1.2.13 Marketable yield per plot

The results of path coefficient revealed that, the starch (0.4354) had positive effect. Whereas it's indirect contribution towards yield *via* fresh weight of tuber per plant (-1.1828), marketable yield per plant (-1.1792), number of tubers per plant (-1.1163), dry weight of tuber per plant (-1.1036), total dry weight of plant (-1.0292), total fresh weight of plant (-1.0258), number of leaves (-0.9432), number of stems (-0.9210), leaf area (-0.8235), plant height (-0.7123) and dry matter (-0.2005) was negative.

4.4.2 Phenotypic path coefficient analysis

All thirteen growth, yield and quality traits were subjected to phenotypic path coefficient analysis by considering total tuber yield per plot as dependent variable and others as independent variables, *viz.*, plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, starch, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant, marketable yield per plot (Table 14).

4.4.1.1 Direct effect of yield contributing characters on total tuber yield

The direct effects *via* marketable yield per plot (1.1080), fresh weight of tuber per plant (0.6029) and dry weight of tuber per plant (0.1141), number of stems (0.0528), starch (0.0234), total dry weight of plant (0.0156) and plant height (0.0048) contributed positively. While, marketable yield per plant (-0.7393), number of leaves (-0.0622), leaf area (-0.0544), total fresh weight of plant (-0.0450), dry matter (-0.0376) and number of tubers per plant (-0.0040) was negatively contributed towards total tuber yield per plot.

4.4.1.2 Indirect effect of yield contributing characters on total tuber yield

4.4.1.2.1 Plant height at 60 DAP

It was observed that the indirect effect of plant height *via* total fresh weight of plant (0.0023), total dry weight of plant (0.0021), marketable yield per plant (0.0021), marketable yield per plot (0.0021), fresh weight of tuber per plant (0.0017), number of leaves (0.0016), number of stems (0.0015), dry weight of tuber per plant (0.0013),

Table 14. Phenotypic path coefficient showing direct and indirect effects of different characters on tuber yield in potato

	1	2	3	4	5	6	7	8	9	10	11	12	13	rP
1	**0.0048**	0.0016	0.0011	0.0015	0.0023	0.0021	0.0002	-0.0001	0.0011	0.0017	0.0013	0.0021	0.0021	0.372**
2	-0.0209	**-0.0622**	-0.0446	-0.0354	-0.0223	-0.0186	0.0031	0.0094	-0.0258	-0.0344	-0.0198	-0.0365	-0.0359	0.490**
3	-0.0121	-0.0390	**-0.0544**	-0.0239	-0.0211	-0.0195	0.0054	-0.0062	-0.0192	-0.0290	-0.0156	-0.0332	-0.0326	0.485**
4	0.0164	0.0301	0.0232	**0.0528**	0.0330	0.0318	0.0090	0.0023	0.0225	0.0281	0.0242	0.0277	0.0274	0.529**
5	-0.0216	-0.0162	-0.0175	-0.0282	**-0.0450**	-0.0438	-0.0139	0.0060	-0.0197	-0.0258	-0.0255	-0.0287	-0.0285	0.586**
6	0.0069	0.0047	0.0056	0.0094	0.0152	**0.0156**	0.0045	-0.0021	0.0068	0.0090	0.0088	0.0101	0.0100	0.599**
7	-0.0016	0.0018	0.0038	-0.0064	-0.0116	-0.0109	**-0.0376**	0.0048	-0.0134	-0.0077	-0.0240	-0.0062	-0.0067	0.238
8	-0.0006	-0.0035	0.0027	0.0010	-0.0031	-0.0031	0.0030	**0.0234**	-0.0091	-0.0086	-0.0084	-0.0075	-0.0077	-0.352*
9	-0.0009	-0.0016	-0.0014	-0.0017	-0.0017	-0.0017	-0.0014	0.0016	**-0.0040**	-0.0035	-0.0034	-0.0030	-0.0031	0.859**
10	0.2196	0.3333	0.3220	0.3211	0.3456	0.3470	0.1239	-0.2206	0.5287	**0.6029**	0.5147	0.5697	0.5737	0.985**
11	0.0319	0.0364	0.0328	0.0524	0.0645	0.0647	0.0727	-0.0412	0.0979	0.0974	**0.1141**	0.0903	0.0917	0.872**
12	-0.3250	-0.4339	-0.4510	-0.3875	-0.4710	-0.4775	-0.1224	0.2360	-0.5667	-0.6987	-0.5852	**-0.7393**	-0.7384	0.951**
13	0.4759	0.6386	0.6638	0.5742	0.7017	0.7133	0.1975	-0.3659	0.8602	1.0543	0.8908	1.1066	**1.1080**	**0.959****

Residual effect = 0.1067 Diagonal value indicates direct effect; Above and below the diagonal value indicates indirect effect.

* & ** Significant at 5% and 1% respectively. rG- Genotypic correlation with total tuber yield per plot (kg)

1. Plant height (cm) 60 DAP 2. Number of leaves at 60 DAP 3.Leaf area (cm^2) at 60DAP 4.Number of stems at 60 DAP

5. Total fresh weight of plant (g) 6.Total dry weight of plant (g) 7. Dry matter (%) 8. Starch (%) 9. Number of tubers per plant

10. Fresh weight of tuber per plant (g) 11. Dry weight of tuber per plant (g) 12. Marketable yield per plant (g) 13. Marketable yield per plot (kg)

leaf area (0.0011), number of tubers per plant (0.0011) and dry matter (0.0002) contributed positively. While it exerted negative effect through starch (-0.0001).

4.4.1.2.2 Number of leaves at 60 DAP

The results of path coefficient revealed that, the starch (0.0094) and dry matter (0.0031) had positive effect. Whereas it's indirect contribution towards yield *via* leaf area (-0.0446), marketable yield per plant (-0.0365), marketable yield per plot (-0.0359), number of stems (-0.0354), fresh weight of tuber per plant (-0.0344), number of tubers per plant (-0.0258), total fresh weight of plant (-0.0223), plant height (-0.0209), dry weight of tuber per plant (-0.0198) and total dry weight of plant (-0.0186) was negative.

4.4.1.2.3 Leaf area at 60 DAP

The results of path coefficient revealed that, the dry matter (0.0054) had positive effect. Whereas it's indirect contribution towards yield *via* number of leaves (-0.0390), marketable yield per plant (-0.0332), marketable yield per plot (-0.0326), fresh weight of tuber per plant (-0.0290), number of stems (-0.0239), total fresh weight of plant (-0.0211), total dry weight of plant (-0.0195), number of tubers per plant (-0.0192), dry weight of tuber per plant (-0.0156), plant height (-0.0121) and starch (-0.0062) was negative.

4.4.1.2.4 Number of stems at 60 DAP

The indirect contribution of number of stems per plant to total tuber yield per plot was positive through *via* total fresh weight of plant (0.0330), total dry weight of plant (0.0318), number of leaves (0.0301), fresh weight of tuber per plant (0.0281), marketable yield per plant (0.0277), marketable yield per plot (0.0274), dry weight of tuber per plant (0.0242), leaf area (0.0232), number of tubers per plant (0.0225), plant height (0.0164), starch (0.0090) and dry matter (0.0023).

4.4.1.2.5 Total fresh weight of plant

The results revealed that the starch (0.0060) had positive effect. Whereas it's indirect contribution towards yield *via* total dry weight of plant (-0.0438), marketable yield per plant (-0.0287), marketable yield per plot (-0.0285), number of stems (-0.0282), fresh weight of tuber per plant (-0.0258), dry weight of tuber per plant (-0.0255), plant height (-0.0216), number of tubers per plant (-0.0197), leaf area (-0.0175), number of leaves (-0.0162) and dry matter (-0.0139) was negative.

4.4.1.2.6 Total dry weight of plant

The results revealed that starch (-0.0021) had negative effect. Whereas it's indirect contribution towards yield *via* total fresh weight of plant (0.0152), marketable yield per plant (0.0101), marketable yield per plot (0.0100), number of stems (0.0094), fresh weight of tuber per plant (0.0090), dry weight of tuber per plant (0.0088), plant height (0.0069), number of tubers per plant (0.0068), leaf area (0.0056), number of leaves (0.0047) and dry matter (0.0045) was positive.

4.4.1.2.7 Dry matter

The indirect contribution of dry matter to total tuber yield per plot was positive through starch (0.0048), leaf area (0.0038) and number of leaves (0.0018). Whereas its exerted negative contribution indirectly through dry weight of tuber per plant (-0.0240), number of tubers per plant (-0.0134), total fresh weight of plant (-0.0116), total dry weight of plant (-0.0109), fresh weight of tuber per plant (-0.0077), marketable yield per plot (-0.0067), number of stems (-0.0064), marketable yield per plant (-0.0062) and plant height (-0.0016).

4.4.1.2.8 Starch

The results showed the indirect effect of starch through dry matter (0.0030), leaf area (0.0027) and number of stems0 (0.0010) was positive. Whereas it exerted negative contribution indirectly through number of tubers per plant (-0.0091), fresh weight of tuber per plant (-0.0086), dry weight of tuber per plant (-0.0084), marketable yield per plot (-0.0077), marketable yield per plant (-0.0075), number of leaves (-0.0035), total fresh weight of plant (-0.0031), total dry weight of plant (-0.0031) and plant height (-0.0006).

4.4.1.2.9 Number of tubers per plant

The indirect contribution of number of tubers per plant to total tuber yield per plot was negative through *via* fresh weight of tuber per plant (-0.0035), dry weight of tuber per plant (-0.0034), marketable yield per plot (-0.0031), marketable yield per plant (-0.0030), number of stems (-0.0017), total fresh weight of plant (-0.0017), total dry weight of plant (-0.0017), number of leaves (-0.0016), leaf area (0.0014), dry matter (-0.0014) and plant height (-0.0009). While it exerted positive effect through starch (0.0016).

4.4.1.2.10 Fresh weight of tuber per plant

The results showed the indirect effect of fresh weight of tuber per plant to total tuber yield per plot was positive through marketable yield per plot (0.5737), marketable yield per plant (0.5697), number of tubers per plant (0.5287), dry weight of tuber per plant (0.5147), total dry weight of plant (0.3470), total fresh weight of plant (0.3456), number of leaves (0.3333), leaf area (0.3220), number of stems (0.3211), plant height (0.2196) and dry matter (0.1239). But it is negatively contributed through starch (-0.2206).

4.4.1.2.11 Dry weight of tuber per plant

The indirect contribution of dry weight of tuber per plant to total tuber yield per plot was positive through number of tubers per plant (0.0979), fresh weight of tuber per plant (0.0974), marketable yield per plot (0.0917), marketable yield per plant (0.0903), dry matter (0.0727), total dry weight of plant (0.0647), total fresh weight of plant (0.0645), number of stems (0.0524), number of leaves (0.0364), leaf area (0.0328) and plant height (0.0319). But it is negatively contributed through starch (-0.0412).

4.4.1.2.12 Marketable yield per plant

The results revealed that marketable tuber yield per plant had negative indirect effect through marketable yield per plot (-0.7384), fresh weight of tuber per plant (-0.6987) dry weight of tuber per plant (-0.5852),), number of tubers per plant (-0.5667), total dry weight of plant (-0.4775), total fresh weight of plant (-0.4710), leaf area (-0.4510), number of leaves (-0.4339), number of stems (-0.3875), plant height (-0.3250) and dry matter (-0.1224). But it is positively contributed through starch (0.2360).

4.4.1.2.13 Marketable yield per plot

The results of path coefficient revealed that, the starch (-0.3659) had negative effect. Whereas it's indirect contribution towards yield *via* marketable yield per plant (1.1066), fresh weight of tuber per plant (1.0543), dry weight of tuber per plant (0.8908), number of tubers per plant (0.8602), total dry weight of plant (0.7133), total fresh weight of plant (0.7017), leaf area (0.6638), number of leaves (0.6386), number of stems (0.5742), plant height (0.4759) and dry matter (0.1975) was positive.

DISCUSSION

V DISCUSSION

The success of crop improvement programme depends on the extent of genetic variability exists in the population or germplasm. The magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or hybridization followed by selection. This necessitated the present investigation for various attributes under hill zone of Karnataka and the results of the experiments are discussed in this chapter.

Potato (*Solanum tuberosum* L.) is an important tuber crop grown for its tubers. It is one of the most popular and cosmopolitan vegetable crops grown in many parts of India, including higher hills and temperate conditions of North India. In the Southern Karnataka, mainly in Hassan district potato is grown for tubers. The objective of evaluation of cultivars is to select high yielding cultivars with better crop growth, yield and quality. Selection of cultivars for a particular region is more important to investigate considerable variability in various characters when grown under a particular environment. The present investigation was undertaken at the experimental unit of Department of Vegetable Science, College of Horticulture, Mudigere with sixteen potato genotypes to assess for their growth, yield and quality parameters.

The maximum per cent emergence at 30 DAP was noticed in C-28 followed by TT7010 and Kufri Surya and minimum was noticed in the genotype FL-1533. The variation in per cent emergence of the potato genotypes tested may be attributed to their inherent genetic makeup and response to environmental condition. These results are in accordance with the results of Santhosh (2004), Hari (2007) and Santhosh (2010).

Leaf area index maximum in genotype Kufri Jyoti followed by C-28 and TT 7008. The minimum leaf area index recorded in TT 7005 and TT 7015. The increase in leaf area index may be due to rapid increase in length and breadth of leaves result in larger leaf surface. This increase in leaf area and more number of leaves per plant will naturally result in increase of leaf area index. These results are in line with the studies made by Al-Mahmud *et al.*2014.

The genotypes showing maximum absolute growth rate C-28 followed by Kufri Jyoti and TT 7011. The minimum absolute growth rate recorded in FL-1533 and TT 7015. The maximum crop growth rate in genotype C-28 followed by Kufri Jyoti. The minimum crop growth rate recorded in FL-1533 and TT 7015. The net assimilation rate maximum in genotype Kufri Jyoti followed by C-28 and minimum net assimilation rate recorded in TT 7005 and TT 7015. This might be due to increase in the number of leaves, plant biomass and leaf surface area which in turn increased dry matter and leaf area of the plant which are used to estimate AGR, CGR and NAR of the plant (Fig.). The results are in conformity with the results of Tekalign and Hammes, (2005) and Al-Mahmud *et al.*2014.

5.1 Genetic variability for growth, yield and quality parameters

Totally 16 genotypes were evaluated to know the amount of variability for growth, yield and quality parameters (Plate 2 and 3). The analysis of variance indicated highly significant differences among genotypes for all the studied characters *viz.*, emergence percentage, plant height, number of leaves, plant spread from North to South and East to West, leaf area, number of stems per plant, fresh weight of leaves, dry weight of leaves, fresh weight of stem, dry weight of stem, fresh weight of root, dry weight of root, total fresh weight of plant, total dry weight of plant, fresh weight of tuber, dry weight of tuber, leaf area index, absolute growth rate, crop growth rate, net assimilation rate, number of tubers per plant, number of tubers per plot, tuber length, tuber circumference, tuber volume, tuber weight, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot, marketable yield per hectare, tuber dry matter content, total soluble solids, number of eyes per tuber, total chlorophyll content, reducing sugars, non-reducing sugars, total sugars and starch. This indicates that, high variability existed for the characters studied and considerable improvement could be achieved in most of the characters by selection. However, the analysis of variance by itself is not enough and conclusive to explain all the inherent genotypic variance in the genotypes.

One of the ways by which the variability present in these characters was assessed through a simple approach of examining the range of variation. Range of variation observed for all the traits in the present study indicated that the presence of sufficient amount of variation among the genotypes for all the characters studied.

The range in the values reflects the amount of phenotypic variability, which is not reliable, since it includes genotypic, environmental and genotype × environment interaction components and does not reveal as to which character is showing higher degree of variability. Further, the phenotype of crop is influenced by additive gene effect (heritable), dominance (non-heritable) and epistasis (non-allelic interaction). Hence, it becomes necessary to split the observed variability into phenotypic coefficient of variation and genotypic coefficient of variation, which ultimately indicate the extent of variability existing for various traits. However, even this does not give a true picture about the extent of inheritance of the character. Therefore, the heritability of a character can be relied upon, as it enables the plant breeder to decide the extent of selection pressure to be applied under a particular environment, which separates out the environmental influence from the total variability. Never the less, its use would be limited as this is prone to change with the environment, material, *etc.* The estimation of heritability has a greater role to play in determining the effectiveness of selection of a character provided it is considered in conjunction with the predicted genetic advance as suggested by Johnson *et al.* (1955). Heritability is influenced by biometrical method, generation of hybrid, sample size of experimental material and environment. With

Plate 2. Potato genotypes used for the experiment

Plate 2. Potato genotypes used for the experiment

Plate 3. Variability for tuber characters in potato

these, the results of the present investigation on various parameters are discussed in this chapter.

The phenotypic and genotypic coefficient of variance was calculated for all the characters (Table 4a, 4b, 6 and 8). The results obtained showed that phenotypic coefficient of variance was in general higher than the genotypic coefficient of variance for all the characters. It is due to presence of substantial influence of environmental factors besides the genetic variation for expression of these traits.

High magnitude of GCV and PCV (>20 per cent) were observed for fresh weight of tuber, dry weight of tuber, tuber volume, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot and marketable yield per hectare. This reveals that influence of the environment for these characters is negligible and the role of the genotypic performance for the full expression of the phenotype.

Whereas, the moderate magnitude of GCV and PCV (10-20 per cent) were observed for plant height at 45 DAP, leaf area at 60 DAP, leaf area at 90 DAP, number of stem per plant at 60 DAP, number of tubers per plant, number of tubers per plot, tuber length, tuber dry matter content, number of eyes per tuber and non-reducing sugars.

The low magnitude GCV and PCV (<10 per cent) was also observed for the character plant height at 60 DAP, number of leaves at 60 DAP, number of leaves at 90 DAP, plant spread from North to South at 60 DAP, plant spread from East to West at 60 DAP, fresh weight of leaves at 60 DAP, fresh weight of leaves at 90 DAP, dry weight of leaves at 60 DAP, dry weight of leaves at 90 DAP, fresh weight of stem at 60 DAP, fresh weight of stem at 90 DAP, dry weight of stem at 60 DAP, dry weight of stem at 90 DAP, fresh weight of root at 60 DAP, fresh weight of root at 90 DAP, dry weight of root at 60 DAP, dry weight of root at 90 DAP, total fresh weight of plant at 60 DAP, total fresh weight of plant at 90 DAP, total dry weight of plant at 60 DAP, total dry weight of plant at 90 DAP, tuber circumference, tuber weight, TSS, total chlorophyll content, reducing sugars, total sugars and total starch in present study.

The above findings indicate that the character with moderate and high magnitude of GCV and PCV indicates the existence of some variability in the population for these characters. Therefore, selection for above traits can also be beneficial for improvement.

These findings are in accordance with the findings by Singh *et al.* (2015) for growth parameters. Verma and Singh (2015) noticed for plant height and quality parameters. Tripura *et al.* (2016) recorded in tuber breadth and tuber number. Asefa *et al.* (2016) recorded in total tuber yield, marketable tuber yield, tuber weight. Fekadu *et al.* (2006) reported plant height, tuber diameter and biological yield. Haydar *et al.*

(2009) recorded in number of branches and tubers number. Kumar *et al.* (2005) reported plant height and quality parameters. Mondal *et al.* (2009) recorded in tubers dry matter and starch. Ozturk and Yildirim (2014) recorded in total sugars and starch. Bisognin *et al*. (2012) noticed tuber size and fresh weight.

5.1.2. Heritability

The ratio of the genotypic variance to the phenotypic variance or total variance is known as heritability. It is a good indicator for inheritance of character from parents to their offspring. The estimate of heritability helps the breeder in selecting the elite genotypes from diverse genetic populations. Thus, estimate of heritability in broad sense calculated for all the characters are presented in (Table 4a, 4b, 6 and 8).

In the present study, heritability estimate in broad sense was calculated for tuber yield and its components. The obtained value of heritability for each character was grouped into high (> 60 per cent), moderate (30 to 60 per cent) and low (< 30 per cent) as per the classification suggested by Robinson (1966).

Estimate of heritability was recorded high for the characters *viz.*, plant height at 60 DAP, leaf area at 60 DAP, leaf area at 90 DAP, total fresh weight of plant at 60 DAP, total fresh weight of plant at 90 DAP, total dry weight of plant at 60 DAP, total dry weight of plant at 90 DAP, fresh weight of tuber, tuber volume, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot, marketable yield per hectare, total chlorophyll content, non-reducing sugars, total sugars and total starch.

Moderate heritability were observed for plant height at 45 DAP, number of leaves at 60 DAP, number of leaves at 90 DAP, plant spread from North to South at 60 DAP, plant spread from East to West at 60 DAP, number of stems per plant at 60 DAP, fresh weight of leaves at 60 DAP, fresh weight of leaves at 90 DAP, dry weight of leaves at 60 DAP, dry weight of leaves at 90 DAP, fresh weight of stem at 60 DAP, fresh weight of stem at 90 DAP, dry weight of stem at 60 DAP, dry weight of stem at 90 DAP, dry weight of tuber, number of tubers per plant, number of tubers per plot, tuber length , tuber circumference, tuber weight, tuber dry matter content, TSS, number of eyes per tuber and reducing sugars.

The low magnitude heritability was also observed for the characters fresh weight of root at 60 DAP, fresh weight of root at 90 DAP, dry weight of root at 60 DAP and dry weight of root at 90 DAP in present study.

High and moderate heritability recorded for indicated that above characters are less influenced by environmental fluctuations and governed by the additive gene effects that are substantially contributing towards the expression of these traits. However, rest of the traits seems to be governed by non additive gene effects. Hence, selection for these traits will lead to accumulation of more desirable genotypes.

The present findings on heritability are in accordance with findings reported by the various workers *viz.* Singh (2008) for number of leaves per plant, plant height, marketable tuber weight per plot, total tuber weight per plot, number of tubers per plant and dry matter content of tubers; Barik (2007) for fresh weight of shoots per plant, harvest index per cent, unmarketable yield per plot, tuber dry matter per plant, per cent emergence, total number of leaves per plant, fresh weight of tuber per plant, total tuber yield per plot, plant height and dry weight of shoots per plant. Similarly, other workers also obtained similar results in terms of heritability for different traits. Chandrakar (2007), Basavaraj *et al.* (2005) and Biswas *et al.* (2005).

5.1.3. Genetic advance

Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance. Genetic advance was worked out as percentage of mean for tuber yield and its components which is presented in (Table 4a, 4b, 6 and 8). Genetic advance is important to find out the genetic gains likely to be achieved in the next generation. These are classified as high (> 20 per cent), medium (10 to 20 per cent) and low (< 10 per cent). The success of genetic advance under selection mainly depends upon genetic variability, heritability and selection intensity.

In the present study highest estimates of genetic advance as percentage of mean were obtained for characters *viz.*, leaf area at 60 DAP, leaf area at 90 DAP, fresh weight of tuber, dry weight of tuber, number of tubers per plot, tuber volume, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot, marketable yield per hectare and non-reducing sugars.

The moderate genetic advance was observed in plant height at 45 DAP, plant height at 60 DAP, number of stem per plant at 60 DAP, fresh weight of leaves at 60 DAP, dry weight of leaves at 60 DAP, fresh weight of stem at 60 DAP, dry weight of stem at 60 DAP, total fresh weight of plant at 60 DAP, total fresh weight of plant at 90 DAP, total dry weight of plant at 60 DAP, total dry weight of plant at 90 DAP, number of tubers per plant, tuber length, tuber weight, tuber dry matter content, number of eyes per tuber, total chlorophyll content, total sugars and total starch.

However, the low genetic advance as per cent of mean was observed for the characters such as number of leaves at 60 DAP, number of leaves at 90 DAP, plant spread from North to South at 60 DAP, plant spread from East to West at 60 DAP, fresh weight of leaves at 90 DAP, dry weight of leaves at 90 DAP, fresh weight of stem at 90 DAP, dry weight of stem at 90 DAP, fresh weight of root at 60 DAP, fresh weight of root at 90 DAP, dry weight of root at 60 DAP, dry weight of root at 90 DAP, tuber circumference, TSS and reducing sugars.

Very often, heritability in broad sense is not the true indicator of inheritance of traits, since only additive component of genetic variance is transferred from generation to generation. Therefore heritability in broad sense may mislead in judging the effectiveness of selection for the trait. Considering heritability in broad sense along with genetic advance over mean may reveal the prevalence of specific components (additive or non-additive) for the trait more accurately.

In the present study, high heritability coupled with high genetic advance as per cent over mean was recorded for the characters *viz.*, leaf area at 60 DAP, leaf area at 90 DAP, fresh weight of tuber, dry weight of tuber, tuber volume, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot, marketable yield per hectare and non-reducing sugars.

Moderate heritability with moderate GAM was observed for plant height at 45 DAP, plant height at 60 DAP, number of stems per plant at 60 DAP, fresh weight of leaves at 60 DAP, dry weight of leaves at 60 DAP, fresh weight of stem at 60 DAP, dry weight of stem at 60 DAP, total fresh weight of plant at 60 DAP, total fresh weight of plant at 90 DAP, total dry weight of plant at 60 DAP, total dry weight of plant at 90 DAP, number of tubers per plant, number of tubers per plot, tuber length, tuber weight, tuber dry matter content, number of eyes per tuber, total chlorophyll content, total sugars and total starch.

The above finding indicates that the characters with high and moderate heritability and genetic advance can be considered for direct selection for improvement. In agreement to the above results, Pradhan *et al.* (2011) recorded the high heritability and genetic advance for number of leaves; Chandrakar (2007), Basavaraj *et al.* (2005), Biswas *et al.* (2005) reported high heritability for various component like tuber length, tuber diameter, total chlorophyll content, reducing sugars and total starch traits in potato. Verma and Singh (2015) noticed for plant height and quality parameters. Tripura *et al.* (2016) recorded in tuber breadth and tuber number. Asefa *et al.* (2016) recorded in total tuber yield, marketable tuber yield, tuber weight. Haydar *et al.* (2009) recorded in number of branches and tubers number. Mondal *et al.* (2009) recorded in tubers dry matter and starch. Ozturk and Yildirim (2014) recorded in total sugars and starch. Bisognin *et al*. (2012) noticed tuber size and fresh weight.

Early blight, late blight and aphids showed non-significant and minimum per cent of incidence in different genotypes (Table 11). Incidence was expected since any resistance or susceptibility of the cultivars to the disease is controlled by the genetic constitution of genotypes and prevailing weather conditions. Similar results were reported by Srivastava *et al.* (2012).

5.2 Character association studies

Variability studies provide information on the extent of improvement possible in different characters, but they do not throw light on the extent and nature of relationship existing between yield and various contributory characters. As a rational approach for the improvement of yield, selection has to be made for components of yield, since there may not be gene for yield mean but for various yield components. Further, many of these yield contributing characters are interacting in desirable and undesirable direction. Hence, a knowledge regarding the association of various characters among themselves and with economic characters is necessary for making indirect selection for improvement of economic characters. Character association or correlation is a measure of the degree of association between two characters.

The phenotypic correlations indicate the extent of the observed relationship between two characters. This does not give true genetic picture of the relationship because it includes hereditary as well as environmental influences. Genotypic correlation provides an estimate of inherent association between genes controlling any two characters. Hence, it is of greater significance and could be effectively utilized in formulating an effective selection scheme. Therefore in the present study, the genotypic and phenotypic correlation coefficients were worked out.

A narrow difference between the genotypic and phenotypic correlation coefficients was observed for various traits in the present finding and this indicates the lesser influence of the environment in the expression of these traits and presence of strong inherent association among the traits.

Correlation revealed the possibility of selecting the plants having characters like more number of stems, more number of tubers per plant and more tuber weight. The higher magnitude of positive and significant association of more number of tubers per plant with yield suggested that the number of tubers per plant was the principal yield attributer and indicated its importance as yield component in influencing the yield of the plant. Therefore, the number of tubers per plant must be given due consideration while making selection.

To estimate the association between two variables, correlation coefficient at phenotypic and genotypic levels, was worked out in all possible combination and presented in Table 11 and 12.

At both genotypic and phenotypic level, plant height at 60 DAP was positively and significantly correlated with marketable yield per plant, marketable yield per plot, total tuber yield per plot, total fresh weight of plant, fresh weight of tuber per plant, total dry weight of plant, number of stems at 60 DAP and number of leaves at 60 DAP. Dry weight of tuber and number of tubers per plant only significantly positive correlated at genotypic level. Similar observations were recorded by Rangare *et al.* (2013), Singh (2008), Chandrakar (2007), Barik (2007), Verma *et al.* (2006), Rasool *et al.* (2007), Yenagi *et al*. (2008), Fekadu *et al.* (2013), Nasiruddin *et al.* (2014) and Tripura *et al.* (2016).

Number of leaves at 60 DAP was positively and significantly correlated with number of stems at 60 DAP, marketable yield per plant, marketable yield per plot, fresh weight of tuber per plant, total tuber yield per plot, total fresh weight of plant, leaf area at 60 DAP, total dry weight of plant and dry weight of tuber per plant at both the levels. Correlation of number of leaves with tuber yield which is supported with the findings of Ara *et al.* (2009), Singh (2008), Chandrakar *et al.* (2007) and Sattar *et al.* (2007), Verma and Singh (2015) and Mishra *et al*. (2017).

The character leaf area at 60 DAP had positive and significant correlation with number of stems at 60 DAP, marketable yield per plant, marketable yield per plot, fresh weight of tuber per plant, total dry weight of plant, total fresh weight of plant, total tuber yield per plot, number of tubers per plant and dry weight of tuber per plant both at genotypic and phenotypic level. Which is supported with the findings of Roy and Singh (2006), Luthra *et al.* (2005), Regassa and Basavaraju (2005), Darabad (2014) and Nasiruddin *et al.* (2014).

Number of stems at 60 DAP had positive and significant correlation with fresh weight of tuber per plant, marketable yield per plant, marketable yield per plot, total tuber yield per plot, total fresh weight of plant, total dry weight of plant, number of tubers per plant and dry weight of tuber per plant both at genotypic and phenotypic level. Similar result for number of shoots per plant was reported by Singh *et al.* (2015), Lamboro *et al.* (2014), Ummyiah *et al*. (2013), Khayatnezhad *et al.* (2011) and Rasool *et al.* (2007), Patel *et al*. (2013), Singh *et al.* (2015), Tripura *et al*. (2016) and Verma and Singh (2016).

At both genotypic and phenotypic level, total fresh weight of plant was positively and significantly correlated with total dry weight of plant, dry weight of tuber per plant, number of tubers per plant, total tuber yield per plot, fresh weight of tuber per plant, marketable yield per plot, marketable yield per plant and dry matter. Total dry weight of plant was positively and significantly correlated with dry weight of tuber per plant, total tuber yield per plot, number of tubers per plant, fresh weight of tuber per plant, marketable yield per plot, marketable yield per plant and dry matter at both the levels.

The above findings suggests that the genotypes having more number of tubers, leaves and shoots per plant and higher fresh weight of shoots per plant is expected to posses high fresh weight of tubers per plant. However, increase in fresh and dry weight of shoots per plant and plant height will adversely affect the total tuber yield. Similar findings of association of fresh weight of tubers per plant with number of tubers was reported by Patel *et al*. (2013), Mondal *et al.* (2009) and Mishra *et al.* (2017).

Total dry matter was positively and significantly correlated with dry weight of tuber per plant and starch. Starch was positively and significantly correlated with dry weight of tuber per plant. But it was negatively and significantly associated with number of tubers per plant, fresh weight of tuber per plant, total tuber yield per plot, marketable yield per plot and marketable yield per plant both at genotypic and phenotypic level. The results were in line with the findings of Rangare *et al.* (2014), Felenji *et al.* (2011), Khayatnezhad *et al.* (2011) and Nasiruddin *et al.* (2014)

Number of tubers per plant exhibited high and positive significant correlation with fresh weight of tuber per plant, total tuber yield per plot, marketable yield per plot, marketable yield per plant and dry weight of tuber per plant. The above findings indicate that higher number of tuber per plant can be obtained by selection of plants showing higher plant canopy cover percentage and more number of leaves and shoots per plant, which will ultimately result in higher tuber yield. Similar finding were reported by Darabad *et al.* (2014), Nasiruddin *et al.*(2014), Santhosh *et al.* (2013), Datta *et al.* (2014), Zakerhamidi and Hassanpanah (2014), Verma and Singh (2015) and Mishra *et al.* (2017).

The character fresh weight of tuber per plant had positive and significant correlation with marketable yield per plot, total tuber yield per plot, marketable yield per plant and dry weight of tuber per plant both at genotypic and phenotypic level indicating that increase in fresh weight of tuber per plant will simultaneously increase the total tuber yield. Similar result showing correlation between tuber yield and fresh weight of tubers was also reported by Singh *et al.* (2015), Darabad *et al.* (2014), Lamboro *et al.* (2014), Ummyiah *et al.* (2013), Ara *et al.* (2009), Khayatnezhad *et al.* (2011), Rangare and Rangare (2013), Santhosh *et al.* (2013), Datta *et al.* (2014), Yerima (2016) and Mishra *et al.* (2017).

At both genotypic and phenotypic level, dry weight of tuber per plant was positively and significantly correlated with total tuber yield per plot, marketable yield per plot and marketable yield per plant. The increase in dry weight of tubers per plant and harvest index per cent will lead to proportionate increase in total tuber yield simultaneously. Above findings indicate that fresh and dry weight of tubers of tubers per plant will increase tuber yield. Similarly, the results showing correlation of tuber yield with fresh and dry weight of tubers per plant percentage is supported by the findings of Nasiruddin *et al.* (2014), Khayatnezhad *et al.* (2011) and Sattar *et al.* (2007), Chandrakar *et al.* (2007), Datta *et al.* (2014), Singh *et al.* (2015), Mishra *et al.* (2017).

Marketable yield per plant had positive and significant correlation with marketable yield per plot and total tuber yield per plot. Marketable yield per plot was positively and significantly correlated with total tuber yield per plot. Similar results were obtained by Rangare *et al.* (2013), Patel *et al.* (2013), Santhosh *et al.* (2013), Hafiz (2015), Singh *et al.* (2015), Verma and Singh (2015), Verma and Singh (2016), Mishra *et al.* (2017).

5.3 Path coefficient analysis

Though correlation analysis indicates the association pattern of component traits with yield, they simply represent the overall influence of a particular trait on yield rather than providing cause and effect relationship. The technique of path coefficient analysis developed by Wright (1921) and demonstrated by Dewey and Lu (1959) facilitates the partitioning of correlation coefficients into direct and indirect contribution of various characters on yield. It is standardized partial regression coefficient analysis. As such, it measures the direct influence of one variable upon other. Such information would be of great value in enabling the breeder to specifically identify the important component traits of yield and utilize the genetic stock for improvement in a planned way.

Path analysis also measures the relative importance of causal factors involved. This is simply a standardized partial regression analysis, where in total correlation values were subdivided into individual causal factors.

In the present study, path coefficient analysis between the components of potato was worked out for total tuber yield per plot both at genotypic and phenotypic level (Table 13 and 14). Genotypic path should be considered with more weightage because it's inherent, whereas phenotypic path will have greater influence of environmental factors.

Present investigation revealed that out of thirteen characters studied, the direct effects *via* fresh weight of tuber per plant, starch and dry weight of tuber per plant positively contributed towards total tuber yield per plot only both at genotypic and phenotypic level. This indicates the true positive association with total yield per plant. Therefore, direct selection for these traits would reward for improvement of yield. While, leaf area, dry matter, and number of leaves was negatively contributed towards total tuber yield per plot both at genotypic and phenotypic level. The results were in accordance with the findings of Rangare *et al.* (2014).

The direct effects *via* marketable yield per plant, total fresh weight of plant and number of tubers per plant contributed positively only at genotypic level. While, marketable yield per plot, number of stems, total dry weight of plant and plant height contributed positively only at phenotypic level.

The direct effects *via* total dry weight of plant, marketable yield per plot, plant height and number of stems per plant was contributed negatively at genotypic level. While, marketable yield per plant, total fresh weight of plant and number of tubers per plant was contributed negatively only at phenotypic level.

Plant height had significant association and positive direct effect with total tuber yield per plot due to its positive indirect effect through number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot only at phenotypic level. But negative direct and indirect effect at genotypic level. These results are in accordance with the findings of Patel *et al.* (2013).

Number of leaves at 60 DAP had significant association and negative direct effect with total tuber yield per plot due to its positive indirect effect through tuber dry matter and total starch only at phenotypic level but total starch only at genotypic level.

Leaf area at 60 DAP had significant association and negative direct effect with total tuber yield per plot due to its positive indirect effect through tuber dry matter both at genotypic level and phenotypic level. Regassa and Basavaraju (2005) and Nasiruddin *et al.* (2014).

The character number of stems at 60 DAP exhibited significant association and positive direct effect with total tuber yield per plot due to its positive indirect effect through number of leaves at 60 DAP, leaf area at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot only at phenotypic level. But negative direct effect due to its positive indirect effect through tuber dry matter at genotypic level. These results are in accordance with the findings of Patel *et al.* (2013).

Total fresh weight of plant had strong positive direct effect and significant association with total tuber yield per plot due to its positive indirect effect through plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total dry weight of plant, dry matter, starch, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot at genotypic level. But negative direct effect due to positive indirect effect through total starch at phenotypic level, this is neglected because it's environmental influence. Similar results were observed by Rangare *et al.* (2014).

Total dry weight of plant had significant association and positive direct effect with total tuber yield per plot due to its positive indirect effect through plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot only at phenotypic level. But negative direct effect at genotypic level due to its positive indirect effect through total starch. These results are in accordance with the findings of Patel *et al.* (2013).

Dry matter had negative direct effect and weak association with total tuber yield per plot due to its positive indirect effect through leaf area at 60 DAP, number of stems at 60 DAP, total starch at genotypic level and total starch at phenotypic level.

At both genotypic and phenotypic level total starch had a positive direct effect and negative association with total tuber yield per plot due to its positive indirect effect *via* plant height at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP and dry matter.

Dry matter and total starch flowering both contributed for yield, but they are negative or weak association established with yield. For yield improvement, balancing of dry matter and total starch with yield is an important task. This may be attributed to pleotrophy or linkage between genes in repulsion phase. Tight linkage can be broken by *inter se* mating and selection. This can upgrade ceiling limit on yield due to negative association of these two important yield contributing characters.

Number of tubers per plant had positive direct effect and strong association with total tuber yield per plot at genotypic level. Due to its positive indirect effect through plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot at genotypic level. But negative direct effect at phenotypic level due to indirect positive effect through total starch. Similar results were also observed by Rangare *et al.* (2014).

At both genotypic and phenotypic level fresh weight of tuber per plant had a strong association and positive direct effect on total tuber yield per plot. It is due to indirect positive effect on plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot. Similar findings were noticed by Santhosh *et al*. (2013), Hafiz (2015), Singh *et al.* (2015), Verma and Singh (2015), Verma and Singh (2016), Mishra *et al.* (2017).

At both genotypic and phenotypic level dry weight of tuber per plant had a strong association and positive direct effect on total tuber yield per plot. It is due to indirect positive effect on plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, marketable yield per plant and marketable yield per plot. Similar findings were noticed by Santhosh *et al.* (2013), Hafiz (2015), Singh *et al.* (2015).

Marketable yield per plant had positive direct effect and significant association with total tuber yield per plot at genotypic level. It is due to positive indirect effect through plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant and marketable yield per plot only at genotypic level. But negative direct effect due to indirect positive effect through total starch at phenotypic level. Similar results were observed by Rangare *et al*. (2014).

The character marketable yield per plot had positive direct effect and significant association with total tuber yield per plot. It is due to positive indirect effect through plant height at 60 DAP, number of leaves at 60 DAP, leaf area at 60 DAP, number of stems at 60 DAP, total fresh weight of plant, total dry weight of plant, dry matter, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant and marketable yield per plant only at phenotypic level. But negative direct effect at genotypic level due to its positive indirect effect through total starch. Similar results were observed by Rangare *et al.* (2014).

On the basis of above findings, it can be suggested that improvement in total tuber yield can be achieved through selection for the characters namely; fresh weight of tuber per plant, dry weight of tuber per plant and total starch. Also with number of tubers per plant, total fresh weight of plant and marketable yield per plant.

The above findings of path studies are in accordance with the findings of Khayatnezhad *et al.* (2011) for dry matter and starch; Felenji *et al*. (2011) for tuber yield, tuber weight, number of tubers per plant, dry matter per cent, number of stem per plant and plant height; Bisognin *et al.* (2012) for number of tubers per plant and fresh weight of tuber; Fekadu *et al.* (2013) for plant height and yield; Panghal *et al.* (2013) for tuber weight; Patel *et al.* (2013) observed for marketable yield, number of tubers per plant and number of stems per plant; Rangare and Rangare (2013) for fresh weight of plant and fresh weight of tubers; Santhosh *et al*. (2013) for number of leaves, tuber weight per plant and marketable tuber yield per plot; Ummyiah *et al.* (2013) for marketable yield per hectare; Darabad (2014) and Lamboro *et al.* (2014) reported that tuber yield; Datta *et al.* (2014) for tuber weight; Nasiruddin *et al.* (2014) for dry matter and leaf area; Zakerhamidi and Hassanpanah (2014) noticed for number of tuber; Hafiz (2015) and Singh *et al.* (2015) for tuber weight; Tripura *et al.* (2016) and Verma and Singh (2015)for leaf area and number of stem; Yerima (2016) and Mishra *et al*. (2017) reported for fresh weight of tuber per plant and dry weight of tuber per plant.

Conclusion

- ✓ The best genotypes identified in present investigation based on mean performance are Kufri Jyoti, C-28 and TT 7011. These genotypes are depicted in plate 4.
- ✓ In the present investigation, the higher phenotypic coefficient of variance, genotypic coefficient of variance and high heritability coupled with high genetic advance as percentage of mean was recorded for the traits *viz.*, fresh weight of tuber, dry weight of tuber, tuber volume, marketable and total tuber yield.

- ✓ The total tuber yield per plot was recorded to have positive and significant correlation both at phenotypic and genotypic levels with number of stems per plant, total fresh weight of plant, total dry weight of plant, number of tubers per plant, fresh weight and dry weight of tuber per plant, marketable and total tuber yield. Hence these traits can be used as selection criteria in potato breeding for high yield.
- ✓ Path coefficient analysis revealed positive and direct effect of fresh weight of tuber per plant, starch and dry weight of tuber per plant positively contributed towards total tuber yield per plot both at genotypic and phenotypic levels. This indicates the true positive association with total yield per plant. Therefore, direct selection for these traits would reward for improvement of yield.

Future line of work

On the basis of present study, the following suggestions could be made to plan out further improvement programme on potato.

- The genotypes included under the investigations may be evaluated at different agro-climatic zones of Karnataka to identify the most suitable genotype showing stability in performance for desirable characters.
- The best genotypes having desirable mean performance identified in present investigation are Kufri Jyoti, C-28, TT 7011 and TT 7010 could be included in hybridization programme for hill zone.
- To identify the genotypes which have processing qualities and exploit in processing industries.
- Development of multiple resistant varieties for biotic and abiotic stresses.

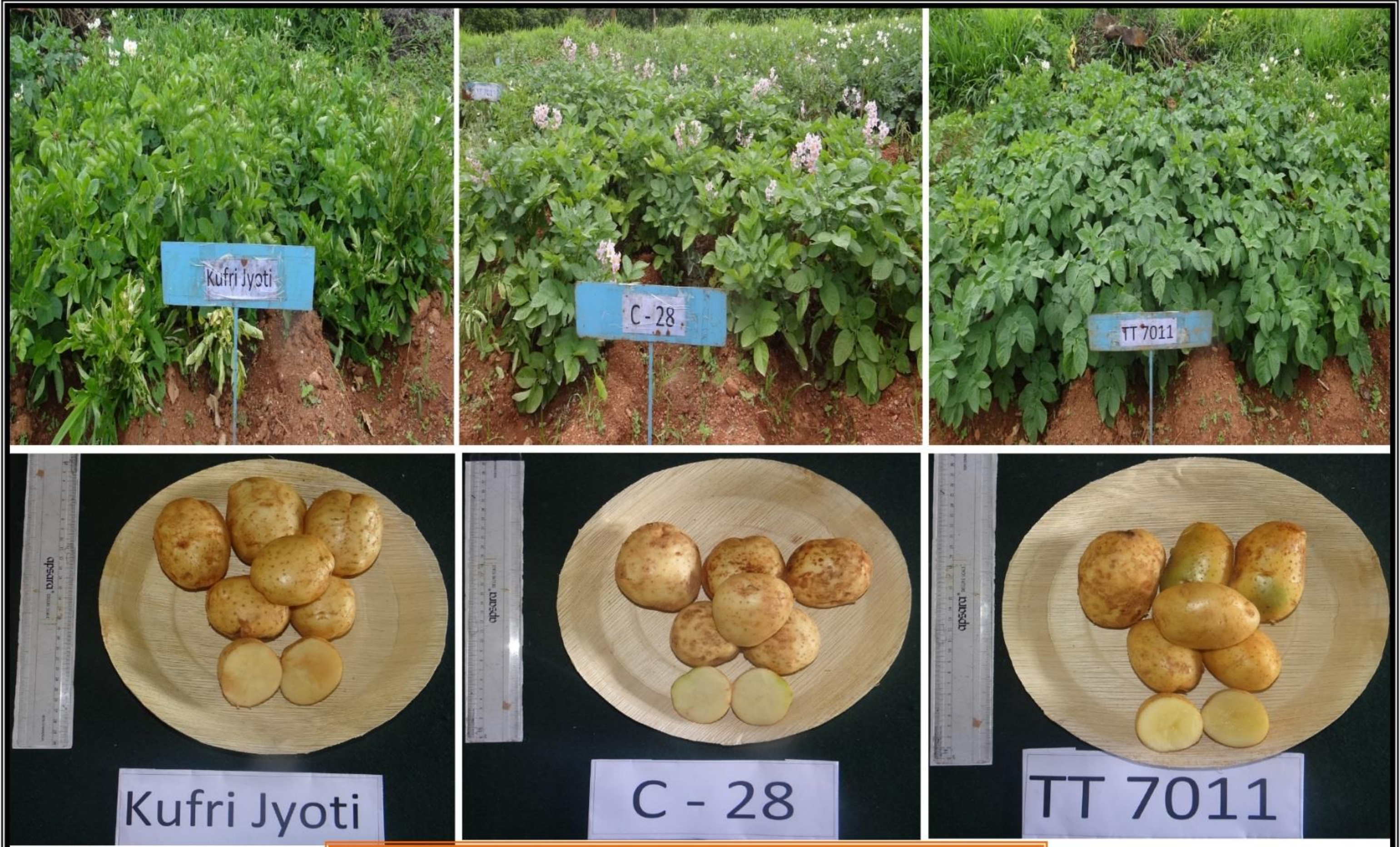

Plate 4. Promising potato genotypes

SUMMARY

VI SUMMARY

The present investigation entitled "Genetic variability studies in potato (*Solanum tuberosum* L.) genotypes under hill zone of Karnataka" was carried out at research field unit, Department of Vegetable Science, College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, (Karnataka) during 2016 – 2017. The experiment was laid under Randomized Complete Block Design (RBD) with three replications and the experimental material consisting of 16 genotypes of potato obtained from CPRI, Shimla and CIP, Peru. The principle objective of the present investigation was to study the genetic variability, character association and path analysis among of growth, yield and quality parameters in potato genotypes.

Observations were recorded for emergence percentage, plant height, number of leaves, plant spread from North to South and East to West, leaf area, number of stems per plant, fresh weight of leaves, dry weight of leaves, fresh weight of stem, dry weight of stem, fresh weight of root, dry weight of root, total fresh weight of plant, total dry weight of plant, fresh weight of tuber, dry weight of tuber, leaf area index, absolute growth rate, crop growth rate, net assimilation rate, number of tubers per plant, number of tubers per plot, tuber length, tuber circumference, tuber volume, tuber weight, total tuber yield per plant, total tuber yield per plot, total tuber yield per hectare, marketable yield per plant, marketable yield per plot, marketable yield per hectare, tuber dry matter content, total soluble solids, number of eyes per tuber, total chlorophyll , reducing sugars, non-reducing sugars, total sugars and starch. Finally, data was subjected to statistical analysis by applying statistical procedure for study of genetic variability, genotypic and phenotypic variance, coefficient of variance, heritability, genetic advance, correlation and path coefficient analysis for above characters.

The analysis of variance indicated the existence of sufficient amount of variability among genotypes for all the characters .The phenotypic variance was in general higher than the genotypic variance for all the characters. Among different yield attributing characters studied, fresh and dry weight of tuber, tuber volume, marketable and total tuber yield had the highest magnitude of PCV and GCV.

The estimates of heritability revealed that characters namely plant height at 60 DAP, leaf area (at 60 DAP & 90DAP), total fresh and dry weight of plant (at 60 DAP & 90DAP), fresh weight of tuber, tuber volume, total chlorophyll , starch, non-reducing sugars, total sugars, marketable and total tuber yield were recorded with high heritability. The highest genetic advance as percentage of mean was recorded for leaf area, fresh weight of tuber, marketable and total tuber yield.

High heritability coupled with high genetic advance as percentage of mean was recorded for the traits *viz.*, leaf area, fresh weight of tuber, tuber volume, non-reducing sugars, marketable and total tuber yield. Hence, these characters were predominantly governed by additive gene action and can be improved through simple selection.

For characters association, both genotypic and phenotypic correlations were considered. In most cases genotypic correlations were higher than phenotypic correlations indicating heritable nature of the characters.

Correlation studies revealed that highly significant and positive association of total tuber yield per plot with plant height, number of leaves, number of stems, total fresh weight of plant, total dry weight of plant, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot both at genotypic and phenotypic level indicating the possibility of simultaneous selection for these traits to improve the tuber yield. On the other hand, negative and strong significant correlation was found between tuber yield and total starch.

In this study high positive significant correlation was found between tuber yield and plant height, number of leaves, number of stems, total fresh weight of plant, total dry weight of plant, number of tubers per plant, fresh weight of tuber per plant, dry weight of tuber per plant, marketable yield per plant and marketable yield per plot. There were significant correlations among the yield contributing characters also. Hence it could be possible to improve the tuber yield by considering these traits.

Plant height had high degree of positive association with marketable yield per plant, number of leaves and leaf area with number of stems; number of stems was positively and significantly correlated with fresh weight of tuber and marketable yield per plant; total fresh weight of plant with total dry weight of plant; total dry weight of plant with dry weight of tuber per plant and total tuber yield per plot

Dry matter was positively and significantly correlated with dry weight of tuber per plant and starch; then starch with dry weight of tuber per plant whereas it was negatively and significantly with most of characters.

Number of tubers per plant exhibited positive significant correlation with fresh weight of tuber per plant, fresh weight of tuber per plant with marketable yield per plot. Finally dry weight of tuber per plant had high degree of positive association with total tuber yield per plot, marketable yield per plot and marketable yield per plant.

Path analysis revealed that out of thirteen characters studied, the direct effects *via* fresh weight of tuber per plant, starch and dry weight of tuber per plant positively contributed towards total tuber yield per plot both at genotypic and phenotypic levels. However under the genotypic level consideration given characters such as total fresh weight of plant, number of tubers per plant and marketable yield per plant because the genotypic associations are inherent. This indicates the true positive association with total yield per plant. Therefore, direct selection for these traits would reward for improvement of yield. While, leaf area, dry matter, and number of leaves were negatively contributed towards total tuber yield per plot both at genotypic and phenotypic levels.

Characters having high positive direct effects along with positive significant correlation with tuber yield per plant can be directly selected and simultaneously the characters which show high positive indirect effects can also be selected for improvement of yield.

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* Original not seen.

APPENDICES

VIII APPENDICES

APPENDIX-I

Monthly meteorological data during the experimental period

Month	Rain fall (mm)	Temperature (^0C)		Relative humidity (%)	Sun shine (hrs.)
		Maximum	Minimum		
April	20.80	33.76	23.20	79.16	9.10
May	148.40	31.54	19.90	80.39	8.11
June	363.60	25.36	20.66	82.53	1.13
July	557.75	25.35	20.32	82.90	0.25
August	201.30	25.50	20.40	82.60	0.20
September	75.70	24.56	20.13	82.38	3.01
October	38.40	29.03	20.06	81.61	6.67
November	41.10	29.70	20.06	78.70	8.30
December	10.60	28.70	20.03	75.60	9.0
January	2.0	28.97	20.06	79.0	8.50
February	Nil	29.79	20.04	76.50	9.30
March	22.0	30.10	20.08	78.0	8.70
Average	**123.47**	**28.53**	**22.08**	**79.94**	**6.02**

APPENDIX II

Physical and Chemical properties of soil at the experimental site

Sl. No.	Particulars	Values	Method employed
Physical properties			
1.	Coarse sand (%)	43.6	International pipette method (Piper, 1966)
2.	Fine sand (%)	23.9	
3.	Silt (%)	19.3	
4.	Clay (%)	13.2	
Chemical properties			
1.	Soil pH	5.98	pH meter (Jackson, 1967)
2.	Electrical Conductivity (dsm^{-1})	0.335	Conductivity bridge (Jackson, 1967)
3.	Organic matter (%)	0.88	Walkey and Blacks method (1965)
4.	Available nitrogen (kg/ha)	439.04	Alkaline permanganate method (Subbaiah and Asija, 1956)
5.	Available phosphorus (kg/ha)	69.21	Bray's method(Jackson,1967)
6.	Available potassium (kg/ha)	108.64	Neutral Normal Ammonium Acetate method by (Jackson, 1967)

APPENDIX III

List of symbols and abbreviations

Symbols	Abbreviations
%	Per cent
@	At
^0C	Degree Celsius
cc	Cubic centimeter
cm	Centimeter
cm^2	Centimeter square
m	Meter
m^2	Meter square
ha	Hectare
et al.	and other
g	Gram
i.e.	That is
kg	Kilogram
t	Tonnes
MT	Metric tonnes
mg	Milligram
ml	Milliliter
LAI	Leaf area index
AGR	Absolute growth rate
CGR	Crop growth rate
NAR	Net assimilation rate
CD	Critical difference
S.Em.	Standard Error of Mean
S.D	Standard deviation
viz.	Namely
DAP	Days after planting
hrs.	Hours