

**“Study on Genetic variability and character
association in onion (*Allium cepa* L.)
genotypes”**

THESIS

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MASTER OF SCIENCE

In

**(AGRICULTURE)
Horticulture (Vegetable science)**

By

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CERTIFICATE- I

This is to certify that the thesis entitled, “**Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN (AGRICULTURE) Horticulture (Vegetable Science)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Nimish Jain** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by him.

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CERTIFICATE-II

This is to certify that the thesis entitled “**Study on genetic variability and character association in onion (*Allium cepa* L.)**” submitted by **Mr. Nimish Jain** to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the Department of **Horticulture (Vegetable Science)** has been after evaluation approved by the External Examiner and by the student’s Advisory Committee after an oral examination on the same.

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Place : Jabalpur

Date :

(Nimish Jain)

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VITA

The author of this thesis **Mr. Nimish Jain**, S/o Shri Nirmal Jain, was born on 19 june, 1984 at Madaiyan, Bankhedi, Distt. Hosangabad (M.P.). He passed his High School (10th) in the year 2000 from Saraswati vidhya mander with 68.00% marks and Higher Secondary in the year 2002 from Saraswati vidhya mander with 68.00% marks.

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INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important bulbous vegetable crop grown all over the world. Onion is the oriented crop earning valuable foreign exchange for the country. It is the second only to tomato in their importance as a vegetable in the tropics. The demand for onion is worldwide. Onions are found in most marketable of the world thought out the year and can be grown under wide range of Agro-climate condition. Irrespective of pries, the demand for remain almost constant in the market as it is primarily, used as seasoning for a wide variety of dishes in many homes almost. Onion (*Allium cepa* L.) belonging to family *Amaryllidaceae* (Alliaceae) and locally known as Pyaj. It is old world crop and it was domesticated in Iran and Pakistan i.e. Central Asia.

It is consumed as a vegetable and condiment. The green leaves, immature and mature bulbs are eaten raw or used in vegetable preparations. It is an indispensable item in every kitchen and used to enhance flavour of different recipes. Onion has many medicinal values and used for preparation of various Homeopathic, Unani and Ayurvedic medicines. Nutritive value of onion varies variety to variety, small size onion is more nutritive then big size, its major value is in flavour. Onion ranks medium in caloric low in protein and very low in Vitamins.

Consumption of onions may prevent gastric ulcers by scavenging free radicals and by preventing growth of the ulcer-forming microorganism, *Helicobacter pylori*, confirm the potency of the onion as a blood thinner and platelet inhibitor. Researchers found that the more pungent onions exhibit strong anti-platelet activity. Platelet aggregation is associated with diseases like Atherosclerosis, Cardiovascular disease, heart attack and stroke. Incremental increase in scientific publications on phenolics strongly advocates the consumption of polyphenolic rich food for management of degenerative diseases particularly cardiovascular diseases, cancer, Alzheimer's, neurodegenerative diseases and diabetes (Manach *et al.*, 2005). Phenolic

compounds can offer significant anti-mellitus atherogenic protection by inhibiting the oxidation of low density lipoproteins (LDLs) (Scalbert *et al.*, 2005).

The pungency in onion is due to sulphur- bearing compound in very small quantity (about 0.005%) in the volatile oil allyl propyl disulphide ($C_6H_{12}O_2$). The colour of the outer skin of onion bulbs is due to quercetin. The quality of onion depends on shape, size, colour and pungency of bulbs. Highly pungent red coloured onions are preferred in India while less pungent, yellow or white skinned ones are demanded in European and Japanese market.

India is next to china in area and production of onion. Among the different states Maharastra is leading state in terms of area and production. Other major onion states are Gujrat, Karnataka, Orisa, Uttar Pradesh, Andhra Pradesh, Tamilnadu and Rajasthan. The area of onion in Madhya Pradesh is 57.30 thousand hectare, total production is 952.30 thousand million tonnes and productivity is about 16.60 tonnes per hectare (NHB 2009-10). Onion accounts for 70 per cent of our total foreign exchange earnings from the export of fresh vegetables. Government of India has declared onion as an essential commodity. Looking to its importance for domestic consumption as well as export greater attention is needed for its improvement. Onion has recently received considerable attention for its high medicinal value.

A logical way to start any breeding programme is to survey the variation in the available materials. It is said that presence of genetic variability is the “sine quanon” of any such programme. Selection is said to be effective in a population having large heritable variability. The genetic variability and its components are the genetic fractions of observed variability that provides measures of transmissibility of the variation and response to selection. The knowledge of pattern of inheritance of various characters are important consideration while, determining the most approximate breeding procedures applicable to any particular crop. The breeder's choice of the material for any improvement work consequently depends on the amount of genetic

variability present. The phenotype is often not the true indicator of its genotype, due to the masking effect of environment over genotype.

Attempts have been made to determine the magnitude of heritable and non-heritable components and genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance as percentage of mean in quantitative characters of onion.

The estimates of correlation coefficient analysis will be more useful in the estimation of inter-relationship among the yield contributing components and onward. Estimation of path coefficient analysis gives the indication of the nature and extent of direct and indirect effect themselves yield contributing components. In view of above aspects the present investigation in onion entitled “Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes” has been carried out with the following objectives:

Objectives

1. To estimate the genetic variability, heritability and genetic advance of yield and its components.
2. To find out the interrelationship among yield and its components.
3. To ascertain the relative importance among yield contributing characters using path coefficient analysis.

REVIEW OF LITERATURE

The success of any plant improvement programme mainly depends on the right selection of material and its skillful management. It is only possible when we possess knowledge of previous work done in the concerned field. In onion substantial contribution has been made to the literature regarding its genetics and breeding in the recent years. The literature pertaining to the various aspects of the present study has been reviewed under the following heads:

- 2.1 Analysis of variance
- 2.2 Mean performance of the genotypes
- 2.3 Coefficient of variation
- 2.4 Heritability and genetic advance
- 2.5 Correlation coefficient analysis
- 2.6 Path coefficient analysis

2.1 Analysis of variance

Aghora and Pathak (1991) reported that highly significant differences for all the characters except for total soluble solids indicating great deal of diversity among them.

Dehdari *et al.* (2001) revealed that the analysis of variance showed significant differences among genotypes for all morphological and agronomic traits studied.

Mohanty (2001c) reported that the analysis of variance for all characters (plant height, number of leaves per plant, neck thickness, bulb diameter, bulb weight, and bulb yield) was significant, indicating considerable diversity among cultivars.

Mohanty and Prusti (2001) revealed that the mean square estimates were significant for all the characteristics indicating sufficient diversity among the cultivars.

Khar *et al.* (2006) observed that the analysis of variance revealed that significant differences among the genotypes for all the traits studied viz., for plant height, number of leaves, polar diameter, equatorial diameter, neck thickness and total soluble solids.

Yaso (2007) found that analysis of variance revealed significant differences among the six genotypes for all the characters, except for percentage of double bulbs.

Hosamani *et al.* (2010) revealed that the analysis of variance revealed that significant differences for all the traits studied indicating existence of genetic differences among the genotypes.

Adsul *et al.* (2010) revealed that the analysis has revealed high genetic variability among cultivars for bulb weight (g), bulb diameter (cm), Total Soluble Solids (%), bolting (%), doubles (%), plant height (cm), number of leaves and pungency (ppm).

2.2 Mean performance of the genotypes

Soni *et al.* (1991) revealed that the No. 102 was recorded significantly higher plant height (44.79cm), number of leaves per plant (9.55), length of leaf (34.50cm), leaf width (3.02cm), bulb length (4.27cm), bulb diameter (5.29cm), and bulb yield 335.36q/ha. Significantly higher TSS was found in Pusa White Flat (13.38) and Pusa Red (12.94).

Bajaj *et al.* (1992) reported that the chemical analysis showed the maximum T.S.S. (11.88) in Punjab Red Round variety of onion.

Sharma *et al.* (1995) reported that the cultivar Agrifound Light red gave the maximum bulb yield and bulb weight followed by Nasik Red and Patna red. The genotype Patna Red took less number of days to maturity followed by Nasik Red and Agrifound Light Red.

Bal and Sidhu (1995) evaluated twenty genotypes for total bulb yield, bulb diameter, number of bolters, neck thickness, plant height and total soluble solids. Punjab Red Round, Lohru, Pusa Madhvi, Red Creole and PWO-1 gave best performance for these traits.

Singh *et al.* (1995) reported that the range of bolting as 1.5 to 5.5%, neck thickness 0.9 to 1.3cm and TSS 11.4 to 13.2% were recorded and Hisar -2 was rated best for commercial trade.

Thamburaj *et al.* (1995) reported that genotype V5 was observed significantly high mean yield of 9.16, bulbs weighing 88.39g, plant height (44.37cm), number of leaves per plant (17.18), leaf area (183.54sq cm), shoot girth (4.92cm), weight of foliage (13.65g), ratio of shoot to bulb (0.15), bulb weight (10.98g), bulb girth (7.69cm), bulb length (4.39cm), bulb diameter (2.90cm) and shape index (1.51).

Sharma *et al.* (1996) reported that sixteen varieties of onion were analyzed for total soluble solids, colouring matter and pyruvic acid content. The variety PWO-1 contained the maximum TSS (15.5) and pyruvate content (5.0).

Gvozdanovic-Varga *et al.* (1996) revealed that the populations of onion differ in shape, colour, average bulb mass and growth, presenting a significant source of genetic variability. The objective of this investigation was to study the variability of characters of onion populations in order to find desirable characters that can be used in breeding. The analysis showed significant differences in bulb mass ranged from 74.0 to 209.8 g. The coefficient of variation for this character was 39.1. The bulbs differed in colour and shape.

Martinovich and Felfoldi (1996) revealed that the shape and colour in onion are two most important characteristics to help customers in choosing cultivars on the market. Hungarian varieties are expected to be spherical in shape and bronze red in colour. Accordingly, the variety Sortiment is rather uniform, hardly any visual difference can be detected among released

varieties. This has an impact on breeding as well as taste is difficult to change and the narrowing of the genetic diversity does not allow a break through, either.

Shrivastava *et al.* (1996) revealed that the a field experiment was conducted during (1989-90 and 1990-91) to evaluate the performance of six onion varieties under three spacing treatments for their morphological attributes of bulb productivity and yield. Inherent genotypic similarities resulted in non significant differences in plant height (at 90 DAT) amongst varieties during both the year. The significant differences in leaves per plant were more pronounced at early stages during both the years and at 90 DAT during 1989 – 90. The increased leaves per plant resulted in significant increase in leaf biomass amongst varieties at 90 DAT during both the years. More over maximum leaf number and biomass were noted in Agrifound Light Red and N-2-4-1 and bulb biomass was comparatively more in Agrifound Light Red.

Verma *et al.* (1999) reported in the experiment based on yield, drying ratio, total soluble solids (TSS) and sugar, Punjab-48 was judged superior to other varieties for dehydration quality followed by Pusa White Flat.

Mohanty (2001) found an experiment was conducted over 2 years to find out the suitable varieties and planting time of onion. The pooled analysis revealed that Agrifound Light Red and Arka Niketan produced significantly taller plants with more number of leaves per plant, larger bulb and higher yield than other varieties tested.

Mohanty (2001a) revealed that the highest genetic variation was observed in bulb yield (150.80-210.60q/ha). Phenotypic variation was high for neck thickness (22.72%), but moderate for plant height (13.07%), bulb weight (10.65%) and number of leaves per plant (10.61%).

Mohanty *et al.* (2001b) revealed that the high performing varieties namely Agrifound Light Red, Arka Niketan, Nasik Red, N2-4-1 and Punjab Red Round showed significantly higher yield than other.

Mohanty, and Prusti (2001) revealed that the three varieties (N2-4-1, Pusa Madhavi and Pusa Ratnar) were found stable for bulb yield of which only Pusa Madhavi was detected for general adaptability mainly because of better relative growth rate. Other varieties producing higher yield were marked unstable.

Hasegawa *et al.* (2001) revealed that the onion bulb shape expressed as the proportionality existent between the diameter and height, was lower in the early local varieties such as Kaizuka-wase and Shizuoka wase, thus reflecting their flattened form. In the later varieties such as Osakamaru and Yamaguchi-kodaka, the value was 1.1 ± 0.02 demonstrating their complete globular shape.

Mennella *et al.* (2002) revealed that the white bulbs for spring yield represent a typical crop in the Agro Nocerino-Sarnese. Cipolla bianca di Pompei ecotypes are characterized by a short day photoperiod and present white bulbs of round-flat shape, uniform, of homogeneous size (80-120 g), suitable for Spring and/or Summer consumption.

Singh *et al.* (2003) found that significantly lowest moisture content (MC, 78.32%) and highest total soluble solids (TSS, 19.50%) and dry matter (21.68%) were recorded in Agri Found Red.

Jansi Rani and Thangaraj (2004) revealed that the plant characters like number of leaves (7.93) and length of leaf (29.58cm) were comparable with white onion cultivar, Agri Found White. Bulb diameter was recorded as 3.46 cm and the girth of bulb was measured as 5.66 cm and individual bulb weight on an average was recorded as 24.31g.

Jogdande *et al.* (2004) reported that the Agrifound Light Red was recorded significant maximum plant height at 90 DAT (69.33cm) and early maturity (103.33day). Number of leaves per plant at 90 DAT (15.33) was maximum under PKY selection white. The variety N-2-4-1 recorded significant maximum weight of fresh bulb (108.80g), diameter of bulb (6.22cm) and highest marketable yield (514.99q/ha).

Gowda *et al.* (2004) revealed that PBR 322, 324, 302, 310 and 298 were found to have resistance for purple blotch with the bulb yield varied from 28-32t/ha; bulb weight 45-65g and bulb size 13-17cm². Bulb colour varied from light to deep red. Bulb shape varied from oval globe to flat globe.

Patil *et al.* (2006) revealed that Phule Samarth was recorded higher yield (403q/ha), superior marketable bulb yield (87.42%), early maturity (87.42days) with occurrence of more than fifty per cent natural foliage top fall, rapid bulb development coupled with controlled vegetative growth (ratio 4.05) resistant to premature bolting (3.88%) and twin bulbs (1.30%), thin bulb neck (0.95cm), Lusterious dark red globular bulbs and excellent keeping quality for three months.

Schiavi *et al.* (2007) reported that three "Rossa di Tropea" types distinguishable for bulb shape, earliness, pungency and storability are presently cultivated in the typical area.

Yaso (2007) revealed Giza 20, Red Giza and Giza 20 x TEYG had the highest values for plant height and number of leaves per plant, while Composite 13 Oblong had the lowest. Composite 13 Oblong was the earliest in bulb maturity, while Giza 20 and Red Giza were the latest ones. Giza 20, Red Giza, Giza 20 x TEYG and Group of Composites were the highest in total and marketable yield and average bulb weight. Composite 13 Oblong had the highest percentage of single bulbs (99.69%), the lowest percentage of double bulbs (0.00%) and normal percentage of bolters (0.31%). Red Giza and Giza 20 had the highest total soluble solids content (TSS >10%), while Composite

13 Oblong had the lowest (7.49%). Giza 20 was the lowest in percentage of sprouted bulbs, while Composite 13 Oblong was the highest.

Singh and Bhonde (2009) revealed that the maximum bulb diameter (5.43 cm) and bulb size index (23.58 cm²) was observed for advance line 652 and it was however at par with line 574 (5.38 cm and 22.91 cm²) and Agrifound Light Red (5.38 cm and 22.78 cm²) respectively. The highest 20 bulbs weight was also recorded for advance lines 652 (1.31 kg) and was at par with advance line 453 (1.18 kg), 574 (1.21 kg), 672 (1.25 kg) and check Agrifound Light Red (1.22 kg).

Mahanthesh *et al.* (2009) reported that the characters were evaluated for bulb yield, bulb weight, total soluble solids, dry matter content of the bulb, dry matter yield of the bulb, physiological storage loss in weight, sprouting and rotting percentage. Based on the bulb yield, dry matter production and storage qualities, the varieties Baswant 780, Arka Kalyan and Agri. Found Light Red (AFLR) were identified as for commercial cultivation in kharif season under rain fed situation in Central Dry Zone of Karnataka.

Singh *et al.* (2010) revealed that the wide range of variability was observed for gross yield (301.99q/ha to 387.81q/ha), marketable yield (239.33q/ha to 338.49q/ha), bulb size index (21.31 to 23.09 cm²) and plant height (62.73 to 68.43 cm). The mean data indicated that the advance line 562 showed highest bulb diameter (5.50), bulb size index (23.09 cm²) and weight of 20 bulbs (1.10 kg) which was however at par with advance line 627 (5.47 cm), (22.75 cm²) and (1.03 kg) and line 629 (5.40 cm), (22.30 cm²) and (1.06 kg) respectively. The considerable amount of variation was observed for all traits.

Hosamani *et al.* (2010) revealed that the plant height mean ranged from 23.33 cm ('Agri found white') to 32.00 cm ('PRO-6'). The 'RO-597' recorded highest number of leaves per plant of 8.33. Maximum bulb length was recorded with 'Arka Niketan' (6.20 cm). Whereas, genotype 'Sel-283' recorded maximum bulb diameter (6.20 cm), bulb neck thickness (1.37 cm) and TSS (12.23%). The highest average bulb weight of 84.00 g was

recorded with 'PKV Sel. White'. The genotype 'NRCWO-2' recorded highest bulb yield (32.42 t/ha) and mean over the genotypes was 26.83 t/ha. The range was maximum for yield per hectare (8.52 to 32.42 t) followed by average bulb weight (26.67 to 84.00 g), dry matter content (15.93 to 24.80 %), bulb neck thickness (0.47 to 1.37 cm). This wide range of variation for these traits provide ample scope for efficient selection.

Singh *et al.* (2011) reported that the traits bulb diameter, bulb size index and weight of 20 bulbs, the collection 687 recorded promising (5.84cm, 24.84cm² and 1.56kg) followed by collection 718 (5.82cm, 23.24cm² and 1.53kg), 652 (5.70cm, 22.53cm² and 1.50kg), 702 (5.69cm, 22.39cm² and 1.46kg), 562 (5.65cm, 22.31cm² and 1.43kg), 691 (5.64cm, 22.22cm² and 1.41kg), 355 (5.62cm, 22.13cm² and 1.38kg) and check Agrifound Light Red (5.61cm, 22.04cm² and 1.35kg) respectively. No bolters showed by collection 355, 357, 397, 400, 411, 417, 432, 457, 446, 449, 477, 494, 511, 540, 552, 574, 580, 587, 629, 666, 681 and 697 so that these genotypes can be utilize for good quality bulb production for consumption and export. The collection 719, 652, 595, 407, 355, 669 and check Agrifound Light Red noted for high total soluble.

Morsy *et al.* (2011) studied characters significantly affected by different cultivars. The highest means of bulb weight were recorded for composite 16, while, the lowest means were recorded for Beth alpha cultivar in both seasons. The highest means of marketable yield/fed and total yield/fed were obtained by Giza 20 and composite 16 cultivars in the first and second seasons, respectively. The lowest means of bulb weight, marketable yield/fed and total yield/fed were obtained by Beth Alpha cultivar in both seasons.

Awale Degewione *et al.* (2011) reported that the accessions differed significantly for most of the characters and relatively wide range of the mean for most of characters indicated the existence of variation among the tested accessions.

Mallor *et al.* (2011) evaluated quality-related bulb traits in 15 grower's open-pollinated lines of this cultivar. Phenotypic variation observed for bulb weight, size and soluble solids content was significantly affected by location, growing season and line, while pungency depended on line and plot location. We found higher levels of genetic variation for bulb size and pungency than for soluble solids content.

2.3 Coefficient of variation

For development of new superior varieties which are far better than the existing ones, we should choose the materials that possess variability having high GCV along with high mean.

Vidyasagar and Singh (1993) recorded lower variation (10.4-15%) among genotypes studied for TSS.

Patil (1997) reported that the higher variability for splitting bulbs among the genotypes. He reported very high phenotypic variance and genotypic variance and moderate GCV and PCV. Significant variation among genotypes was observed for number of days to maturity and low genotypic and phenotypic coefficient of variation among 25 onion genotypes for neck thickness, polar diameter and equatorial diameter. Moderate PCV and GCV were recorded for leaf number per plant. The estimates of genetic and phenotypic variance were low, the GCV and PCV also reported to be low for number of days to maturity and TSS.

Sidhu *et al.* (1986) and Balareddy (1999) recorded low PCV (phenotype coefficient of variation) and GCV (genotype coefficient of variation) were recorded for TSS.

Dehdari *et al.* (2001) Dry weight and number of days to emergence had the highest and lowest coefficients of genetic variability, respectively. Plant fresh weight, yield of 30 plants and total yield also had high coefficients of variability.

Mohanty, and Prusti (2001). revealed that the substantial difference within phenotypic and genotypic coefficient of variation was marked for all the attributes.

Mohanty (2002) Evaluation of 12 onion cultivars during rabi 1994/95 and 1995/96 at Bhawanipatna, Orissa, India revealed moderate to high estimates of genetic coefficient of variation for neck thickness, bulb weight and number of leaves per plant which could be improved by simple selection.

Trivedi *et al.* (2006a) the genotypic coefficients of variation (GCV) were lower than the phenotypic coefficients of variation (PCV). Maximum phenotypic variability was observed for bulb weight, followed by percentage of doubles and marketable yield, whereas moderate variability was observed for the percentage of 'A' and 'B' grade bulbs. A similar trend was observed with respect to genotypic variability.

Trivedi *et al.* (2006) In general, phenotypic coefficient of variation was higher than the genotypic coefficient of variation for bulb weight, bulb dry matter and marketable yield of onion, indicating the high environmental effects.

Gurjar and Singhania (2006) Evaluation of 30 cultivars and local landraces of onion in Raipur, Rajasthan, India, revealed that the phenotypic coefficients of variation (PCV) were higher than the genotypic coefficients of variation (GCV) for the different traits studied. Moderate to high GCV were recorded for bulb neck thickness, bulb weight and bulb yield, indicating that these traits could be improved by simple selection. low GCV were observed for plant height, days to maturity, number of leaves per plant, equatorial bulb diameter and dry matter content, indicating the potential of heterosis breeding for their amelioration.

Ananthan and Balakrishnamoorthy (2007) higher estimates of genotypic and phenotypic coefficients of variation were recorded for bulb weight

Yaso (2007) revealed In general, the genetic coefficient of variation (GCV) values for all the characters were lower than those of phenotypic coefficient variation (PCV) ones. The results of PCV and GCV indicated the possibility of effective selection for percentage of sprouted bulbs to raise the bulb storage ability.

Hayder *et al.* (2007) reported that highest genotypic and phenotypic coefficient of variation was recorded in fresh weight of bulb and days to harvest followed by bulb yield indicated that there was scope for selection.

Hosamani *et al.* (2010) revealed that the genotypic coefficient of variation and phenotypic coefficient of variation were high for yield t/ ha and average bulb weight. Whereas, moderate variation for all the characters except total soluble solids and number of leaves per plant. This shows prevalence of greater genetic variability among the genotypes which offers good opportunities for crop improvement through selection.

Singh *et al.* (2010) revealed that the PCV was higher than the GCV in all characters. A higher magnitude of coefficient of variation was recorded for marketable yield (10.18- 9.13%), followed by gross yield (9.80-9.16%) and weight of 20 bulbs (9.87 and 5.89%). Medium phenotypic coefficient of variation was observed for dry matter (6.26%), TSS (6.08%) and number of leaf per plant (5.73%).

Awale Degewione *et al.* (2011) High Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient Variation (GCV) were recorded for leaf diameter and percentage of bulb sprouting.

Morsy *et al.* (2011) Weight loss% at 60 days exhibited the highest values of coefficient of phenotypic and genotypic variance in both seasons, while days to maturity and bulb weight exhibited the lowest values in the first and second seasons, respectively.

2.4 Heritability and genetic advance

It is well known that right selection of the material is one of the important causes for the success of any improvement programme. The proper selection will depend on the knowledge of heritability. Estimation of genetic advance is an important parameter to evaluate effectiveness of selection.

Sandhu and Korla (1975) observed low heritability and genetic advance for plant height in onion genotypes.

Suthanthira Pandian and Muthukrishnan (1982) reported very high heritability for number of leaves per plant, coupled with low genetic advance.

Patil *et al.* (1986) reported that the very high heritability with high value of genetic advance for number of leaves per plant and low heritability with low genetic advance for neck thickness. Moderate to high heritability values with high genetic advance were observed for the characters total loss, bulb weight, per cent sprouting and per cent bolting.

Sidhu *et al.* (1986) observed moderate heritability for days to maturity with low genetic advance. He also observed wide variation among different onion genotypes for shape index. Shape index showed low heritability coupled with lower genetic advance.

Vidyasagar and Singh (1993) observed low heritability in combination with low genetic advance for number of leaves per plant. He also reported high heritability with low genetic advance for days to maturity and shape index.

Patil (1997) revealed that the lower heritability coupled with low genetic advance for neck thickness. Moderate to high estimates of heritability coupled with high genetic advance were noticed for days to maturity. The heritability was moderate coupled with low genetic advance for polar diameter, equatorial diameter and bulb size index. High heritability (97.3%) associated with very high genetic advance (124.13%) for splitting bulbs.

Balareddy (1999) reported that the very high heritability associated with medium genetic advance for TSS.

Mohanty, and Prusti (2001) revealed that the high value of heritability associated with moderate to high genotypic coefficient of variation and genetic gain were manifested by bulb yield, bulb weight, plant height, number of leaves per plant and neck thickness, which might be attributed to additive gene action regulating their inheritance and phenotypic selection.

Fatema (2001) reported high heritability associated with high genetic advance as percentage of mean for plant height.

Mohanty (2001a) reported that the moderate to high values of heritability coupled with moderate to high genetic coefficient of variation and genetic gain were observed for the number of leaves per plant, neck thickness, plant height, and bulb weight.

Mohanty (2001b) reported that the high heritability with moderate to high genotypic coefficient of variation and genetic gain were recorded for weight of bulb, neck thickness, bulb yield and number of leaves per plant which could be improved by simple selection.

Mohanty (2002) revealed moderate to high estimates of heritability and genetic gain for neck thickness, bulb weight and number of leaves per plant which could be improved by simple selection.

Mohanty (2004) evaluation of 12 varieties of onion over 4 years revealed moderate to high estimates of heritability and genotypic coefficient of variation with moderate genetic gain for neck thickness, weight of bulb and number of leaves/plant which could be improved by simple selection.

Krishna Prasad *et al.* (2005) observed significant variation in plant height among 209 onion lines. Plant height had high heritability associated with low genetic advance.

Melke and Ravishankar (2006) reported that the higher heritability and high genetic advance for the traits like leaves per plant, soluble solids, biological yield per plant and plant height.

Trivedi *et al.* (2006) revealed that the high heritability was also recorded for marketable yield, polar bulb diameter, total soluble solids and physical loss in weight.

Trivedi *et al.* (2006a) reported that the very high estimates of heritability were observed for polar diameter of bulbs, followed by TSS. Total yield, neck thickness and percentage of 'A' grade bulbs showed moderate heritability. The highest genetic advance was observed for bulb weight, followed by percentage of 'A' grade bulbs.

Gurjar and Singhania (2006) evaluation of 30 cultivars and local landraces of onion in Raipur, Rajasthan, India, revealed that the high heritability with moderate to high genetic gain were recorded for bulb neck thickness, bulb weight and bulb yield, indicating that these traits could be improved by simple selection. Moderate to high heritability with low genetic gain were observed for plant height, days to maturity, number of leaves per plant, equatorial bulb diameter and dry matter content, indicating the potential of heterosis breeding for their amelioration.

Pramoda and Gangaprasad (2007) reported that the high heritability was observed with respect to yield per plant, plant height and number of leaves per plant.

Yaso (2007) revealed that the heritability in broad sense ranged from 0 (percentage of bolters) to 80.75% (days to maturity). High estimates of genetic advance as a percentage of mean were realized for percentage of sprouted bulbs (32.02%) and TSS content (28.95%). Moderate to high values of heritability, GCV and genetic advance were observed for total and marketable yields, bulb weight and percentage of sprouted bulbs. Moderate to high estimates of $h_{b,s}^2$ coupled with low GCV and Gs% were noticed for days to maturity.

Hayder *et al.* (2007) reported that the plant height, bulb yield and bulb length were found to show high broad sense heritability. Bulb yield per hectare and number of green leaves per plant had high broad sense heritability estimates with high genetic gain.

Dhotre *et al.* (2010) reported that the high heritability with moderate to high GCV and genetic advance were recorded for double/split bulb per cent, fresh bulb weight and bulb yield. Number of rings per bulb and TSS exhibited high heritability coupled with high expected genetic advance.

Hosamani *et al.* (2010) reported that the heritability in broad sense ranged from 37.33 (number of leaves per plant) to 80.30 per cent (dry matter content). Higher heritability estimates were obtained for the yield/ha (79.63%), TSS (74.24%) and average bulb weight (64.64%) and it was moderate for other traits. The genetic advance as percentage of mean varied from 10.36 to 47.88 per cent for plant height and average bulb weight respectively. High GA were observed for average bulb weight, yield per hectare, bulb neck thickness, bulb diameter and bulb length. Hence, selection for these characters is likely to be more effective, as high heritability values were associated with high GA. This could be due to additive gene effects.

Singh *et al.* (2010) revealed that the very high heritable characters for onion are days for bulbs initiation, days for harvest, gross yield, marketable yield, weight of 20 bulbs and number of leaves per plant. High genetic advance for recorded in gross yield (17.62%), marketable yield (19.88%) and days for bulbs initiation (8.85%) and rest of others characters showed low genetic advance. Gross yield, marketable yield and days for bulbs initiation indicated higher estimates of genetic advance as percent of mean coupled with high heritability. High to moderate heritability associated with low genetic advance as percent of mean observed for number of leaves per plant, plant height, neck thickness and TSS, indicating that these traits are governed by non additive gene action.

Awale Degewione *et al.* (2011) reported that the high GCV along with high heritability and genetic advance was obtained from leaf diameter and percentage of bulb sprouting.

Morsy *et al.* (2011) revealed that the maximum estimates of heritability in broad sense were obtained for plant weight, while the minimum ones were obtained for weight loss% at 120 days and culls yield, in the first and second seasons, respectively. Days to maturity and bulb weight gave the lowest genetic advance percentage in the first and second seasons, respectively.

2.5 Correlation coefficient analysis

Correlation studies are of considerable importance in plant breeding programme. The need for coefficient of correlation is to describe the degree of association between two variables.

The correlations between yields its components give an idea for selection pressure, which could profitably be exercised to obtain an increase in yielding ability. As such, it is necessary to estimate the correlation coefficients to aid in estimating the true association due to genetic cause. A brief review related to this aspect is being given here.

Suthanthira Pandian and Muthukrishnan (1982) reported that number of leaves, number of bulbs and weight of plant exhibited significant positive association with yield as well as between themselves.

Sidhu *et al.* (1986) reported that bulb yield was positively associated with bulb diameter and 10 bulb weight.

Netrapal and Choudhary (1988) revealed that bulb yield was positively correlated with bulb weight, diameter and plant height.

Singh *et al.* (1995) found that the bulb yield showed strong positive correlation with bulb weight and neck girth.

Sharma *et al.* (1995) reported that the bulb yield showed positive correlation with bulb weight, bulb diameter, plant height and marketable bulb weight.

Asati *et al.* (1995) reported that the plant height and number of leaves per plant showed positive and significant correlation with seed yield per hectare.

Thakur *et al.* (1997) reported that bulb yield was significantly and positively correlated with weight per bulb, plant height, leaves per plant and leaf length and width.

Rajalingam and Haripriya (2000) showed that the yield components, including plant height, leaf length, leaf breadth, number of leaves, weight of plant, number of bulb, bulb length, bulb diameter and volume of bulb exhibited significant positive association with yield. These components were also positively inter-correlated among themselves.

Mohammed *et al.* (2000) reported that the bulb production was significantly and highly correlated with equatorial bulb diameter, quantity of marketable bulbs and polar diameter of bulb. It also had a positive relationship with the number of rings per bulb and bulb neck thickness. The equatorial bulb diameter was significantly correlated with polar diameter of bulb and marketable bulbs. Bolting, sprouting and split percentage in bulb production were negatively correlated with bulb yield, quality of marketable bulbs, equatorial bulb diameter and polar bulb diameter.

Mohanty (2001) reported that the phenotypic and genotypic associations of bulb yield were significantly and positively correlated with plant height, number of leaves per plant, bulb diameter and weight of bulb, but were significantly negative for neck thickness.

Mohanty (2001a) reported that the bulb yield was significantly and positively correlated with number of leaves per plant and bulb weight at phenotypic and genotypic levels. Neck thickness was positively correlated

with plant height and bulb diameter, but was negatively correlated with bulb weight and yield at both levels.

Mohanty (2001b) reported that bulb yield manifested positive and significant correlation with plant height, bulb diameter and weight of bulb.

Dehdari *et al.* (2002) reported that the bulb weight exhibited the highest and lowest coefficients of correlation with bulb diameter and number of days to emergence respectively.

Rahman *et al.* (2002) showed that total bulb yield had significant positive correlation with plant height, number of leaf per plant, bulb diameter and bulb yield per plant.

Mohanty (2002) reported that the phenotypic and genotypic associations of bulb yield were significantly positive with plant height, number of leaves per plant, bulb diameter and bulb weight, but significantly negative with neck thickness.

Mohanty (2004) evaluation of 12 varieties of onion over 4 years revealed The phenotypic and genotypic associations of bulb yield were significantly positive with plant height, number of leaves/plant, diameter, and weight of bulb but significantly negative with neck thickness.

Wani (2004) revealed that bulb yield was positively and significantly associated with number of leaves, bulb volume, bulb weight.

Shrivastava *et al.* (2004) revealed that bulb weight had a significant and positive association with equatorial circumference of bulb and radial circumference of bulb similarly equatorial circumference of bulb also showed the positive and significant correlation with radial circumference of bulb.

Shrivastava *et al.* (2004b) revealed that the plant height was positively and significantly correlated with leaf biomass and fresh plant weight. More over the bulb biomass had also a positive and significant association with leaf biomass. Bulb Weight had a significant and

positive association with equatorial circumference of bulb and radial circumference of bulb. Similarly equatorial circumference of bulb with radial circumference of bulb. Bulb biomass was positively and significantly correlated with bulb weight per plant.

Trivedi *et al.* (2006) revealed that the yield was positively associated with bulb weight and equatorial bulb diameter.

Trivedi *et al.* (2006a) showed that yield was significantly and positively associated with plant height, dry matter of leaves, equatorial diameter, bulb weight, percentage of 'A' grade bulb and marketable yield. It was also positively associated with polar diameter and percentage of 'B' grade bulb, but it was significantly and negatively correlated with TSS, percentage of C grade bulb and bolter. The present study indicates that yield improvement could be possible by increasing equatorial diameter and polar diameter of bulb, bulb weight and percentage of 'A' grade bulbs.

Gurjar and Singhania (2006) evaluation of 30 cultivars and local landraces of onion in Raipur, Rajasthan, India, revealed that the genetic correlation were higher than corresponding phenotypic ones for most characters, indicating the inherent relationship among them. Bulb yield expressed positive and significant phenotypic and genetic association with plant height, number of leaves per plant, bulb neck thickness, bulb weight, equatorial and polar bulb diameter.

Pavlovic *et al.* (2007) investigated genotypes showed a great variability regarding the correlation coefficient. Yield, diameter and fresh weight of bulb had high positive both genetic and phenotypic correlation values, while dry matter content, total sugar and mineral content in onion bulb had high statistically significant genetic correlations but low phenotypic correlations.

Aliya *et al.* (2007) revealed that cured bulb yield had significant positive correlation with plant height, number of leaves per plant, bulb diameter and bulb weight but had negative association with percentage culled bulbs.

Hayder *et al.* (2007) studied correlation coefficients and path analysis in onion. Analysis indicated that bulb yield had highly positive significant correlation with bulb length and bulb diameter. Bulb diameter also had positive significant association with plant height, fresh weight per bulb and bulb length.

Meena *et al.* (2007) revealed that the bulb yield showed significant positive correlation with plant height, number of leaves per plant, equatorial bulb diameter and polar bulb diameter and bulb weight. These traits were also inter-correlated.

Singh and Bhonde (2009) revealed that the plant height, bulb diameter, bulb size index and weight of bulb positively correlated to increase for yield.

Singh *et al.* (2010) showed that the marketable yield was significantly and positively correlated with plant height, bulb diameter, weight of 20 bulbs, days for bulbs initiation, dry matter content and gross yield at both phenotypic and genotypic levels and neck thickness and number of leaves per plant at genotypic levels. Gross yield was positively and significantly correlated with bulb diameter, weight of 20 bulbs and dry matter at both levels and negatively correlated with days for harvesting. Neck thickness was positively correlated with number of leaves per plant. Bulb size index positively and significantly correlated with plant height, number of leaves per plant, neck thickness at genotypic levels and bulb diameter at both phenotypic and genotypic level. Weight of 20 bulbs was significantly and positively correlated with plant height and number of leaves per plant at genotypic level and bulb diameter at both phenotypic and genotypic levels.

Hosamani *et al.* (2010) revealed that the genotypic correlations were of higher magnitude than the corresponding phenotypic correlation associations among various characters studied. The interrelationship of bulb yield was significantly positive with bulb diameter, bulb neck thickness and average bulb weight. Whereas, bulb length and average bulb weight were significant for

bulb yield at phenotypic level. While, the yield is negatively associated with TSS in both phenotypic and genotypic correlations.

Dhotre *et al.* (2010) reported that the bulb yield exhibited positive and significant association with fresh bulb weight, equatorial diameter, TSS and number of rings per bulb and neck thickness.

Singh *et al.* (2011) reported that the bulb diameter, bulb size index and weight of 20 bulbs are correlated to each other. When bulb diameter will increase bulb size index and weight of 20 bulbs also increased and it increased the gross yield and marketable yield.

Mallor *et al.* (2011) evaluated quality-related bulb traits in 15 grower's open-pollinated lines of this cultivar. Significant phenotypic correlations indicated that milder onion tend to show larger size and lower soluble solids content.

Awale Degewione *et al.* (2011) revealed that the bulb yield was positively and significantly associated with plant height, leaf length, leaf sheath length, leaf sheath diameter, bulb length, bulb diameter, bulb dry weight, biological yield per plant and marketable yield per plant at both phenotypic and genotypic levels.

Morsy *et al.* (2011) reported that the bulb weight had highly significant positive correlation with plant weight and TSS% in both seasons. The significant positive correlation was obtained between bulb weight and each of plant height and number of leaves/plant in both seasons. Marketable yield had highly significant positive correlation with plant height and total yield in both seasons. The significant positive correlation was obtained between marketable yield and each of number of leaves/plant, bulb length, and TSS% in both seasons. Total yield had highly significant positive correlation with plant height, plant weight, days to maturity and marketable yield in both seasons. Significant positive correlation was obtained between total yield and each of number of leaves/plant, bulb length, and TSS% in both seasons. The

negative and significant correlation was obtained between total yield and weight loss% at 120 days in the second season.

2.7 Path coefficient analysis

As numbers of factors are involved in correlation studies, their association becomes more complex and confusing. Under such circumstances, the path coefficient analysis help in removing the complication by measuring the direct and indirect influence of one variable upon the other by partitioning the correlation coefficient into the components of direct and indirect effects. This has also an advantage to point out the true yield determinants for genetic improvement of crop.

Rajalingam and Haripriya (2000) reported that the plant height, leaf breadth, weight of plant, bulb length, shape index, days to maturity and harvest index, had direct positive effect on yield, while leaf length, number of leaves, number of bulbs, bulb diameter, and volume of bulb and storage life had negative direct effects. Plant height and weight of plant are dependable indices of selection in identifying the yield potential of individual ecotypes.

Mohanty (2001a) revealed that the bulb weight, followed by bulb diameter, had the highest positive direct effect on bulb yield. It was concluded that these two parameters as well as the number of leaves per plant, were the most important components in the selection for high bulb yield.

Singh (2001) revealed that the genotypic path coefficient were higher than the corresponding phenotypic value indicating a masking effect of the environment. Among the yield components, bulb diameter and bulb weight had the maximum contribution towards onion bulb yield.

Mohanty (2001b) revealed that the path analysis showed that weight and diameter of bulb had high positive direct effect on yield and relatively highest and positive indirect effect through each other. Other

characters also exerted positive indirect effect via these traits on bulb yield.

Mohanty (2002) showed that plant height and number of leaves per plant produced high positive direct effect on yield and high positive indirect effect through each other on yield. Bulb weight and bulb diameter also exerted high positive indirect effects via the above traits on yield.

Dehdari *et al.* (2002) path coefficient analysis revealed that the bulb diameter had the highest positive direct effect on bulb yield, while plant height, through bulb diameter, exhibited the highest indirect effect.

Mohanty (2004) path analysis showed that weight and diameter of bulb produced positive direct effect on yield and positive indirect effect through each other on yield. Plant height and number of leaves/plant also exerted positive indirect effects via these traits on yield suggesting giving emphasis on such traits while making selection for bulb yield in onion.

Gurjar and Singhania (2006) revealed that the path analysis showed that plant height, number of leaves per plant, bulb neck thickness, bulb weight, equatorial and polar bulb diameter had high positive direct effect through each other on yield. Other characters also exerted positive indirect effect via these traits on yield suggesting giving emphasis on such traits simultaneously or in combination with diameter of bulb while imposing selection for amenability in bulb yield of onion crop.

Meena *et al.* (2007) revealed that the maximum direct effect towards bulb yield was inhibited by bulb weight followed by number of leaves per plant, polar bulb diameter and equatorial bulb diameter.

Aliya *et al.* (2007) revealed that path analysis indicated that bulb diameter, plant height and numbers of leave per plant were the principal component of yield.

Dhotre *et al.* (2010) reported that the fresh bulb weight, equatorial diameter and bulb shape index exerted positive direct effect and polar diameter and double/split bulb per cent showed negative direct effect on bulb yield. It was proposed to emphasize more on such characters to improve bulb yield.

Hosamani *et al.* (2010) revealed that the bulb neck thickness had a maximum positive direct effect (3.658) on bulb yield followed by bulb length (2.522), TSS (1.556) and plant height (0.109). Therefore, these are good contributors to bulb yield. Plant height revealed a positive indirect effect on yield and was favourable through bulb length, bulb neck thickness, TSS and dry matter content.

Awale Degewione *et al.* (2011) genotypic path-coefficient analysis revealed that bulb dry weight exerted maximum positive direct effect on bulb yield and also exhibited positive association with bulb yield per plant, suggesting their possible utilization to improve bulb yield per plant.

MATERIAL AND METHODS

This chapter comprises the details about the materials used and the methods adopted during the course of present investigation entitled “Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes” was carried out in rabi season during the year 2011-12.

3.1 Experimental site

The experiment was conducted at Vegetable Research Farm, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.).

3.1.1 Soil

The soil of the experimental field was medium black with good drainage and uniform texture with medium NPK status.

3.1.2 Climate and weather conditions

Jabalpur is situated on ‘Kymore Plateau’ agro-climatic region of Madhya Pradesh at 23.91° North latitude, 79.5° East longitudes and on an altitude of 411.78 meters above the mean sea level. The tropic of cancer passes through the middle of the district. The climate of region is typically semi arid and sub tropical having extreme winter and summer. The average annual rainfall is 1350 mm, which is mostly received during June to October from South-west monsoon. The average maximum temperature is 46°C and minimum temperature 6.8°C. The average annual relative humidity is 74%.

The meteorological parameter during the crop season such as minimum and maximum temperature, sunshine hours, rainfall number of rainy days and relative humidity were recorded at Meteorological observatory Krishi Nagar, JNKVV, Jabalpur are presented in Table 1.

Table 3.1. Meteorological information (week wise) during entire crop season of the year 2012 at Jabalpur

Months	Weeks	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	No. of rainy days	Sun shine (hrs.)
		Max.	Min.	Max.	Min.			
January	01	21.0	03.1	95	35	000.0	00	08.5
	02	23.8	03.5	87	25	000.0	00	09.2
	03	24.6	06.1	87	25	000.0	00	09.4
	04	26.3	08.7	85	36	000.0	00	08.6
February	05	26.3	08.5	88	37	000.0	00	08.3
	06	29.0	09.9	85	36	000.0	00	09.5
	07	29.6	12.7	79	35	000.0	00	07.9
	08	26.2	10.1	83	38	001.4	00	08.7
March	09	29.5	12.6	86	40	004.2	01	08.5
	10	32.1	13.6	82	34	000.0	00	08.8
	11	32.2	11.2	73	20	000.0	00	09.3
	12	36.3	17.9	47	14	000.0	00	08.3
April	13	36.6	15.8	54	12	000.0	00	08.8
	14	36.0	15.5	54	13	000.0	00	08.3
	15	37.1	18.8	62	23	000.3	00	06.8
	16	34.2	19.4	53	17	000.0	00	07.2
	17	38.7	22.7	52	16	000.0	00	07.4
May	18	38.6	25.5	54	15	000.0	00	08.0
	19	40.5	27.0	54.2	14.8	000.0	00	08.3
	20	42.0	28.2	53.5	14.4	000.0	00	08.4

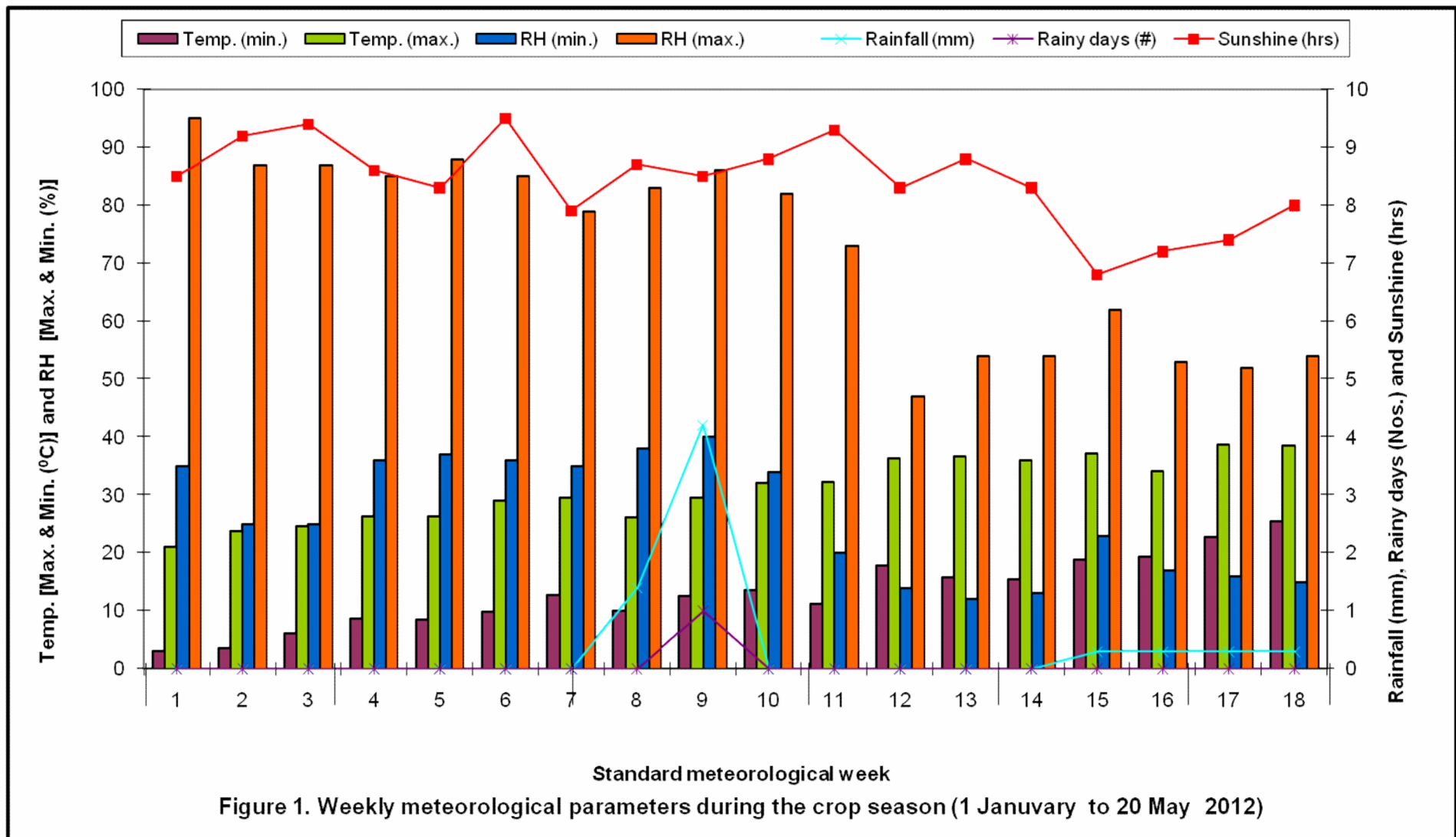


Table 3.2. Details of the experiment are given below

1.	Location	:	Vegetable Research Farm, Department of Horticulture, Maharajpur, JNKVV, Jabalpur (M.P.)
2.	Design of experiment	:	Randomized Complete Block Design
3.	Type of Soil	:	Medium Black
4.	Number of replication	:	3
5.	Number of genotype	:	38
6.	Total number of plots	:	114
7.	Plot size	:	3.0 x 2.0 m
8.	Spacing	:	15 x 10 cm
9.	Number of rows per plot	:	20
10.	Number of plants per row	:	20
11.	Total number of plants per plot	:	400
12.	Gross experimental area	:	1084.0 sq m
13.	Net experimental area	:	684.0 sq m.
14.	Number of plants for observation per plot	:	10
15.	Plot to plot distance	:	0.50m
16.	Distance between replication	:	1.0m
17.	Crop	:	Onion
18.	Season	:	Rabi, 2011-12
19.	Date of transplanting	:	2 nd Jan., 2012
20.	Manure and fertilizer	:	20t FYM, NPK 100:75:50 Kg/ha.

3.3 Treatment detail

The following thirty eight genotypes of onion were included in trial.

S. No.	Genotypes	Source	S. No.	Genotypes	Source
1.	ASRO 1101	DOGR	20.	CSRO 1141	DOGR
2.	ASRO 1104	DOGR	21.	CSRO 1143	DOGR
3.	ASRO 1106	DOGR	22.	CSRO 1148	DOGR
4.	ASRO 1109	DOGR	23.	CSRO 1155	DOGR
5.	ASRO 1111	DOGR	24.	CSRO 1157	DOGR
6.	ASRO 1113	DOGR	25.	CSRO 1160	DOGR
7.	ASRO 1115	DOGR	26.	CSRO 1163	DOGR
8.	ASRO 1119	DOGR	27.	CSRO 1165	DOGR
9.	ASRO 1121	DOGR	28.	CSRO 1168	DOGR
10.	BSRO 1115	DOGR	29.	CSRO 1170	DOGR
11.	BSRO 1119	DOGR	30.	CSRO 1173	DOGR
12.	BSRO 1121	DOGR	31.	CSRO 1175	DOGR
13.	BSRO 1123	DOGR	32.	CSRO 1177	DOGR
14.	BSRO 1125	DOGR	33.	CSRO 1179	DOGR
15.	BSRO 1127	DOGR	34.	CSRO 1181	DOGR
16.	BSRO 1129	DOGR	35.	CSRO 1186	DOGR
17.	CSRO 1115	DOGR	36.	CSRO 1188	DOGR
18.	CSRO 1119	DOGR	37.	CSRO 1190	DOGR
19.	CSRO 1139	DOGR	38.	ALR (Local check)	AADF

All the thirty seven genotypes of onion (*Allium cepa* L.) collected from Directorate, onion and garlic research and one local check ALR was selected for investigation.

PLAN OF LAYOUT

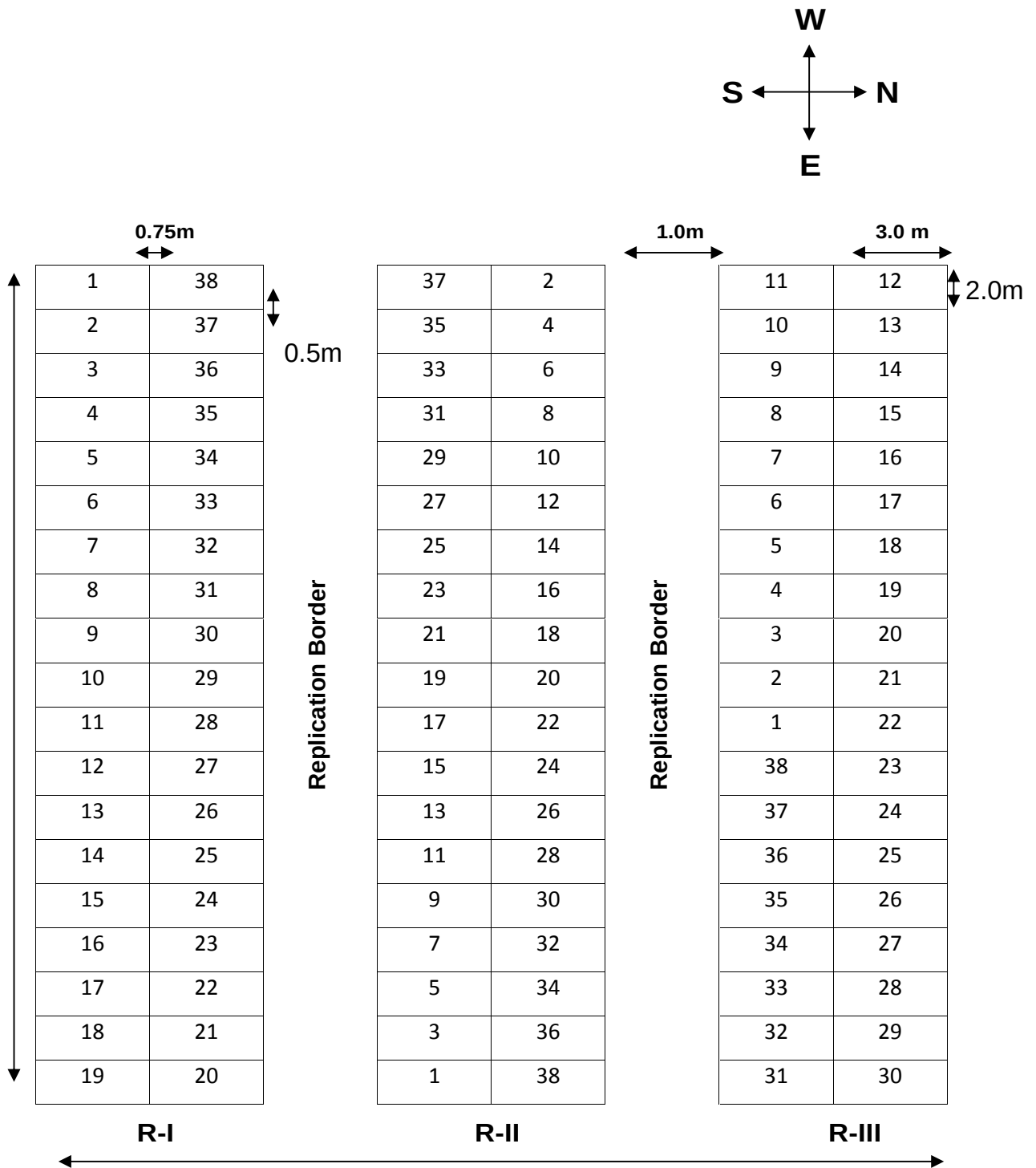


Fig.2. Plan of the layout of experimental plot

3.4 Agronomical operation:

3.4.1 Raising of seedling:

The nursery beds were dug and prepared thoroughly. All the grass, roots, bricks pieces, residue of previous crop, weeds and other undesirable material, if any were removed from the beds. The nursery beds were prepared 1m wide and 3m long and elevated up to 20cm from ground levels. Treated seeds (curisour) of different genotypes of onion were sown on the nursery beds in rows 5cm apart. After sowing seeds were covered with a thin layer of sieved FYM and paddy straw. Sprinkling of water with water cans was done immediately. This practice was repeated frequently as and when required to make the beds well moisturized till the germination. After germination of seeds, cover of dry paddy straw was removed. Weeding was done manually as and when weeds appeared in the nursery beds without disturbing the seedling.

3.4.2 Land preparation:

The experimental area was ploughed and harrowed in order to bring the soil in well pulverized condition. Plots were made according to the layout plan after leveling.

3.4.3 Transplanting and gap filling:

Seedling were uprooted from the nursery bed and transplanted in the plots at a spacing of 15 cm (row to row) and 10 cm (plant to plant). Transplanting was done in the afternoon hours immediately followed by irrigation for proper establishment of the seedlings.

A week after transplanting gap filling was done. All the other recommended package of practices was followed to raise a heating crop.

3.4.4 Fertilizer application:

A basal dose of 100 kg Nitrogen, 75 kg phosphorus and 50 kg potassium were applied, in the form of urea, single super phosphate and murate of potash respectively. Full quantity of FYM, phosphorus and potassium fertilizer along with one third of nitrogen was applied before

transplanting the seedling. While, rest of the nitrogen were applied in two equal splits at 25 and 50 days after transplanting.

3.4.5 Irrigation:

Light irrigation was given just after transplanting and subsequent irrigation was given as and when required depends upon soil type and climatic conditions.

3.4.6 Intercultural operations

The experimental plots were kept weed free. Hand weeding was done as and when needed. The crop was sprayed with monocrotophas, and trizophas alternate to keep the crop free from pest during crop growth period.

3.5 Sampling

Sampling was done at 30 days up to till harvest for growth analysis. Ten plants were randomly selected from each treatment and replication for the study in net plot.

3.6 Observation

The data recorded on various parameters were subdivided into three categories during the period of experimentation.

(A) Morphological Parameters

3.6.1 Plant height (cm)

Plant height was measured from ground level up to tip of longest leaf with the help of meter scale. The height was recorded at (i) 30 days after transplanting. (ii) 60 days after transplanting (iii) 90 days after transplanting and (iv) 120 days after transplanting.

3.6.2 Number of leaves per plant

The number of leaves of selected plants was counted and average was worked out at (i) 30 days after transplanting. (ii) 60 days after transplanting (iii) 90 days after transplanting and (iv) 120 days after transplanting.

3.6.3 Pseudostem length (cm)

Length of pseudostem of selected and tagged plants was measured from the ground level to first emerged green leaf.

3.6.4 Pseudostem diameter (cm)

Diameter of pseudostem of selected and tagged plants was measured at base.

3.6.5 Foliage colour

The colour of the foliage was recorded at 60 days after transplanting in following categories.

- Light green
- Green
- Dark green

3.6.6 Foliage cranking

The cranking of the foliage was recorded at 60 days after transplanting in following categories.

- Absent
- Weak
- Strong

3.6.7 Days to maturity

Days taken for maturity was recorded at the end when leaf completely dry.

(B) Yield Parameters

3.6.8 Neck diameter (cm)

Neck diameter of bulb from each plot and replication was recorded with the help of Vernier's calipers and the mean neck diameter was work out.

3.6.9 Polar diameter of bulb (cm)

Polar diameter of bulb from each plot and replication was recorded with the help of Vernier's calipers and the mean polar diameter was work out.

3.6.10 Equatorial diameter of bulb (mm)

Equatorial diameter of ten randomly selected bulbs from each plot was recorded with the help of Vernier's calipers and the mean equatorial diameter was work out.

3.6.11 Bulb shape

Shape of mature bulb was recorded in following categories.

- Elliptic
- Oval
- Globe
- Flat globe
- Flat

3.6.12 Bulb colour

Colour of dry external scales was recorded in following categories for bulb colour.

- White
- Yellowish
- Pink
- Light red
- Dark red
- Brown
- purple

3.6.13 Bulb yield/plant (g)

Ten selected plant from each genotypes and replication were weighted to determine the average weight for bulb yield of a plant.

3.6.14 Marketable yield (kg/plot)

The onion bulbs harvested from each plot. Weight of marketable bulb was recorded separately.

3.6.15 Marketable yield (q/ha)

Marketable bulb yield per plot (kg) was converted in quintal per hectare by multiplying with factor.

3.6.16 Unmarketable yield (kg/plot)

The after harvesting of onion bulbs from each plot, weighting of unmarketable bulb was recorded separately.

3.6.17 Total bulb yield (kg/plot)

The crop was harvested and bulbs of each plot were weighted in kilograms.

3.6.18 Unmarketable yield (q/ha)

Unmarketable bulb yield per plot (kg) was converted in quintal per hectare by multiplying with factor.

3.6.19 Total bulb yield (q/ha)

Total yield of bulb (kg) per plot was converted in quintal per hectare by multiplying with factor.

3.6.20 Split bulb percentage

The splitting percentage of bulb was calculated by counting the number of splitted bulbs after harvesting.

3.6.21 Bolting percentage

The bolting percentage was calculated by counting the number of bolted plants before harvesting.

C. Quality Parameter

3.6.22 Total Soluble Solid (T.S.S) %

Total soluble solid was estimated with the help of refractometers.

3.7 Statistical methodology

The data obtained in respect of all the characters has been subjected to the following statistical analysis.

3.7.1 Mean: It was calculated by using following formula.

$$\text{Mean} = \frac{\sum x}{n}$$

Where,

$\sum x$ = The sum of all the observation

n = Number of observation

3.7.2 Analysis of variance

The data based on the mean of individual plants selected for observation were statistically analysed described by Panse and Sukhatme (1963) to find out overall total variability present in the material under study for each character and for all the populations. The first and foremost step is to carry out analysis of variance to test the significance of differences among the populations. The skeleton of analysis of variance was used as follows:

Table 3.4: ANOVA for Completely Randomized Block Design

Source of variation	D.F.	Sum of square	Mean sum of square	F value	F _t 5% or 1% table value
Replication	r-1	RSS	RMS	RMS/EMS	-
Genotypes	t-1	TrSS	TrMS	TrMS/EMS	-
Error	(r-1)(t-1)	ESS	EMS	-	-
Total	rt-1	TSS	-	-	-

Where,

r = Number of replications

t = Number of treatments

D.F. = Degree of freedom

RSS = Replication sum of square

TrSS = Genotypes sum of square

ESS = Error sum of square

TSS = Total sum of square

RMS = Replication mean sum of square

TrMS = Genotypes mean sum of square

EMS = Error mean sum of square

A significant value of “F” test indicates that the test entries differ significantly among themselves, which requires computing.

$$C.V. = \frac{\sqrt{EMS}}{GM} \times 100$$

$$S E m \pm = \sqrt{\frac{EMS}{r}}$$

$$S E \text{ diff} = \sqrt{\frac{2 EMS}{r}}$$

CD at 5% prob. Level = SE diff x $t_{5\%}$ table value

Where,

C.V. = Coefficient of variation

SEm $\pm$ = Standard error of means

S E diff = Standard error of difference

GM = Grand mean

C.D. = Critical difference

t 5% = t, table value 5% probability level at error d.f.

Estimation of mean, components of variance, phenotypic, genotypic and environmental coefficient of variation, heritability, genetic advance and genetic advance as percentage of mean:

The mean of different characters were calculated by conventional method:

$$\text{Mean} = \frac{\sum x_i}{n}$$

Where,

$\sum x_i$ = The sum of all the observation for i^{th} character.

N = Number of observations.

Range was recorded by observing the lowest and the highest mean values for each character.

The component of variance was calculated as follows:

S. No.	Source	M.S.S.	Expected M.S.S.
1.	Replication	-	-
2.	Treatment	M_i	$\pm^2 e_i + r. \pm^2 g_i$
3.	Error	E_i	$\pm^2 e_i$

$$\pm^2 g_i = \frac{M_i - E_i}{r}$$

$$\pm^2 e_i = E_i$$

$$\pm^2 p_i = \pm^2 g_i + \pm^2 e_i$$

Where,

$\pm^2 g_i$ = Genotypic variance for i^{th} character.

$\pm^2 e_i$ = Environmental variance for i^{th} character.

$\pm^2 p_i$ = Phenotypic variance for i^{th} character.

Phenotypic and genotypic coefficient of variation (expressed in %) were calculated by using the formula given by Burton (1952). Genotypic coefficient of variation (GCV) was calculated as below:

$$\text{GCV}\% = \frac{\sqrt{\sigma^2 g_i}}{\bar{X}_i} \times 100$$

Phenotypic coefficient of variation (PCV)

$$\text{PCV}\% = \frac{\sqrt{\sigma^2 p_i}}{\bar{X}_i} \times 100$$

Where,

$$\begin{aligned} \bar{X}_i &= \text{General mean of the } i^{\text{th}} \text{ character under consideration} \\ \sigma^2 g_i \text{ and } \sigma^2 p_i &= \text{Genotypic and phenotypic standard deviation of the } i^{\text{th}} \text{ character respectively} \end{aligned}$$

Heritability and genetic advance

Heritability (broad sense) which is ratio of genotypic variance to the total phenotypic variance is symbolized as h^2 (BS) and expressed in percentage. Estimation of heritability was done as per the formula given by Hanson *et al.* (1956).

$$h^2 \text{ (BS)} = \frac{\sigma^2 g_i}{\sigma^2 p_i} \times 100$$

OR

$$h^2 \text{ (BS)} = \frac{\text{Genotypic variance of the } i^{\text{th}} \text{ character}}{\text{Phenotypic variance of the } i^{\text{th}} \text{ character}}$$

Expected genetic advance was calculated by using the method suggested by Johnson *et al.* (1955) at 5% selection intensity.

$$\text{Genetic advance (GA)} = K \cdot P_i \cdot h^2_i$$

Genetic advance as percentage of mean was calculated as follows:

$$\frac{\text{Genetic advance}}{\bar{X}_i} \times 100$$

Where,

K = Selection intensity its value at 5% selection level is 2.06

P_i = Phenotypic standard deviation of the ith character

h²_i = Broad sense heritability (fraction) of the ith character

$\bar{X}_i$ = General mean of the ith character under consideration

Correlation coefficients

Correlation coefficients were calculated in all possible combinations taking all the characters in to consideration at genotypic, phenotypic and environmental levels by using the formula as proposed by Miller *et al.* (1958).

$$r = \frac{\sum xy - \frac{\sum x \times \sum y}{n}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{n} \right) \left(\sum y^2 - \frac{(\sum y)^2}{n} \right)}}$$

Where,

r = Correlation coefficient

n = Number of treatments

X and Y = Character under study

Genotypic, phenotypic and environmental correlations were computed by substituting corresponding variance and covariance in the above formula, e. g.

$$r_G (X_i X_j) = \frac{G \text{ Cov } (X_i X_j)}{\sqrt{V_G (X_i) \cdot V_G (X_j)}}$$

$$r_P (X_i X_j) = \frac{P \text{ Cov } (X_i X_j)}{\sqrt{V_P (X_i) \cdot V_P (X_j)}}$$

$$r_E (X_i X_j) = \frac{E \text{ Cov } (X_i X_j)}{\sqrt{V_E (X_i) \cdot V_E (X_j)}}$$

Testing of correlations:

The phenotypic correlations are tested for their significance by following formula based on “t” test:

$$t_c = r \sqrt{\frac{n-2}{1-R^2}} \quad \text{at } (n-2) \text{ d.f.}$$

Where,

N= Number of treatments.

R= phenotypic correlations coefficient.

The calculated value of “t” is compared with table of “t” at (n-2) d.f. If the calculated value is equal to or greater than table value, it is significant at given probability level. If $t_c < t_T$, it is non significant.

Path coefficients analysis:

Path coefficients analysis was worked out to show the cause and effect relationship between yield and various yield components and to partition the total correlation coefficient into direct and indirect effects. This procedure was developed by Wright (1921) and as per consent used by Li (1956) and followed by Dewey and Lu (1959).

Path coefficients are the standardized partial regression coefficients and as such measure the direct influence of one variable upon another variable and permits partition of correlation coefficient into components of direct and indirect effects. The sum of the direct and all possible indirect effects via all other traits must be equal to correlation coefficient of dependent traits with independent characters under consideration.

Path coefficients were obtained by setting simultaneous equations which express basic relationship between correlation and path coefficient analysis.

1. $r_{1,y} = P_{1,y} + r_{1,2} P_{2,y} + r_{1,3} P_{3,y} + \dots + r_{1,10} P_{10,y}$
2. $r_{2,y} = P_{2,y} + r_{2,1} P_{1,y} + r_{2,3} P_{3,y} + \dots + r_{2,10} P_{10,y}$
10. $r_{10,y} = P_{10,y} + r_{10,1} P_{1,y} + r_{10,2} P_{2,y} + \dots + r_{10,9} P_{9,y}$

Where,

1, 2, ... 10 are the component characters and y is dependent upon which direct and indirect effects are studied.

Unexplained variation of the residual effect was obtained from the following equation:

$$R = \sqrt{1 - \sum di r_{ij}}$$

Where,

R = Residual effect.

di = Direct effect of the i^{th} character.

rij = Correlation coefficient between the i^{th} character and j^{th} dependent character.

Direct and indirect effects of bulb yield per plant were calculated at both genotypic and phenotypic levels.

RESULTS

The results obtained from the present investigation “Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes” are presented under the following heads.

4.1 Analysis of variance

4.2 Genetic Variability

4.2.1 Range and Mean Performance

4.2.2 Coefficient of variation

4.2.3 Heritability

4.2.4 Genetic advance

4.3 Correlation Coefficient analysis

4.4 Path Coefficient analysis

4.5 Quality parameters

4.1 Analysis of variance

The analysis of variances for all the characters studied has been presented in Table 4.1. Mean squares due to genotypes were highly significant for all the characters, indicating that the presence of genetic diversity in the existing material.

Three characters is i.e. unmarketable bulb yield per hectare, bulb yield per hectare and bulb yield per plant showed the value of higher magnitude.

4.2 Genetic Variability

4.2.1 Range and mean performance of the genotype

Range and mean performance (minimum and maximum) of the thirty eight genotypes of onion for all the twenty two characters are depicted in the Table 4.2 a, b and c.

Table 4.1: Analysis of variance for various characters in Onion (mean sum of squares)

Source of variance	D.F.	Plant height (cm)				Leaves per plant			
		30DAT	60DAT	90DAT	120DAT	30DAT	60DAT	90DAT	120DAT
Replications	2	0.219	2.970	0.834	0.670	0.103	0.097	0.050	0.512
Genotypes	37	26.593**	28.875**	41.870**	48.501**	0.448**	0.544**	0.592**	2.426**
Error	74	4.155	1.279	1.273	0.077	0.061	0.053	0.018	0.022

Source of variance	D.F.	Pseudostem length (cm)	Pseudostem diameter (cm)	Days to maturity	Neck thickness (cm)	Polar diameter of bulb(cm)
Replications	2	0.035	0.0003	91.684	0.0038	0.316
Genotypes	37	4.319**	0.0915**	23.410**	0.1788**	1.010**
Error	74	0.053	0.0003	0.603	0.0001	0.016

Source of variance	D.F.	Equatorial diameter of bulb (cm)	Bulb yield /plant (g)	Bulb yield /plot (kg)	Bulb yield /ha.(q)
Replications	2	0.202	1.903	30.819	8277.84
Genotypes	37	0.471**	1223.47**	26.022**	7183.96**
Error	74	0.017	5.750	0.409	313.96

Source of variance	D.F.	Unmark. Bulb yield /plot (kg)	Unmark. Bulb yield /ha.(q)	Split bulb (%)	Bolting (%)	TSS (%)
Replications	2	0.181	98.670	0.07	0.67	71.55
Genotypes	37	0.925**	9536.951**	0.80**	7.22**	3.49**
Error	74	0.027	562.150	0.05	0.46	1.81

4.2.1.1 Plant height (cm)

Plant height varied from 21.33 to 35.20 cm, 25.77 to 41.43 cm, 32.70 to 49.10 cm and 27.67 to 41.83 cm with overall mean performance of 29.00, 35.01, 41.08 and 34.49 cm at 30, 60, 90 and 120 DAT respectively. Genotypes ASRO-1109 was recorded maximum plant height 35.20, 41.43, 49.10 and 41.83 cm and genotype CSRO-1160 was observed minimum plant

height of 21.33, 25.77, 32.70 and 27.67 cm at 30, 60, 90 and 120 DAT respectively.

4.2.1.2 Number of leaves per plant

Number of leaves per plant ranged from 3.40 to 4.90, 3.83 to 5.83, 4.70 to 7.10 and 4.93 to 8.87 leaves per plant with grand mean performance of 4.04, 4.80, 5.46 and 6.46 leaves at 30, 60, 90 and 120 DAT respectively. Highest number of leaves 4.90, 5.83, 7.10 and 8.87 were recorded in genotype Agrifound Light Red (local check) and minimum was noted in CSRO-1160, 3.40, 3.83, 4.70 and 4.93 at 30, 60, 90 and 120 DAT respectively for the same traits.

4.2.1.3 Pseudostem length (cm)

The maximum 10.60 cm length of pseudostem was recorded in genotypes ASRO-1109, while it was found minimum 5.83 cm in genotype CSRO-1160. The average for pseudostem length was 8.65 cm and it varied from 5.83 to 10.60 cm.

4.2.1.4 Pseudostem diameter (cm)

Pseudostem diameter lied between 0.49 to 1.12 cm with the average performance of 0.75 cm. Agrifound Light Red was recorded the maximum (1.12 cm) pseudostem diameter, while it was minimum in ASRO-1115 (0.49cm).

4.2.1.5 Days to maturity

Early maturity was recorded in genotype BSRO-1125 (122.00 days) followed by CSRO-1143, CSRO-1173, CSRO-1175 and BSRO-1123 which mature in 123.0 days. However late maturity was observed in CSRO-1181 (133.30 days). The average days for maturity were 126.44 days and it varied from 122.00 to 133.30 days.

4.2.1.6 Neck thickness (cm)

Neck thickness varied from 0.40 to 1.40 cm with an overall mean performance of 0.71 cm. Genotype BSRO-1121 was recorded minimum neck thickness (0.40 cm) while, it was showed maximum in ASRO-1111 (1.40 cm).

Table 4.2a: Mean performance of morphological parameters of onion

Genotypes	Plant height (cm) at DAT				Leaves per plant at DAT				Pseudo-stem length (cm)	Pseudo-stem diameter (cm)	Days to maturity
	30	60	90	120	30	60	90	120			
CSRO 1115	27.23	36.30	37.63	37.60	3.67	4.57	5.43	6.00	9.27	0.91	128
CSRO 1119	27.80	33.90	42.13	36.20	3.93	4.67	4.90	6.10	9.37	0.74	126
CSRO 1139	28.70	35.03	42.90	28.47	3.97	5.17	5.23	5.37	10.33	0.56	124
CSRO 1141	28.70	36.57	43.60	34.53	3.47	4.87	5.07	5.93	10.23	0.83	126
CSRO 1143	29.13	32.86	37.40	34.27	4.17	4.97	5.33	5.63	7.83	0.66	123
CSRO 1148	24.70	31.53	39.73	31.40	3.70	4.43	5.03	5.90	8.57	0.59	125
CSRO 1155	28.36	32.53	42.97	38.50	3.50	4.43	5.40	7.97	7.97	0.99	127
CSRO 1157	27.76	32.47	38.50	35.43	3.57	4.27	5.30	7.20	7.70	1.05	130
CSRO 1160	21.33	25.77	32.70	27.67	3.40	3.83	4.70	4.93	5.83	0.55	132
CSRO 1163	27.80	34.07	42.00	30.20	4.27	4.43	5.53	5.53	9.17	0.69	127
CSRO 1165	26.06	32.27	38.40	32.27	3.57	4.83	5.60	6.17	8.53	0.55	128
CSRO 1168	26.43	31.57	38.93	32.23	4.27	4.63	5.33	6.27	7.27	0.63	126
CSRO 1170	26.20	30.77	34.43	33.67	3.73	4.43	5.03	6.23	7.63	0.54	125
CSRO 1173	28.46	30.63	38.83	36.13	3.67	4.30	5.57	6.03	7.40	0.78	123
CSRO 1175	24.80	36.53	42.83	40.23	4.17	5.03	5.63	6.17	7.77	0.95	123
CSRO 1177	29.13	36.10	41.37	35.17	4.23	5.53	5.80	5.80	9.63	0.93	125
CSRO 1179	31.63	37.27	45.03	35.67	4.60	4.93	5.57	6.00	9.63	0.88	132
CSRO 1181	32.26	38.13	38.93	34.40	3.80	4.73	5.33	6.17	9.27	0.77	133.3
CSRO 1186	29.00	35.30	44.17	32.80	3.93	5.20	4.87	5.53	10.23	0.72	127
CSRO 1188	30.40	35.00	44.73	36.97	3.83	5.07	5.00	7.67	9.23	0.94	129
CSRO 1190	30.16	38.70	46.63	41.00	3.57	5.37	5.83	7.73	8.97	0.95	131
BSRO 1115	31.20	34.93	38.67	32.67	3.83	4.83	5.90	5.93	7.43	0.64	128
BSRO 1119	30.83	33.00	39.17	27.77	3.83	5.03	5.63	6.10	7.77	0.67	125
BSRO 1121	32.76	33.73	41.53	29.77	4.53	4.70	5.53	6.23	7.47	0.52	124
BSRO 1123	32.83	36.57	41.03	34.60	4.27	5.67	5.67	6.70	8.33	0.76	123
BSRO 1125	24.70	33.73	34.83	28.63	4.17	4.67	5.60	6.13	7.03	0.62	122
BSRO 1127	28.53	37.73	38.80	32.53	4.03	5.33	6.37	5.80	8.10	0.57	125
BSRO 1129	25.36	31.87	35.53	29.47	3.73	4.40	5.20	6.17	7.03	0.72	125
ASRO 1101	31.96	36.27	43.20	35.40	4.33	4.00	5.40	8.60	8.40	0.88	124
ASRO 1104	32.43	35.30	42.43	40.20	4.00	4.43	5.57	8.10	9.67	0.86	125.3
ASRO 1106	35.03	40.30	45.83	39.90	4.27	5.13	5.60	6.60	8.00	1.01	126.3
ASRO 1109	35.20	41.43	49.10	41.83	4.30	4.83	4.90	6.33	10.60	0.57	125
ASRO 1111	30.20	37.60	47.13	40.20	4.27	4.73	5.83	7.57	10.57	1.03	126
ASRO 1113	29.10	34.47	44.03	30.40	4.67	4.53	5.57	6.57	10.23	0.66	128
ASRO 1115	27.86	39.87	45.53	35.43	4.73	4.97	6.00	7.03	10.13	0.49	124
ASRO 1119	29.46	34.90	39.40	35.63	4.60	4.90	5.17	6.57	10.00	0.86	129
ASRO 1121	31.83	38.83	38.00	30.60	4.27	4.63	5.10	6.03	7.63	0.65	130
ALR(L. C)	26.70	36.87	42.97	40.87	4.90	5.83	7.10	8.87	8.50	1.12	125
S.Em±	1.16	0.64	0.64	0.15	0.14	0.13	0.07	0.08	0.13	0.10	0.44
C.D.5% level	3.31	1.84	1.83	0.45	0.40	0.37	0.22	0.24	0.37	0.03	1.26

Table 4.2b: Mean performance of sink parameters of onion

Genotypes	Neck thickness (cm)	Polar diameter of bulb(cm)	Equatorial diameter of bulb (cm)	Bulb yield /plant (g)	Bulb yield /plot (kg)	Bulb yield /ha.(q)
CSRO 1115	1.09	5.13	3.73	49.33	19.783	329.53
CSRO 1119	0.71	4.05	3.70	75.67	21.017	355.78
CSRO 1139	0.76	4.06	4.03	61.00	18.883	314.59
CSRO 1141	1.01	4.30	4.23	60.67	19.183	319.26
CSRO 1143	0.45	3.67	3.40	36.33	17.700	294.88
CSRO 1148	0.56	3.08	3.17	24.33	16.800	279.88
CSRO 1155	1.04	4.03	3.83	29.67	15.125	252.67
CSRO 1157	0.57	3.43	4.01	49.67	17.250	287.38
CSRO 1160	0.43	3.23	3.73	24.33	15.573	231.68
CSRO 1163	0.66	4.02	4.30	66.00	16.500	274.89
CSRO 1165	0.53	3.43	3.73	25.00	17.450	290.71
CSRO 1168	0.59	3.60	3.80	30.33	14.450	240.73
CSRO 1170	0.51	3.40	3.53	26.67	14.250	282.73
CSRO 1173	1.16	3.30	3.33	30.00	14.100	234.90
CSRO 1175	0.96	4.20	4.40	61.33	22.877	381.12
CSRO 1177	0.55	4.08	3.27	79.33	22.967	383.18
CSRO 1179	0.78	5.20	3.87	97.67	23.207	387.06
CSRO 1181	0.60	4.50	3.67	49.67	18.300	304.87
CSRO 1186	0.47	4.37	3.97	62.00	20.100	335.42
CSRO 1188	0.93	4.63	4.02	75.00	22.417	373.45
CSRO 1190	0.72	4.60	4.23	60.00	21.533	358.74
BSRO 1115	0.64	4.03	3.70	28.67	18.017	300.15
BSRO 1119	0.60	3.13	3.47	30.00	14.542	242.26
BSRO 1121	0.40	3.23	3.50	27.00	21.900	364.85
BSRO 1123	0.50	3.67	3.73	29.67	15.917	274.17
BSRO 1125	0.44	3.70	3.20	23.67	13.660	227.57
BSRO 1127	0.56	4.57	3.30	29.33	15.337	259.39
BSRO 1129	0.90	3.20	3.43	31.00	14.700	244.90
ASRO 1101	1.01	3.37	3.07	50.67	15.760	262.56
ASRO 1104	0.82	4.01	3.27	51.00	16.253	270.78
ASRO 1106	1.03	4.33	4.01	79.33	20.417	340.14
ASRO 1109	0.63	3.60	4.30	51.33	15.600	259.89
ASRO 1111	1.40	3.87	4.67	75.00	17.250	284.05
ASRO 1113	0.71	3.40	4.00	48.67	18.500	280.44
ASRO 1115	0.65	4.57	4.37	82.00	23.100	384.84
ASRO 1119	0.43	4.33	3.67	59.00	18.083	301.26
ASRO 1121	0.41	3.73	3.30	40.33	14.697	246.51
ALR(L. C)	0.82	5.13	4.07	52.00	15.017	250.17
S.Em±	0.007	0.07	0.074	1.36	0.36	10.23
C.D.5% level	0.03	0.21	0.21	3.90	1.04	28.93

Table 4.2c: Mean performance of various parameters of onion.

Genotypes	Unmark. Bulb yield /plot (kg)	Unmark. Bulb yield /ha.(q)	Split bulb (%)	Bolting (%)	TSS (%)
CSRO 1115	1.38	23.04	0.33	0.08	14.3
CSRO 1119	1.89	31.43	0.33	0.00	16.0
CSRO 1139	1.85	30.81	0.00	0.83	15.0
CSRO 1141	2.31	38.48	0.25	0.00	16.0
CSRO 1143	1.70	28.37	0.75	0.33	15.8
CSRO 1148	1.82	30.37	0.00	0.50	12.4
CSRO 1155	1.38	23.04	0.67	0.08	15.4
CSRO 1157	1.79	29.81	0.67	0.00	15.0
CSRO 1160	1.07	17.76	0.08	1.58	15.8
CSRO 1163	1.12	18.60	0.17	1.33	14.2
CSRO 1165	1.28	21.26	0.00	2.33	14.2
CSRO 1168	1.05	17.54	0.08	2.25	14.0
CSRO 1170	1.31	21.87	0.00	2.00	14.0
CSRO 1173	0.61	10.15	0.17	0.08	16.4
CSRO 1175	0.37	6.16	0.25	0.17	16.5
CSRO 1177	0.52	8.66	0.42	1.50	14.0
CSRO 1179	1.12	18.71	0.92	0.42	14.2
CSRO 1181	1.73	28.87	1.08	0.25	13.0
CSRO 1186	1.49	24.76	0.17	0.17	14.0
CSRO 1188	1.25	20.82	2.50	0.17	14.2
CSRO 1190	1.21	20.15	0.08	0.08	15.8
BSRO 1115	1.07	17.76	0.08	0.25	17.0
BSRO 1119	0.77	12.87	0.17	0.00	15.0
BSRO 1121	0.24	3.99	0.00	0.33	15.0
BSRO 1123	0.86	14.26	0.75	0.00	13.0
BSRO 1125	0.10	1.66	0.25	0.08	15.4
BSRO 1127	0.77	12.88	0.50	0.42	15.4
BSRO 1129	0.69	11.54	0.08	0.00	16.0
ASRO 1101	0.84	13.60	0.83	0.25	12.4
ASRO 1104	2.37	39.42	1.25	0.17	16.0
ASRO 1106	2.39	39.70	0.50	0.42	16.8
ASRO 1109	1.97	32.87	0.00	0.75	15.0
ASRO 1111	1.65	27.54	1.00	0.42	16.2
ASRO 1113	2.22	36.92	0.08	9.33	16.4
ASRO 1115	1.71	28.48	0.33	0.75	14.0
ASRO 1119	2.28	38.03	0.08	0.08	14.8
ASRO 1121	1.92	31.92	0.00	1.67	16.0
ALR(L. C)	0.83	13.82	1.50	0.00	14.3
S.Em±	0.09	1.57	0.13	0.38	0.76
C.D.5% level	0.26	4.48	0.39	1.11	2.19

4.2.1.7 Polar diameter of bulb (cm)

It was ranged between 3.08 to 5.20 cm with a mean value of 3.95 cm. The maximum 5.20 cm polar diameter of bulb was observed in CSRO-1179 and minimum (3.08cm) was recorded in CSRO-1148.

4.2.1.8 Equatorial diameter of bulb (cm)

Equatorial diameter of bulb ranged from 3.07 to 4.67 cm with average being 3.76 cm. The genotype ASRO-1111 was recorded maximum (4.67 cm) equatorial diameter of bulb, while it was minimum in genotypes ASRO-1101 (3.07 cm).

4.2.1.9 Bulb yield per plant (g)

Genotype CSRO-1179 was recorded maximum bulb yield per plant (97.67g) followed by ASRO-1115 (82.00 g) and CSRO-1177 (79.33 g). While it was noted minimum in genotype BSRO-1125 (23.67 g). The average yield per plant was 49.01 g and it ranged from 23.67 to 96.67 g.

4.2.1.10 Bulb yield per plot (kg)

Bulb yield per plot varied from 13.660 kg to 23.207 kg. with an overall mean performance of 17.84 kg. Highest 23.207, 23.100 and 22.967 kg bulb yield per plot were recorded in CSRO-1179, ASRO – 1115 and CSRO-1177 respectively and which were at par with each other. Therefore, lowest 13.660 kg bulb yield was recorded in BSRO-1125.

4.2.1.11 Bulb yield per hectare (q)

Highest 387.06, 384.84 and 383.18 q/ha bulb yield were exhibited in genotypes CSRO-1179, ASRO - 1115 and CSRO-1177 receptively and which were at par with each other. However, lowest 227.57 q/ha bulb yield was recorded with BSRO-1125. The mean performance of 297.56 q/ha and it was varied from 227.57 to 387.06 q/ha.

4.2.1.12 Unmarketable bulb yield per plot (kg)

Minimum 0.10 kg unmarketable bulb yield per plot was recorded in BSRO-1125, while it was maximum 2.39 kg/plot in genotypes ASRO-1106.

The unmarketable bulb yield varied from 0.10 kg to 2.39 kg/plot with an average of 1.40 kg/plot.

4.2.1.13 Unmarketable bulb yield per hectare (q)

Lowest unmarketable bulb yield was noted in genotype BSRO-1125 (1.66 q/ha) and highest was recorded in genotype ASRO-1106 (39.70 q/ha). The unmarketable bulb yield (q/ha.) varied from 1.66 q/ha to 39.70 q/ha and average unmarketable yield in quintal per hectare was found to be 23.40 q/ha.

4.2.1.14 Split bulb (%)

Minimum (0.0%) splitting percentage was recorded in genotypes viz., CSRO-1139, CSRO-1148, CSRO-1165, CSRO-1170, BSRO-1121, ASRO-1109 and ASRO-1121. Genotype CSRO-1188 was recorded maximum (2.50%) split bulb.

4.2.1.15 Bolting (%)

Bolting percentage was recorded 0.0% in genotypes viz., CSRO-1119, CSRO-1141, CSRO-1157, BSRO-1119, BSRO-1123, BSRO-1129, and Agrifound Light Red. Highest bolting percent was recorded in ASRO 1113 (9.33%).

4.2.1.16 Total soluble solid (TSS%).

Maximum 17.00 percent total soluble solid was obtained in genotype BSRO-1115 followed by ASRO-1106 (16.80%) and it was recorded minimum in genotype CSRO-1148 (12.40%). The total soluble solid varied from 12.40% to 17.00% with an average of 15.00%.

4.2.2 Coefficient of variation

Estimation of components of genetic parameters of variation for yield and its attributes exhibited a wide range of variation for the characters studies (Table 4.3). Result indicated that the value of phenotypic coefficient of variations were higher in magnitude than that of genotypic coefficient of variation for all the characters showing that the environment had an important role in influencing the expression of the characters.

The phenotypic and genotypic coefficient of variation varied from 2.26% to 41.39% and 2.18% to 41.10 % respectively. The highest PCV and GCV were recorded for bulb yield per plant (41.39%), neck thickness (34.30%) and pseudostem diameter (23.11%). However, it was exhibited in low for character viz., days to maturity (2.26 %), number of leaves per plant at 90 DAT (8.38%), plant height at 60 DAT (9.24%), plant height at 90 DAT (9.36%) and number of leaves per plant at 60 DAT (9.70%). Rest of the characters i.e. polar diameter of bulb (14.92%), number of leaves per plant 120 DAT (14.03%), pseudostem length (14.03%), plant height at 30 DAT (11.76%) and at 120 DAT (11.67%) exhibited lowest phenotypic coefficient of variation. Equatorial diameter of bulb (10.91%), number of leaves per plant at 30 DAT (10.79%) and TSS (10.27%) were found to be moderate phenotypic coefficient of variation.

Table 4.3: Genetic parameters in twenty two characters in onion

Characters	Grand Mean	Range		Coefficient of variations		Heritability % (BS)	Genetic Advance	GA as % of mean
		Min.	Max.	Phe.	Gen.			
Plant height 30 DAT	29.00	21.33	35.20	11.76	9.42	64.29	4.51	15.57
Plant height 60 DAT	35.01	25.77	41.43	9.24	8.66	87.79	5.85	16.71
Plant height 90 DAT	41.08	32.70	49.10	9.36	8.95	91.40	7.24	17.63
Plant height 120 DAT	34.49	27.67	41.83	11.67	11.64	99.52	8.25	23.93
Leaves / plant 30 DAT	4.04	3.40	4.90	10.79	8.87	67.52	0.60	15.01
Leaves / plant 60DAT	4.80	3.83	5.83	9.70	8.42	75.42	0.72	15.07
Leaves / plant 90 DAT	5.46	4.70	7.10	8.38	8.00	91.21	0.86	15.75
Leaves / plant 120 DAT	6.46	4.93	8.87	14.03	13.84	97.33	1.81	28.14
Pseudostem length (cm)	8.65	5.83	10.60	14.03	13.77	96.39	2.41	27.86
Pseudostem diameter (cm)	0.75	0.49	1.12	23.11	22.98	98.87	0.35	47.08
Days to maturity	126.44	122.00	133.33	2.26	2.18	92.65	5.46	4.32
Neck thickness (cm)	0.71	0.40	1.40	34.30	34.25	99.74	0.50	70.48
Polar diameter of bulb(cm)	3.95	3.08	5.20	14.92	14.56	95.17	1.15	29.26
Equatorial diameter of bulb (cm)	3.76	3.07	4.67	10.91	10.34	89.82	0.76	20.19
Bulb yield /plant (g)	49.01	23.67	97.67	41.39	41.10	98.60	41.21	84.07
TSS (%)	15.00	12.40	17.00	10.27	4.98	23.53	0.74	4.98

4.2.3 Heritability

The heritability (BS) was computed for each of the characters by the variance components for estimating their relative magnitudes of genotypic and phenotypic variability contributed through environmental factors. The estimates of heritability (BS) for all the characters have been discussed as follows (Table 4.3). It was partitioned as very high (above 90%), high (70 to 90%), medium (50-70%) and low (less than 50%).

Results revealed that the heritability estimate were very high form neck thickness (99.74%) followed by plant height at 120 DAT (99.52%), pseudostem diameter (98.87%), bulb yield per plant (98.60%), number of leaves per plant at 120 DAT (97.33%), pseudostem length (96.39%), polar diameter of bulb (95.17%), days to maturity (92.65%), plant height at 90 DAT (91.40%) and number of leaves per plant at 90 DAT (91.21%). However, high heritability was recorded in the character viz., equatorial diameter of bulbs (89.82%), plant height at 60 DAT (87.79%) and number of leaves per plant at 60 DAT (75.42%). However, it was recorded to be moderate for number of leaves per plant at 30 DAT (67.52%) and plant height at 30 DAT (64.29%). Low estimate of heritability was recorded in total soluble solid (23.53%).

4.2.4 Genetic advance

Based on the estimate of heritability (BS), expected genetic advance was computed on the hypothetical selection at 5 per cent best individual ($K=2.06$). Due to masking influence of environment upon characters concerned, values of genetic advance exhibited high fluctuations. Therefore, to attain relative comparison of the characters in relation to environment genetic advance as percentage of mean was calculated to predict the genetic gain (Table 4.3).

The highest estimate of genetic advance as percentage of mean was recorded for bulb yield per plant (84.07%) followed by neck thickness (70.48%), pseudostem diameter (47.08%), polar diameter of bulb (29.26%), number of leaves per plant at 120 DAT (28.14%), pseudostem length (27.86%), plant height at 120 DAT (23.93%) and equatorial diameter of bulb

(20.19%). Plant height at 90 DAT (17.63%), plant height at 60 DAT (16.71%), number of leaves per plant (15.75%), plant height at 30 DAT (15.57%) number of leaves per plant at 60 DAT (15.07%) and at 30 DAT (15.01%) exhibited moderate value, while total soluble solid (4.98%) and days to maturity (4.32%) had the lowest estimate.

4.3 Correlation coefficient analysis

Correlation coefficients were worked out at phenotypic, genotypic and environmental levels for all possible combination of yield and its attributing characters (Table 4.4). Results indicated that genotypic correlation coefficient, in general, were of higher magnitude than the corresponding phenotypic correlation coefficient for all the characters.

The results of phenotypic correlation coefficients have been discussed only as the genotypic and environmental correlation were mostly influenced by the environmental conditions, hence phenotypic correlation will give the correct idea about the association between two variables.

Plant height at 30 DAT

Plant height at 30 DAT had high significant and positive association with plant height at 60 DAT (0.593), pseudostem length (0.327) plant height at 90 DAT (0.370), number of leaves per plant at 30 DAT (0.361), plant height at 120 DAT (0.276) and numbers of leaves per plant at 60 DAT (0.214).

Plant height at 60 DAT (cm)

Plant height at 60 DAT showed positive and significant correlation with polar diameter of bulb (0.545), plant height at 90 DAT (0.541), bulb yield per plant (0.540), pseudostem length (0.530), number of leaves at 60 DAT (0.491), plant height at 120 DAT (0.484), number of leaves per plant at 30 DAT (0.418), equatorial diameter (0.338), pseudostem diameter (0.261) and neck thickness (0.195).

Plant height at 90 DAT (cm)

Significant and positive correlation of plant height at 90 DAT was recorded with pseudostem length (0.641), bulb yield per plant (0.613),

equatorial diameter of bulb (0.584), plant height at 120 DAT (0.577), pseudostem diameter (0.486), polar diameter of bulb (0.484), neck thickness (0.449), number of leaves per plant at 60 DAT (0.417), at 90 DAT (0.317) at 30 DAT (0.262) and at 120 DAT (0.230).

Plant height at 120 DAT (cm)

Highly significant and positive association of plant height at 120 DAT was observed with pseudostem diameter (0.706), neck thickness (0.565), bulb yield per plant (0.549), number of leaves per plant at 120 DAT (0.508), polar diameter of bulb (0.488), equatorial diameter of bulb (0.399), pseudostem length (0.339) and number of leaves per plant at 60 DAT (0.232).

Table 4.4 : Estimates of genotypic and phenotypic correlation coefficients among yield and its contributing characters

Characters		Plant height (cm)			Leaves per plant (cm)				Pseudostem length (cm)	Pseudo stem diameter (cm)	days to maturity	Neck thickness (cm)	Polar diameter & bulb (cm)	Equatorial diameter of bulb (cm)	TSS (%)	Bulb yield/plant (g)
		60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT								
plant height at 30 DAT (cm)	G	0.723	0.460	0.351	0.365	0.310	-0.015	0.181	0.406	0.187	0.074	0.110	0.180	0.055	0.182	0.197
	P	0.593**	0.370**	0.276**	0.361**	0.214*	-0.020	0.146	0.327**	0.153	0.042	0.091	0.139	0.037	0.085	0.168
Plant height at 60 DAT (cm)	G		0.619	0.521	0.479	0.567	0.199	0.025	0.568	0.276	0.015	0.212	0.599	0.379	0.229	0.572
	P		0.541**	0.484**	0.418**	0.491**	0.183	0.011	0.530**	0.261**	0.014	0.195*	0.545**	0.338*	0.092	0.540**
Plant height at 90 DAT (cm)	G			0.604	0.363	0.488	0.343	0.232	0.677	0.513	0.037	0.472	0.510	0.623	0.232	0.651
	P			0.577**	0.262**	0.417**	0.317**	0.230*	0.641**	0.486	0.026	0.449**	0.484**	0.584**	0.105	0.613**
Plant height at 120 DAT (cm)	G				0.056	0.264	0.183	0.516	0.346	0.713	0.033	0.567	0.498	0.425	0.123	0.554
	P				0.044	0.232*	0.179	0.508**	0.339**	0.706**	0.031	0.565**	0.488**	0.399**	0.055	0.549**
Leaves/plant at 30 DAT (cm)	G					0.349	0.304	-0.178	0.370	-0.023	-0.253	-0.177	0.167	0.038	0.060	0.236
	P					0.278**	0.230*	-0.148	0.298**	-0.023	-0.220*	-0.144	0.138	0.037	0.022	0.185
Leaves/plant at 60 DAT (cm)	G						0.476	-0.321	0.400	0.218	-0.181	-0.118	0.547	0.247	0.121	0.289
	P						0.424**	-0.269**	0.326**	0.185*	-0.174	-0.098	0.489**	0.219*	0.132	0.247**
Leaves/plant at 90 DAT (cm)	G							0.069	-0.041	0.199	-0.167	0.054	0.248	0.098	0.216	-0.013
	P							0.057	-0.034	0.192*	-0.150	0.051	0.229*	0.096	0.066	-0.01
Leaves/plant at 120 DAT (cm)	G								0.034	0.444	0.051	0.550	-0.066	-0.003	-0.017	0.083
	P								0.027	0.431**	0.011	0.540**	-0.064	0.008	-0.009	0.078
Pseudostem length (cm)	G									0.323	0.105	0.328	0.530	0.423	0.180	0.705
Pseudostem diameter (cm)	P									0.319**	0.095	0.321	0.510**	0.393**	0.062	0.691**
Pseudostem diameter (cm)	G										0.191	0.602	0.467	0.281	0.125	0.521
Days to maturity	P										0.185*	0.598**	0.453**	0.265**	0.054	0.519**
Days to maturity	G											-0.107	0.316	0.197	-0.046	0.122
Neck thickness (cm)	P											-0.101	0.278**	0.172	-0.026	0.118
Neck thickness (cm)	G												0.251	0.362	0.086	0.478
	P												0.245**	0.339**	0.067	0.475**
Polar diameter of bulb (cm)	G													0.395	0.087	0.696
	P													0.359**	0.037	0.676**
Equatorial diameter of bulb (cm)	G														0.228	0.596
	P														0.116	0.556**
TSS(%)	G															0.361
	P															0.173

Significant at 5% level= *
significant at 1% level= **

Number of leaves per plant at 30 DAT

Correlation coefficient of this trait was positive and significant with pseudostem length (0.298), number of leaves per plant at 60 DAT (0.278) and at 90 DAT (0.230). But the association with days to maturity (-0.220) was negative and significant.

Number of leaves per plant at 60 DAT

Number of leaves per plant at 60 DAT expressed positive and significant correlation with polar diameter of bulb (0.489), number of leaves per plant at 90 DAT (0.424), pseudostem length (0.326), bulb yield per plant (0.247), equatorial diameter of bulb (0.219) and pseudostem diameter (0.185). However association was significant and negative with number of leaves per plant at 120 DAT (-0.269).

Number of leaves per plant at 90 DAT

Number of leaves per plant at 90 DAT exhibited positive and significant association with polar diameter of bulb (0.229) and pseudostem diameter (0.192).

Number of leaves per plant at 120 DAT

A highly significant and positive correlation of number of leaves per plant at 120 DAT was recorded with neck thickness (0.540) and pseudostem diameter (0.431).

Pseudostem length (cm)

Pseudostem length expressed a significant and positive association with bulb yield per plant (0.691), polar diameter of bulb (0.510), equatorial diameter of bulb (0.393), neck thickness (0.321) and pseudostem diameter (0.319).

Pseudostem diameter (cm)

Correlation coefficient for pseudostem diameter was significant and positive with neck thickness (0.598), bulb yield per plant (0.519), polar diameter of bulb (0.453), equatorial diameter of bulb (0.265) and days to maturity (0.185).

Days to maturity

Days to maturity expressed a significant and positive correlation with polar diameter of bulb (0.278).

Neck thickness (cm)

Neck thickness found to be significant and positively associated with bulb yield per plant (0.475), equatorial diameter of bulb (0.339) and polar diameter of bulb (0.245).

Polar diameter of bulb (cm)

Correlation coefficient was noted to be positive and significant with bulb yield per plant (0.676) and equatorial diameter of bulb (0.359).

Equatorial diameter of bulb (cm)

Equatorial diameter of bulb had positive and significant association with bulb yield per plant (0.556).

Bulb yield per plant (g)

Correlation coefficient of bulb yield per plant was recorded positive and significant with pseudostem length (0.691), followed by polar diameter of bulb (0.676), plant height at 90 DAT (0.613), equatorial diameter of bulb (0.556), plant height at 120 DAT (0.549), plant height at 60 DAT (0.540), pseudostem diameter (0.519), neck thickness (0.475), number of leaves per plant at 60 DAT (0.247) and at 30 DAT (0.185).

4.4 Path coefficient analysis

To measure the direct as well as indirect association of one variable (cause) through another on the end product (effect), path coefficients were calculated at genotypic and phenotypic levels for all the yield attributing traits. The observed correlation coefficients of yield with its contributing traits were partitioned into direct and indirect effects. In the present investigation, important characters i.e. bulb yield per plant have been used as dependable variables with other traits. Since the values of genotypic path are more reliable in predicting the correct idea about the direct and indirect effects of the component traits, only this has been discussed as below.

The estimates of path coefficient were furnished in the Table 4.5. In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects. The results obtained from genotypic direct and indirect effects are presented as under.

Direct effect

Path coefficient analysis of different characters contributing towards bulb yield per plant showed that number of leaves per plant at 60 DAT (0.5863) had highest positive direct effect followed by pseudostem length (0.5649), pseudostem diameter (0.3957), TSS percent (0.3106), plant height at 90 DAT (0.2689), polar diameter of bulb (0.2333), plant height at 120 DAT (0.1405) and equatorial diameter of bulb (0.0171). Whereas number of leaves per plant (-0.6488) had the highest negative direct effect on bulb yield per plant followed by neck thickness (-0.3231), plant height at 30 DAT (-0.3149), days to maturity (-0.2683), number of leaves per plant at 90 DAT (-0.2409), at 120 DAT (-0.2094) and at 30 DAT (-0.1195).

Indirect effect

Plant height (cm)

Plant height at 30 DAT imparted highest positive indirect effect on bulb yield per plant via number of leaves per plant at 90 DAT (0.0049). Whereas indirect effect was visible to be highest via plant height at 60 DAT (-0.2271) and at 90 DAT (-0.1451), pseudostem length (-0.1281), number of leaves per plant at 30 DAT (-0.1152), plant height at 120 DAT (-0.1107) number of leaves per plant at 60 DAT (-0.0978) pseudostem diameter (-0.0590), TSS percent (-0.0576), number of leaves per plant at 120 DAT (-0.0571), polar diameter of bulb (-0.0567), neck thickness (-0.0348), days to maturity (-0.0233) and equatorial diameter of bulb (-0.0176).

Plant height at 60 DAT manifested highest positive indirect effect through plant height at 30 DAT (0.4239), and at 90 DAT (0.3633), polar diameter of bulb (0.3515), pseudostem length (0.3332), number of leaves per plant at 60 DAT (0.3325), plant height at 120 DAT (0.3058), number of leaves

per plant at 30 DAT (0.2810), equatorial diameter of bulb (0.2227), psedostem diameter (0.1621), TSS percent (0.1344), neck thickness (0.1248), number of leaves per plant at 90 DAT (0.1168) and at 120 DAT (0.0150) and days to maturity (0.0091).

Plant height at 90 DAT exhibited highest positive indirect effect via psedostem length (0.1823), equatorial diameter of bulb (0.1677), plant height at 60 DAT (0.1666), and at 120 DAT (0.1625), psedostem diameter (0.1380), polar diameter of bulb 0.1372), number of leaves per plant at 60 DAT (0.1313), neck thickness (0.1271), plant height at 30 DAT (0.1239), number of leaves per plant at 30 DAT (0.0976) at 90 DAT (0.0923), TSS percent (0.0625), number of leaves per plant at 120 DAT (0.0624) and days to maturity (0.0101).

Plant height at 120 DAT imported highest positive indirect effect on bulb yield per plant via psedostem diameter (0.1002), plant height 90 DAT (0.0848), neck thickness (0.0797), plant height at 60 DAT (0.0733), number of leaves per plant at 120 DAT (0.0726), polar diameter of bulb (0.0701), equatorial diameter of bulb (0.0598), plant height at 30 DAT (0.0494), psedostem length (0.0486), number of leaves per plant at 60 DAT (0.0371) and at 90 DAT (0.0258), TSS percent (0.0173), number of leaves per plant at 30 DAT (0.0079) and days to maturity (0.0047).

Number of leaves per plant

Number of leaves per plant at 30 DAT exhibited significant positive indirect effect via days to maturity (0.0303), number of leaves per plant at 120 DAT (0.0213), neck thickness (0.0212) and psedostem diameter (0.0028). Highest negative indirect effect was observed through plant height at 60 DAT (-0.0572), psedostem length (-0.0443), plant height at 30 DAT (-0.0437), and at 90 DAT (-0.0434), number of leaves per plant at 60 DAT (-0.0418), and at 90 DAT (-0.0363), polar diameter of bulb (-0.0200), and TSS percent (-0.0072).

Number of leaves per plant at 60 DAT was reported to have highest positive indirect effect on bulb yield per plant through, number of leaves per plant at 120 DAT (0.2089), days to maturity (0.1178) and neck thickness (0.0769). Whereas, it was expressed high negative indirect effect via plant height at 60 DAT (-0.3679), polar diameter of bulb (-0.3554), plant height at 90 DAT (-0.3168), number of leaves per plant at 90 DAT (-0.3093), pseudostem length (-0.2595), number of leaves per plant at 30 DAT (-0.2269) and plant height at 30 DAT (-0.2015).

Number of leaves per plant at 90 DAT expressed highest positive indirect effect through days to maturity (0.0404), pseudostem length (0.0100) and plant height at 30 DAT (0.0035). Its indirect negative effect was high via number of leaves per plant at 60 DAT (-0.1149), plant height at 90 DAT (-0.0827), number of leaves per plant at 30 DAT (-0.0733), polar diameter of bulb (-0.0598), TSS percent (-0.0522), pseudostem diameter (-0.0481), plant height at 60 DAT (-0.0480) and at 120 DAT (-0.0442).

Number of leaves per plant at 120 DAT manifested positive indirect effect through number of leaves per plant at 60 DAT (0.0674) and at 30 DAT (0.0373) and polar diameter of bulb (0.0140). It showed negative indirect effect through neck thickness (-0.1153), plant height at 120 DAT (-0.1082), pseudostem diameter (-0.0930), plant height at 90 DAT (-0.0486) and at 30 DAT (-0.0380).

Pseudostem length(cm)

Pseudostem length revealed high values of positive indirect on bulb yield per plant through plant height at 90 DAT (0.3830) and at 60 DAT (0.3210), polar diameter of bulb (0.2996), equatorial diameter of bulb (0.2392), plant height at 30 DAT (0.2297), number of leaves per plant at 60 DAT (0.2260), at 30 DAT (0.2095), plant height at 120 DAT (0.1956), neck thickness (0.1857) and pseudostem diameter (0.1824).

Pseudostem diameter (cm)

Pseudostem diameter expressed a positive indirect effect on bulb yield per plant through plant height at 120 DAT (0.2823), neck thickness (0.02384), plant height at 90 DAT (0.2031), polar diameter of bulb (0.1850), number of leaves per plant at 120 DAT (0.1758), pseudostem length (0.1278), equatorial diameter of bulb (0.1115) and plant height at 60 DAT (0.1094).

Days to maturity

Days to maturity revealed high values of positive indirect effect on bulb yield per plant through number of leaves per plant at 30 DAT (0.0680), at 60 DAT (0.0487), at 90 DAT (0.0450), neck thickness (0.0288) and TSS percent (0.0126). While the remaining characters showed high negative indirect effect i.e. Polar diameter of bulb (-0.0850), equatorial diameter of bulb (-0.0529), pseudostem diameter (-0.0514), pseudostem length (-0.0284), plant height at 30 DAT (-0.0199) and at 90 DAT (-0.0101).

Neck thickness (cm)

Neck thickness manifested highest positive indirect effect on bulb yield per plant through number of leaves per plant at 30 DAT (0.0574), at 60 DAT (0.0383) and days to maturity (0.0347). However rest of the characters showed negative indirect effect viz., pseudostem diameter (-0.1946), plant height at 120 DAT (-0.1833), number of leaves per plant at 120 DAT (-0.1779), plant height at 90 DAT (-0.1527), equatorial diameter of bulb (-0.1172) and pseudostem length (-0.1062).

Polar diameter of bulb (cm)

Polar diameter of bulb expressed a positive indirect effect on bulb yield per plant through plant height at 60 DAT (0.1399), number of leaves per plant at 60 DAT (0.1278), pseudostem length (0.1238), plant height at 90 DAT (0.1191) and at 120 DAT (0.1164), pseudostem diameter (0.1091), equatorial diameter of bulb (0.0923) and days to maturity (0.0739).

Equatorial diameter of bulb (cm)

Highest positive indirect effect of equatorial diameter of bulb on bulb yield per plant was recorded through plant height at 90 DAT (0.0106), and at 120 DAT (0.0073), pseudostem length (0.0072), polar diameter of bulb (0.0067), plant height at 60 DAT (0.0065), neck thickness (0.0062), pseudostem diameter (0.0048) and number of leaves per plant at 60 DAT (0.0042).

TSS (%)

Total soluble solid percentage exhibited positive indirect effect via. Plant height at 90 DAT (0.0710), at 60 DAT (0.0772), equatorial diameter of bulb (0.0710), number of leaves per plant at 90 DAT (0.0673), neck thickness (0.0580), plant height at 30 DAT (0.0568) and pseudostem length (0.0562).

Table 4.5 : Estimate of genotypic and phenotypic path coefficient analysis showing direct and indirect effect on bulb yield per plant

Characters		Plant height (cm)				Leaves per plant				Pseudostem length (cm)	Pseudostem diameter (cm)	Days to maturity	Neck thickness (cm)	Polar diameter of bulb (cm)	Equatorial diameter of bulb (cm)	TSS (%)	"r" value of bulb yield/plant (g)
		30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT								
Plant height at	G	-0.3149	-0.2271	-0.1451	-0.1107	-0.1152	-0.0978	0.0049	-0.0571	-0.1281	-0.0590	-0.0233	-0.0348	-0.0567	-0.0176	-0.0576	0.197
30 DAT (CM)	P	-0.0142	-0.0084	-0.0526	-0.0393	-0.0515	-0.0305	0.0029	-0.0209	-0.0465	-0.0218	-0.0060	-0.0130	-0.0199	-0.0053	-0.0121	0.168
Plant height at	G	0.4239	0.5863	0.3633	0.3058	0.2810	0.3325	0.1168	0.0150	0.3332	0.1621	0.0091	0.1248	0.3515	0.2227	0.1344	0.572
60 DAT (cm)	P	0.0878	0.1481	0.0801	0.0718	0.0619	0.0728	0.0272	0.0016	0.0785	0.0387	0.0021	0.0290	0.0807	0.0501	0.0136	0.540
Plant height at	G	0.1239	0.1666	0.2689	0.1625	0.0976	0.1313	0.0923	0.0624	0.1823	0.1380	0.0101	0.1271	0.1372	0.1677	0.0625	0.651
90 DAT (cm)	P	0.0160	0.0233	0.0431	0.0249	0.0113	0.0180	0.0137	0.0100	0.0276	0.0210	0.0011	0.0194	0.0209	0.0252	0.0045	0.631
Plant height at	G	0.0494	0.0733	0.0849	0.1405	0.0079	0.0371	0.0258	0.0726	0.0486	0.1002	0.0047	0.0797	0.0701	0.0598	0.0017	0.554
120 DAT (cm)	P	0.0074	0.0129	0.0154	0.0266	0.0012	0.0062	0.0048	0.0135	0.0090	0.0188	0.0008	0.0151	0.0130	0.0106	0.0015	0.549
Leaves/plant at	G	-0.0437	-0.0572	-0.0434	-0.0067	-0.1195	-0.0418	-0.0363	0.0213	-0.0443	0.0028	0.0303	0.0212	-0.0200	-0.0045	-0.0072	0.236
30 DAT (CM)	P	0.0322	0.0373	0.0234	0.0039	0.0891	0.0248	0.0205	-0.0132	0.0266	-0.0021	-0.0196	-0.0129	0.0123	0.0033	0.0020	0.185
Leaves/plant at	G	-0.2015	-0.3679	-0.3168	-0.1714	-0.2269	-0.6488	-0.3093	0.2089	-0.2595	-0.1471	0.1178	0.0769	-0.3554	-0.1604	-0.0786	0.289
60 DAT (cm)	P	-0.0429	-0.0982	-0.0834	-0.0464	-0.0555	-0.1998	-0.0848	0.0538	-0.0652	-0.0371	0.0349	0.0197	-0.0979	-0.0438	-0.0265	0.247
Leaves/plant at	G	0.0035	-0.0480	-0.8270	-0.0442	-0.0733	-0.1149	-0.2409	-0.0168	0.0100	-0.4810	0.0404	-0.0132	-0.0598	-0.0238	-0.0522	-0.013
90 DAT (cm)	P	0.0028	-0.0251	-0.0434	-0.0245	-0.0314	-0.0579	-0.1365	-0.0078	0.0048	-0.0263	0.0205	-0.0071	-0.0313	-0.0131	-0.0090	-0.011
Leaves/plant at	G	-0.0380	-0.0053	-0.0486	-0.1082	0.0373	0.0674	-0.0146	-0.2094	-0.0073	-0.0930	-0.0033	-0.1153	0.0140	0.0008	0.0036	0.083
120 DAT (cm)	P	-0.0138	-0.0010	-0.0218	-0.0479	0.0139	0.0254	-0.0054	-0.0942	-0.0025	-0.0407	-0.0011	-0.0509	0.0060	-0.0008	0.0009	0.078
Pseudostem length (cm)	G	0.2297	0.3210	0.3830	0.1956	0.2095	0.2260	-0.0233	0.0197	0.5649	0.1824	0.0597	0.1857	0.2996	0.2392	0.1022	0.705
	P	0.0868	0.1407	0.1701	0.0901	0.0793	0.0867	-0.0093	0.0072	0.2654	0.0085	0.0254	0.0854	0.1356	0.1043	0.0166	0.691
Pseudostem diameter (cm)	G	0.0742	0.1094	0.2031	0.2823	-0.0092	0.0864	0.0789	0.1758	0.1278	0.3957	0.7580	0.2384	0.1850	0.1115	0.0498	0.521
	P	0.0224	0.0382	0.0712	0.1035	-0.0034	0.0272	0.0282	0.0632	0.0468	0.1464	0.0271	0.0876	0.0664	0.0388	0.0080	0.519
Days to maturity	G	-0.0199	-0.0042	-0.0101	-0.0090	0.0680	0.0487	0.0450	-0.0042	-0.0284	-0.0514	-0.2683	0.0288	-0.0850	-0.0529	0.0126	0.122
	P	-0.0043	-0.0015	-0.0027	-0.0032	0.0224	0.0177	0.0152	-0.0012	-0.0097	-0.0188	-0.1014	0.0103	-0.0282	-0.0175	0.0026	0.118
Neck thickness (cm)	G	-0.0357	-0.0688	-0.1527	-0.1833	0.0574	0.0383	-0.0177	-0.1779	-0.1062	-0.1946	0.0347	-0.3231	-0.0811	-0.1172	-0.0603	0.478
	P	0.0069	0.0149	0.0342	0.0430	-0.0110	-0.0075	0.0039	0.4120	0.0245	0.0455	-0.0077	0.0761	0.0187	0.0258	0.0074	0.475
Polar diameter of bulb (cm)	G	0.6420	0.1399	0.1191	0.1164	0.3910	0.1278	0.0579	-0.0516	0.1238	0.1091	0.0739	0.0586	0.2333	0.0923	0.0204	0.696
	P	0.0455	0.1773	0.1575	0.1587	0.0450	0.1593	0.0745	-0.0208	0.1661	0.1475	0.0904	0.0799	0.3252	0.1170	0.0123	0.676
Equatorial diameter of bulb (cm)	G	0.0010	0.0065	0.0106	0.0073	0.0060	0.0042	0.0017	-0.0001	0.0072	0.0048	0.0034	0.0062	0.0067	0.0171	0.0039	0.596
	P	0.0084	0.0760	0.1312	0.0897	0.0083	0.0492	0.0216	0.0019	0.0883	0.0596	0.0388	0.0762	0.0809	0.2247	0.0261	0.556
TSS(%)	G	0.0568	0.0712	0.0722	0.0383	0.0188	0.0376	0.0673	-0.0053	0.0562	0.0391	-0.0146	0.0580	0.0271	0.0710	0.3106	0.361
	P	0.0101	0.0109	0.0124	0.0065	0.0026	0.0157	0.0078	-0.0011	0.0074	0.0065	-0.0115	0.0115	0.0045	0.0138	0.1183	0.173

Genotypic residual effect = 0.3256

Phenotypic residual effect = 0.4433

4.5 Quality parameters

Qualitative characters like foliage colour, foliage cranking, bulb shape and bulb colour, are summarized in Table 4.6 to 4.9.

Foliage Colour

The colour of foliage was observed dark green, green and light green at 60 DAT. Most of the genotypes had green foliage while, genotypes CSRO 1168, CSRO 1173, CSRO 1175, ASRO 1106 and ALR(L. C) exhibited dark green and genotypes CSRO 1143, CSRO 1148, CSRO 1155, CSRO 1160, BSRO 1121, BSRO 1123, BSRO 1125 and ASRO 1109 exhibited light green foliage.

Table 4.6: Categorization of onion genotypes based on foliage colour

Dark green	Green	Light green
CSRO 1168, CSRO 1173, CSRO 1175, ASRO 1106, ALR(L. C),	CSRO 1115, CSRO 1119, CSRO 1139, CSRO 1141, CSRO 1157, CSRO 1163, CSRO 1165, CSRO 1170, CSRO 1177, CSRO 1179, CSRO 1181, CSRO 1186, CSRO 1188, CSRO 1190, BSRO 1115, BSRO 1119, BSRO 1127, BSRO 1129, ASRO 1101, ASRO 1104, ASRO 1111, ASRO 1113, ASRO 1115, ASRO 1119, ASRO 1121	CSRO 1143, CSRO 1148, CSRO 1155, CSRO 1160, BSRO 1121, BSRO 1123, BSRO 1125, ASRO 1109,

Foliage cranking

Variation were observed among the genotypes for foliage cranking i.e. Week, strong and absent (Table 4.7). Foliage cranking were observed strong in genotypes, CSRO 1139, CSRO 1155, CSRO 1157, CSRO 1173, CSRO 1175, CSRO 1181, BSRO 1119, BSRO 1123, BSRO 1127, BSRO 1129 and ASRO 1121, whereas CSRO 1168 and ASRO 1106 showed absent foliage cranking and rest of the genotypes exhibited week foliage cranking.

Table 4.7: Categorization of onion genotypes based on foliage cranking

Week	Strong	Absent
CSRO 1115, CSRO 1119, CSRO 1141, CSRO 1143, CSRO 1148, CSRO 1160, CSRO 1163, CSRO 1165, CSRO 1170, CSRO 1177, CSRO 1179, CSRO 1186, CSRO 1188, CSRO 1190, BSRO 1115, BSRO 1121, BSRO 1125, ASRO 1101, ASRO 1104, ASRO 1109, ASRO 1111, ASRO 1113, ASRO 1115, ASRO 1119, ALR(L. C),	CSRO 1139, CSRO 1155, CSRO 1157, CSRO 1173, CSRO 1175, CSRO 1181, BSRO 1119, BSRO 1123, BSRO 1127, BSRO 1129, ASRO 1121,	CSRO 1168, ASRO 1106,

Bulb Shape

Variability were observed for bulb shape viz. flat, flat globe, globe and oval. Flat bulb shape was visible in genotypes CSRO 1177, CSRO 1179, CSRO 1186 and ALR(L. C). Genotypes CSRO 1141, CSRO 1155, CSRO 1163, BSRO 1125, ASRO 1101 and ASRO 1104 were recorded in globe shape of bulb, while genotypes CSRO 1139, ASRO 1109, ASRO 1113 and ASRO 1121 were observed in oval shape. The remaining genotypes showed flat globe shape of bulb (Table 4.8).

Table 4.8: Categorization of onion genotypes based on bulb shape

Flat	Flat globe	Globe	Oval
CSRO 1177, CSRO 1179, CSRO 1186, ALR(L. C),	CSRO 1115, CSRO 1119, CSRO 1143, CSRO 1148, CSRO 1157, CSRO 1160, CSRO 1165, CSRO 1168, CSRO 1170, CSRO 1173, CSRO 1175, CSRO 1181, CSRO 1188, CSRO 1190, BSRO 1115, BSRO 1119, BSRO 1121, BSRO 1123, BSRO 1127, BSRO 1129, ASRO 1106, ASRO 1111, ASRO 1115, ASRO 1119,	CSRO 1141, CSRO 1155, CSRO 1163, BSRO 1125, ASRO 1101, ASRO 1104,	CSRO 1139, ASRO 1109, ASRO 1113, ASRO 1121,

Bulb Colour

Variability were observed for bulb colour viz brown, light red, red, white and pink. Brown bulb colour was visible in genotypes CSRO 1115, CSRO 1190, BSRO 1115, BSRO 1119, BSRO 1123, BSRO 1129, ASRO 1109, ASRO 1119 and ASRO 1121. Genotypes CSRO 1119, CSRO 1157, CSRO 1163, CSRO 1165, CSRO 1168, CSRO 1170, CSRO 1175, CSRO 1177, BSRO 1127, ASRO 1101, ASRO 1106, ASRO 1113 and ALR(L. C) were recorded in light red colour of bulb and genotypes CSRO 1143, CSRO 1148, CSRO 1186 and CSRO 1188 were observed in white bulb. Genotype ASRO 1115 exhibited pink colour of bulb. The remaining genotypes showed red bulb (Table 4.9).

Table 4.9: Categorization of onion genotypes based on bulb colour

Brown	Light red	Red	White	Pink
CSRO 1115, CSRO 1190, BSRO 1115, BSRO 1119, BSRO 1123, BSRO 1129, ASRO 1109, ASRO 1119, ASRO 1121,	CSRO 1119, CSRO 1157, CSRO 1163, CSRO 1165, CSRO 1168, CSRO 1170, CSRO 1175, CSRO 1177, BSRO 1127, ASRO 1101, ASRO 1106, ASRO 1113, ALR(L. C),	CSRO 1139, CSRO 1141, CSRO 1155, CSRO 1160, CSRO 1173, CSRO 1179, CSRO 1181, BSRO 1121, BSRO 1125, ASRO 1104, ASRO 1111,	CSRO 1143, CSRO 1148, CSRO 1186, CSRO 1188,	ASRO 1115,

DISCUSSION

The experimental findings of the present investigation “Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes” have been discussed on the following heads in light of the available literature.

5.1 Analysis of variance

5.2 Genetic variability

5.2.1 Range and mean performance

5.2.2 Coefficient of variation

5.2.3 Heritability and genetic advance

5.3 Association analysis

5.3.1 Correlation coefficient analysis

5.3.2 Path coefficient analysis

5.4 Characterization of onion genotypes based on Quality parameters.

5.1 Analysis of variance

The main objective of the present investigation was to study the diversity present in thirty eight genotypes of onion. The estimates of mean sum of square due to genotypes were highly significant for all the characters, (Table 4.1) indicating the presence of genetic diversity in the existing material. Aghora and Pathak (1991), Dehdari *et al.* (2001), Mohanty (2001c), Mohanty and Prusti (2001), Khar *et al.* (2006), Yaso (2007), Hosamani *et al.* (2010) and Adsul *et al.* (2010), also reported the high estimates of variability for selection of important genotypes to achieve the good breeding material.

5.2 Genetic variability

5.2.1 Mean performance of the genotypes

The mean performance of the genotypes (Table 4.2) revealed a wide range of variability for all the traits. The variation was highest for bulb yield per hectare (227.57 - 387.06 q/ha.) followed by bulb yield per plant (23.67-97.67g), plant height at 90 DAT (32.7 – 49.10 cm), plant height at 60 DAT

(25.77 – 41.43cm), plant height at 120 DAT (27.67 – 41.83cm), plant height at 30 DAT (21.33 – 35.20 cm), days to maturity (122.00 – 133.33 days) and bulb yield per plot (13.66 – 23.207 kg). The findings were quite similar to as reported by Singh *et al.* (1995), Mohanty (2001a), Singh *et al.* (2010) and Hosamani *et al.* (2010).

5.2.2 Coefficient of variation

In the present findings PCV were observed to be higher than the corresponding GCV for all the characters studied, however the differences was narrow which implied their relative resistance to environmental variation. It also described that genetic factors were predominantly responsible for expression of those attributes and selection could be made effectively on the basis of phenotypic performance. The finding of Trivedi *et al.* (2006a), Trivedi *et al.* (2006), Gurjar and Singhania (2006), Yaso (2007) and Singh *et al.* (2010) are also corroborated with the present findings.

The phenotypic and genotypic coefficient of variation varied from 2.26% to 41.39% and 2.18% to 41.10 % respectively. The highest PCV and GCV were recorded for bulb yield per plant, neck thickness and pseudostem diameter. The high values of GCV suggested greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. The findings are in close harmony with the result of Dehdari *et al.* (2001), Trivedi *et al.* (2006a), Trivedi *et al.* (2006), Gurjar and Singhania (2006), Hayder *et al.* (2007) and Singh *et al.* (2010) for bulb yield per plant, Mohanty (2002) and Gurjar and Singhania (2006) for neck thickness, Mohanty (2002), Hosamani *et al.* (2010) and Singh *et al.* (2010) for bulb weight.

However, it was exhibited low for characters viz., days to maturity, number of leaves per plant at 90 DAT, plant height at 60 DAT, plant height at 90 DAT and number of leaves per plant at 60 DAT, indicating the potential of heterosis breeding for their amelioration. The findings are similar to that of the present findings Patil (1997), Gurjar and Singhania (2006) and Morsy *et al.*

(2011) for days to maturity, Gurjar and Singhania (2006) for plant height, Gurjar and Singhania (2006) for number of leaves per plant.

Rest of the characters i.e. polar diameter of bulb, number of leaves per plant 120 DAT, pseudostem length, plant height at 30 DAT and at 120 DAT, equatorial diameter of bulb, number of leaves per plant at 30 DAT and TSS were exhibited moderate phenotypic coefficient of variation. The finding of Patil (1997) and Singh *et al.* (2010) for number of leaves per plant was similar to the present finding which indicated that there is limited scope for improvement.

5.2.3 Heritability and Genetic advance

Heritability which denotes the proportion of genetically controlled variability expressed by a programme for a particular character or a set of character is very important biometrical tool for guiding plant breeders for adoption of appropriate breeding procedures. High heritability in broad sense is helpful in identifying appropriate character for selection and enables the breeder to select superior genotypes on the basis of phenotypic expression of quantitative characters. The estimated values of heritability in broad sense were classified as very high (more than 90%), high (more than 70- 90%), medium (50-70%) and low (less than 50%).

Very high estimates of heritability were obtained for the traits like neck thickness followed by plant height at 120 DAT, pseudostem diameter, bulb yield per plant, number of leaves per plant at 120 DAT, pseudostem length, polar diameter of bulb, days to maturity, plant height at 90 DAT and number of leaves per plant at 90 DAT. However, high heritability was recorded in the character viz., equatorial diameter of bulbs, plant height at 60 DAT and number of leaves per plant at 60 DAT. Indicated that the high values of broad sense heritability for these characters expressed that they were least influenced by environmental modification. It reflected that the phenotypes were the true representative of their genotypes and selection based on phenotypic performance would be reliable. The results were in close

proximate to that of Sandhu and Korla (1975), Mohanty and Prusti (2001), Fatema (2001), Mohanty (2001a), Mohanty (2001b), Krishna Prasad *et al.* (2005), Melke and Ravishankar (2006) and Pramoda and Gangaprasad (2007) for plant height, Suthanthira Pandian and Muthukrishnan (1982), Patil *et al.* (1986), Mohanty and Prusti (2001), Mohanty (2001a), Mohanty (2001b), Mohanty (2002), Mohanty (2004), Melke and Ravishankar (2006), Pramoda and Gangaprasad (2007) and Hayder *et al.* (2007) for number of leaves per plant, Vidyasagar and Singh (1993), Patil (1997), Gurjar and Singhania (2006) and Yaso (2007) for days to maturity, Mohanty and Prusti (2001), Gurjar and Singhania (2006) and Pramoda and Gangaprasad (2007) for bulb yield per plant, Mohanty and Prusti (2001), Mohanty (2001a), Mohanty (2001b), Mohanty (2002), Mohanty (2004), Trivedi *et al.* (2006a) and Gurjar and Singhania (2006) for neck thickness, Trivedi *et al.* (2006) and Trivedi *et al.* (2006a) for polar diameter of bulb, Gurjar and Singhania (2006) for equatorial diameter of bulbs.

However, it was recorded moderate for number of leaves per plant at 30 DAT and plant height at 30 DAT. The findings were in agreement to Mohanty (2001a) for number of leaves per plant. Low estimate of heritability was recorded in total soluble solid.

Heritability however indicates only the effectiveness with which selection of a genotype can be based on phenotypic performance, but fails to indicate the genetic progress. Heritability estimates along with genetic gains are more effective and reliable in predicting the improvement through selection (Johnson *et al.*, 1955). Estimation of genetic advance helps to predict the extent of improvement that can be achieved for improving the different characters. The estimated values of genetic advance as percent of mean were classified as high (more than 35%), moderate (20-35%) and low (less than 20%).

The highest estimate of genetic advance as percentage of mean was recorded for bulb yield per plant followed by neck thickness, pseudostem diameter, polar diameter of bulb, number of leaves per plant at 120 DAT,

pseudestem length, plant height at 120 DAT and equatorial diameter of bulb. The results were in consonance with Patil *et al.* (1986), Mohanty and Prusti (2001), Mohanty (2001a), Mohanty (2001b), Mohanty (2002), Melke and Ravishankar (2006) and Hayder *et al.* (2007) for number of leaves per plant, Mohanty and Prusti (2001) and Gurjar and Singhania (2006) for bulb yield per plant, Mohanty and Prusti (2001), Mohanty (2001a), Mohanty (2001b), Mohanty (2002), Gurjar and Singhania (2006) and Hosamani *et al.* (2010) for neck thickness, Mohanty and Prusti (2001), Fatema (2001), Mohanty (2001a), Mohanty (2001b) and Melke and Ravishankar (2006) for plant height.

Plant height at 90 DAT and at 60 DAT, number of leaves per plant at 90 DAT, plant height at 30 DAT, number of leaves per plant at 60 DAT and at 30 DAT exhibited moderate value of genetic advance as percentage of mean. The findings were in agreement to the findings of Mohanty (2001a) and Mohanty (2004) for number of leaves per plant.

Whereas, total soluble solid and days to maturity had the lowest estimate of genetic advance as percentage of mean. The findings were in agreement to the findings of Sidhu *et al.* (1986), Vidyasagar and Singh (1993), Gurjar and Singhania (2006), Yaso (2007) and Morsy *et al.* (2011) for days to maturity, Singh *et al.* (2010) for total soluble solid.

High heritability coupled with high genetic advance for traits like bulb yield per plant followed by neck thickness, pseudostem diameter, polar diameter of bulb, number of leaves per plant at 120 DAT, pseudostem length, plant height at 120 DAT and equatorial diameter of bulb. Suggested that the preponderance of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters are governed by additive gene actions. The results were in consonance with Mohanty and Prusti (2001), Mohanty (2001a), Mohanty (2001b), Mohanty (2002), Melke and Ravishankar (2006) and Hayder *et al.* (2007) for number of leaves per plant, Mohanty and Prusti (2001) and Gurjar and Singhania (2006) for bulb yield per plant, Mohanty and Prusti (2001), Mohanty (2001a), Mohanty (2001b), Mohanty (2002) and Gurjar and Singhania (2006) for neck thickness,

Mohanty and Prusti (2001), Fatema (2001), Mohanty (2001a), Mohanty (2001b) and Melke and Ravishankar (2006) for plant height.

High heritability supplemented with moderate genetic advances as percentage of mean were manifested by Plant height at 90 DAT, plant height at 60 DAT, number of leaves per plant at 90 DAT and number of leaves per plant at 60 DAT, which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought about. The findings were in agreement to the findings of Mohanty (2004) for number of leaves per plant.

High heritability coupled with low genetic advance as percentage of mean was observed for days to maturity which revealed the predominance of non-additive gene action in the expression of these characters. The findings were in agreement to the findings of Vidyasagar and Singh (1993), Gurjar and Singhania (2006) and Yaso (2007) for days to maturity.

Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by total soluble solid, indicated that this character was highly influenced by environmental effects and consequently its selection would be ineffective.

5.3 Association analysis

5.3.1 Correlation coefficient analysis

A wide range of variation in quantitative characters provides the basis for selection in plant breeding programme. The knowledge of association among the characters is useful to the breeder for improving the efficiency of selection. Correlation coefficient analysis measures the mutual relationship between plant characters and determines the component character on which selection can be made for genetic improvement of yield. Investigation regarding the presence of component and nature of association among themselves is essential and pre-requisite for improvement in yield. Correlation coefficient provides a clear picture of the extent of association between a pair of traits and indicates whether simultaneous improvement of the correlated

traits may be possible or not. The knowledge of genetic association between yield and its component characters help in improving the efficiency of selection for yield by making proper choice and balancing one component with another.

The magnitude of genotypic correlation was higher than the phenotypic correlation for all the traits that indicated inherent association between various characters. The findings were in agreement to Gurjar and Singhania (2006) and Hosamani *et al.* (2010).

Correlation coefficient of bulb yield per plant was recorded positive and significant with pseudostem length, followed by polar diameter of bulb, plant height at 90 DAT, equatorial diameter of bulb, plant height at 120 DAT, plant height at 60 DAT, pseudostem diameter, neck thickness, number of leaves per plant at 60 DAT and at 30 DAT. The highest positive and significant correlation coefficient of bulb yield per plant was noted with pseudostem length, followed by polar diameter of bulb, plant height at 90 DAT, equatorial diameter of bulb, plant height at 120 DAT, plant height at 60 DAT, pseudostem diameter, neck thickness, number of leaves per plant at 60 DAT and at 30 DAT indicating that these characters is the primary yield determinant in onion. These findings corroborated the earlier findings of Suthanthira Pandian and Muthukrishnan (1982), Thakur *et al.* (1997), Rajalingam and Haripriya (2000), Mohanty (2001), Mohanty (2001a), Mohanty (2004), Wani (2004), Gurjar and Singhania (2006) and Meena *et al.* (2007) for number of leaves per plant, Sidhu *et al.* (1986), Netrapal and Choudhary (1988), Sharma *et al.* (1995), Rajalingam and Haripriya (2000), Mohammed *et al.* (2000), Mohanty (2001), Mohanty (2001b), Mohanty (2004), Shrivastava *et al.* (2004), Trivedi *et al.* (2006), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for diameter of bulb, Netrapal and Choudhary (1988), Sharma *et al.* (1995), Thakur *et al.* (1997), Rajalingam and Haripriya (2000), Mohanty (2001), Mohanty (2001b), Mohanty (2004), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for plant height, Singh *et al.* (1995), Mohammed *et al.* (2000) and Gurjar and Singhania (2006) for neck thickness, Rajalingam and Haripriya (2000), Mohammed *et al.* (2000),

Mohanty (2001b), Mohanty (2004), Shrivastava *et al.* (2004), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for polar diameter of bulb.

Plant height at 30 DAT had high significant and positive association with plant height at 60 DAT, pseudostem length, plant height at 90 DAT, number of leaves per plant at 30 DAT, plant height at 120 DAT and numbers of leaves per plant at 60 DAT. Plant height at 60 DAT showed positive and significant correlation with polar diameter of bulb, plant height at 90 DAT, bulb yield per plant, pseudostem length, number of leaves at 60 DAT, plant height at 120 DAT, number of leaves per plant at 30 DAT, equatorial diameter, pseudostem diameter and neck thickness. These findings corroborated the earlier findings of Netrapal and Choudhary (1988), Sharma *et al.* (1995), Thakur *et al.* (1997), Rajalingam and Haripriya (2000), Mohanty (2001), Mohanty (2001b), Mohanty (2004), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for bulb yield per plant, Mohanty (2001a) for neck thickness.

Significant and positive correlation of plant height at 90 DAT was recorded with pseudostem length, bulb yield per plant, equatorial diameter of bulb, plant height at 120 DAT, pseudostem diameter, polar diameter of bulb, neck thickness, number of leaves per plant at 30, 60, 90 and 120 DAT. These findings corroborated the earlier findings of Netrapal and Choudhary (1988), Sharma *et al.* (1995), Thakur *et al.* (1997), Rajalingam and Haripriya (2000), Mohanty (2001), Mohanty (2001b), Mohanty (2004), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for bulb yield per plant, Mohanty (2001a) for neck thickness. Highly significant and positive association of plant height at 120 DAT was observed with pseudostem diameter, neck thickness, bulb yield per plant, number of leaves per plant at 120 DAT, polar diameter of bulb, equatorial diameter of bulb, pseudostem length and number of leaves per plant at 60 DAT. These findings corroborated the earlier findings of Netrapal and Choudhary (1988), Sharma *et al.* (1995), Thakur *et al.* (1997), Rajalingam and Haripriya (2000), Mohanty (2001), Mohanty (2001b), Mohanty (2004), Trivedi *et al.* (2006a), Gurjar and

Singhania (2006) and Meena *et al.* (2007) for bulb yield per plant, Mohanty (2001a) for neck thickness.

Correlation coefficient of this trait was positive and significant with pseudostem length, number of leaves per plant at 60 DAT and at 90 DAT. But the association with days to maturity was negative and significant. Number of leaves per plant at 60 DAT expressed positive and significant correlation with polar diameter of bulb, number of leaves per plant at 90 DAT, pseudostem length, bulb yield per plant, equatorial diameter of bulb and pseudostem diameter. However association was significant and negative with number of leaves per plant at 120 DAT. These findings corroborated the earlier findings of Suthanthira Pandian and Muthukrishnan (1982), Thakur *et al.* (1997), Rajalingam and Haripriya (2000), Mohanty (2001), Mohanty (2001a), Mohanty (2004), Wani (2004), Gurjar and Singhania (2006) and Meena *et al.* (2007) for bulb yield per plant.

Number of leaves per plant at 90 DAT exhibited positive and significant association with polar diameter of bulb and pseudostem diameter. A highly significant and positive correlation of number of leaves per plant at 120 DAT was recorded with neck thickness and pseudostem diameter.

Pseudostem length expressed a significant and positive association with bulb yield per plant, polar diameter of bulb, equatorial diameter of bulb, neck thickness and pseudostem diameter. Correlation coefficient for pseudostem diameter was significant and positive with neck thickness, bulb yield per plant, polar diameter of bulb, equatorial diameter of bulb and days to maturity. Days to maturity expressed a significant and positive correlation with polar diameter of bulb. These findings corroborated the earlier findings of Morsy *et al.* (2011).

Neck thickness found to be significant and positively associated with bulb yield per plant, equatorial diameter of bulb and polar diameter of bulb. The findings were in agreement to Singh *et al.* (1995), Mohammed *et al.* (2000) and Gurjar and Singhania (2006) for bulb yield per plant, Mohanty (2001a) for equatorial and polar diameter of bulb.

Correlation coefficient was noted to be positive and significant with bulb yield per plant and equatorial diameter of bulb, indicate that yield improvement could be possible by increasing equatorial diameter and polar diameter of bulb. The findings were in agreement to Sidhu *et al.* (1986), Netrapal and Choudhary (1988), Sharma *et al.* (1995), Rajalingam and Haripriya (2000), Mohammed *et al.* (2000), Mohanty (2001b), Shrivastava *et al.* (2004), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for bulb yield per plant, Mohammed *et al.* (2000), Mohanty (2001), Mohanty (2004) and Shrivastava *et al.* (2004) for polar diameter of bulb.

Equatorial diameter of bulb had positive and significant association with bulb yield per plant, indicates that yield improvement could be possible by increasing equatorial diameter. The findings were in agreement to Sidhu *et al.* (1986), Netrapal and Choudhary (1988), Sharma *et al.* (1995), Rajalingam and Haripriya (2000), Mohammed *et al.* (2000), Mohanty (2001), Mohanty (2001b), Mohanty (2004), Shrivastava *et al.* (2004), Trivedi *et al.* (2006), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007) for bulb yield per plant.

5.3.2 Path coefficient analysis

Correlation coefficients are the indication of simple association between variables. In a biological system, however the relationship may exist in a very complex form. It is therefore, essential to study the relationship among variable in a comprehensive way. Path coefficient analysis is a powerful tool, which enable portioning of the given relationships in its further components. In other words, it takes into account not only the relationship of component characters with the dependent character, but simultaneously takes care of its relationship with other component also. Thus, it helps in understanding the causal system in a better way because it enables portioning the total correlations coefficient into direct and indirect effects of various characters.

In the present investigation path coefficient analysis was carried out for characters under study using genotypic and phenotypic correlation coefficient and taking bulb yield per plant as dependable variables, in order to see the

causal factor and so as to identify the components which are responsible for producing bulb yield per plant. In general the genotypic direct as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct and indirect effects indicating that the masking effect of the environment. The findings were in agreement to Singh (2001).

Path coefficient analysis of different characters contributing towards bulb yield per plant showed that plant height at 60 DAT had highest positive direct effect followed by pseudostem length, pseudostem diameter, TSS percent, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb. The results are in propinquity with Rajalingam and Haripriya (2000), Mohanty (2002), Gurjar and Singhania (2006), Aliya *et al.* (2007) and Hosamani *et al.* (2010) for plant height, Mohanty (2001a), Singh (2001), Mohanty (2001b), Dehdari *et al.* (2002), Mohanty (2004), Gurjar and Singhania (2006), Meena *et al.* (2007), Aliya *et al.* (2007), Dhotre *et al.* (2010) and Hosamani *et al.* (2010) for diameter of bulb (equatorial and polar), Hosamani *et al.* (2010) for TSS. The characters plant height at 60 DAT, pseudostem length, pseudostem diameter, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb had correlation coefficient values at par with their direct effect on bulb yield per plant. This indicates true relationships with bulb yield per plant and direct selection for these traits would result in higher breeding efficiency for improving yield. Thus, these traits might be reckoned as the most important component trait of bulb yield per plant.

Whereas number of leaves per plant at 60 DAT had the highest negative direct effect on bulb yield per plant followed by neck thickness, plant height at 30 DAT, days to maturity, number of leaves per plant at 30, 90 and 120 DAT. The results are in propinquity with Rajalingam and Haripriya (2000) for number of leaves per plant. Characters like number of leaves per plant at 60 DAT expressed highest negative direct effects on bulb yield per plant followed by neck thickness, plant height at 30 DAT, days to maturity, number of leaves per plant at 30, 90 and 120 DAT. But number of leaves per

plant at 60 DAT, neck thickness, plant height at 30 DAT, days to maturity, number of leaves per plant at 120 DAT and 30 DAT were positively correlated to it. This indicated that the indirect effect was the cause of correlation and the indirect causal factors are to be considered simultaneously for selection.

Number of leaves per plant at 90 DAT imparted a negative direct effect on bulb yield per plant, as well as they were negatively correlated to it. Under such circumstance direct selection for this character should be avoided, instead indirect selection should be followed.

Total soluble solid exhibit, higher direct effect on bulb yield, they expressed higher indirect effect on it through plant height at 30, 60 and 90 DAT, equatorial diameter of bulb, number of leaves per plant at 90 DAT, neck thickness, and pedostem length respectively and hence simultaneous selection for these characters can be made for the improvement of yield. The findings were in agreement to Mohanty (2001b).

Path coefficient analysis revealed that plant height at 60 DAT had highest positive direct effect followed by pedostem length, pedostem diameter, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb were the most important characters contributing towards bulb yield per plant and hence purposeful and balanced selection based on these characters would be made rewarding for improvement of onion. Direct selection of neck thickness, days to maturity and number of leaves per plant should be avoided instead of indirect selection.

5.4 Quality parameters

Considerable variability was observed among the genotypes for foliage colour, foliage cranking, bulb shape and bulb colour. Foliage colour in green onion and shape and colour of onion bulb are most important characteristics to help customers in choosing cultivars on the market. These results are in close harmony with the findings of Gvozdanovic-Varga *et al.* (1996), Martinovich and Felfoldi (1996), Hasegawa *et al.* (2001), Mennella *et al.* (2002), Gowda *et al.* (2004) and Schiavi *et al.* (2007) for bulb shape and bulb colour.

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

6.1 Summary

The present investigation “Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes” was carried out during rabi season of 2011-2012 at the Vegetable Research Farm, Department of Horticulture, College of Agriculture, J.N.K.V.V., Jabalpur (M.P.). The experimental material for the present investigation was comprised of 38 genotypes of onion. These genotypes were sown in Randomized Complete Block Design with three replications, to estimate the genetic variability and association analysis (Correlation and Path coefficient). Observations were recorded on the basis of ten random competitive plants selected from each genotype separately for morphological, yield and quality parameters were evaluated as per standard procedure. The variance components and coefficient of variation were determined according to Burton (1952). The heritability (broad sense) and genetic advance was worked out by Hanson *et al.* (1956) and Johnson *et al.* (1955). Correlation coefficient and path coefficient was computed by the formula suggested by Miller *et al.* (1958) and Dewey and Lu (1959). On the basis of results, the present investigation is summarized as follows:

The estimates of mean sum of square due to genotypes were highly significant for all the characters, indicating the presence of genetic diversity in the existing material.

The mean performance of the genotypes revealed a wide range of variability for all the traits. The variation was highest for bulb yield per hectare followed by bulb yield per plant, plant height at 90 DAT, plant height at 60 DAT, plant height at 120 DAT, plant height at 30 DAT, days to maturity and bulb yield per plot.

The present study revealed that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits which might be due to interaction of the genotypes with the environment to some degree or other explaining environmental factors influencing the expression of these characters. High phenotypic and genotypic coefficient of variation was observed for bulb yield per plant, neck thickness and pseudostem diameter. The high values of GCV suggested greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. However, days to maturity, number of leaves per plant at 90 DAT, plant height at 60 DAT, plant height at 90 DAT and number of leaves per plant at 60 DAT showed low estimates of genotypic and phenotypic coefficient of variation, indicating the potential of heterosis breeding for their amelioration.

Very high estimates of heritability were obtained for the traits like neck thickness followed by plant height at 120 DAT, pseudostem diameter, bulb yield per plant, number of leaves per plant at 120 DAT, pseudostem length, polar diameter of bulb, days to maturity, plant height at 90 DAT and number of leaves per plant at 90 DAT. However, high heritability was recorded in the character viz., equatorial diameter of bulbs, plant height at 60 DAT and number of leaves per plant at 60 DAT. Indicated that the high values of broad sense heritability for these characters expressed that they were least influenced by environmental modification. It reflected that the phenotypes were the true representative of their genotypes and selection based on phenotypic performance would be reliable.

High heritability coupled with high genetic advance as percentage of mean for traits like bulb yield per plant followed by neck thickness, pseudostem diameter, polar diameter of bulb, number of leaves per plant at 120 DAT, pseudostem length, plant height at 120 DAT and equatorial diameter of bulb. Suggested that the preponderance of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters are governed by additive gene actions.

High heritability supplemented with moderate genetic advances as percentage of mean were manifested by Plant height at 90 DAT, plant height at 60 DAT, number of leaves per plant at 90 DAT and number of leaves per plant at 60 DAT, which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought about.

High heritability coupled with low genetic advance as percentage of mean was observed for days to maturity. This revealed the predominance of non-additive gene action in the expression of these characters.

Low estimates of heritability coupled with low genetic advances as percentage of mean were displayed by total soluble solid indicated that this character was highly influenced by environmental effects and consequently its selection would be ineffective.

The genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic one, indicating there by strong inherent association between different traits studied. The phenotypic expression of correlation was lessened possibly due to multiple influences of environmental components. In view of their correspondence, selection on phenotypic basis would be effective.

The highest positive and significant correlation coefficient of bulb yield per plant was noted with pseudostem length, followed by polar diameter of bulb, plant height at 90 DAT, equatorial diameter of bulb, plant height at 120 DAT, plant height at 60 DAT, pseudostem diameter, neck thickness, number of leaves per plant at 60 DAT and at 30 DAT, which indicated that effective improvement in onion yield through these components could be achieved. The yield attributing characters exhibited varying trend amongst them.

Plant height at 30 DAT had high significant and positive association with plant height at 60 DAT, pseudostem length, plant height at 90 DAT, number of leaves per plant at 30 DAT, plant height at 120 DAT and numbers

of leave per plant at 60 DAT. Plant height at 60 DAT showed positive and significant correlation with polar diameter of bulb, plant height at 90 DAT, bulb yield per plant, pseudostem length, number of leaves at 60 DAT, plant height at 120 DAT, number of leaves per plant at 30 DAT, equatorial diameter, pseudostem diameter and neck thickness. Significant and positive correlation of plant height at 90 DAT was recorded with pseudostem length, bulb yield per plant, equatorial diameter of bulb, plant height at 120 DAT, pseudostem diameter, polar diameter of bulb, neck thickness, number of leaves per plant at 30, 60, 90 and 120 DAT. Highly significant and positive association of plant height at 120 DAT was observed with pseudostem diameter, neck thickness, bulb yield per plant, number of leaves per plant at 120 DAT, polar diameter of bulb, equatorial diameter of bulb, pseudostem length and number of leaves per plant at 60 DAT.

Correlation coefficient of number of leaves per plant at 30 DAT was positive and significant with pseudostem length, number of leaves per plant at 60 DAT and at 90 DAT. But the association with days to maturity was negative and significant. Number of leaves per plant at 60 DAT expressed positive and significant correlation with polar diameter of bulb, number of leaves per plant at 90 DAT, pseudostem length, bulb yield per plant, equatorial diameter of bulb and pseudostem diameter. However association was significant and negative with number of leaves per plant at 120 DAT. Number of leaves per plant at 90 DAT exhibited positive and significant association with polar diameter of bulb and pseudostem diameter. A highly significant and positive correlation of number of leaves per plant at 120 DAT was recorded with neck thickness and pseudostem diameter.

Pseudostem length expressed a significant and positive association with bulb yield per plant, polar diameter of bulb, equatorial diameter of bulb, neck thickness and pseudostem diameter. Correlation coefficient for pseudostem diameter was significant and positive with neck thickness, bulb yield per plant, polar diameter of bulb, equatorial diameter of bulb and days to maturity. Days to maturity expressed a significant and positive correlation with polar diameter

of bulb. Neck thickness found significant and positively associated with bulb yield per plant, equatorial diameter of bulb and polar diameter of bulb.

Correlation coefficient of polar diameter of bulb was noted positive and significant with bulb yield per plant and equatorial diameter of bulb, indicate that yield improvement could be possible by increasing equatorial diameter and polar diameter of bulb. Equatorial diameter of bulb had positive and significant association with bulb yield per plant.

Path coefficient analysis of different characters contributing towards bulb yield per plant showed that plant height at 60 DAT had highest positive direct effect followed by pseudostem length, pseudostem diameter, TSS percent, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb. The characters plant height at 60 DAT, pseudostem length, pseudostem diameter, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb had correlation coefficient values at par with their direct effect on bulb yield per plant. This indicates true relationships with bulb yield per plant and direct selection for these traits would result in higher breeding efficiency for improving yield. Thus, these traits might be reckoned as the most important component trait of bulb yield per plant.

Whereas number of leaves per plant at 60 DAT had the highest negative direct effect on bulb yield per plant followed by neck thickness, plant height at 30 DAT, days to maturity, number of leaves per plant at 30, 90 and 120 DAT. Characters like number of leaves per plant at 60 DAT expressed highest negative direct effects on bulb yield per plant followed by neck thickness, plant height at 30 DAT, days to maturity, number of leaves per plant at 30, 90 and 120 DAT. But number of leaves per plant at 60 DAT, neck thickness, plant height at 30 DAT, days to maturity, number of leaves per plant at 120 DAT and 30 DAT were positively correlated to it. This indicated that the indirect effect was the cause of correlation and the indirect causal factors are to be considered simultaneously for selection.

Number of leaves per plant at 90 DAT imparted a negative direct effect on bulb yield per plant, as well as they were negatively correlated to it. Under such circumstance direct selection for this character should be avoided, instead indirect selection should be followed.

Total soluble solid exhibit, higher direct effect on bulb yield, they expressed higher indirect effect on it through plant height at 30, 60 and 90 DAT, equatorial diameter of bulb, number of leaves per plant at 90 DAT, neck thickness, and pedostem length respectively and hence simultaneous selection for these characters can be made for the improvement of yield.

Considerable variability was observed among the genotypes for foliage colour, foliage cranking, bulb shape and bulb colour. Foliage colour in green onion and shape and colour of onion bulb are most important characteristics to help customers in choosing cultivars on the market.

6.2 Conclusion

The estimates of mean sum of square due to genotypes were highly significant for all the characters, indicating the presence of genetic diversity in the existing material.

The mean performance of the genotypes revealed a wide range of variability for all the traits. The variation was highest for bulb yield per hectare followed by bulb yield per plant, plant height at 90 DAT, plant height at 60 DAT, plant height at 120 DAT, plant height at 30 DAT, days to maturity and bulb yield per plot.

The PCV was higher than the GCV for all the characters. High PCV and GCV was observed for bulb yield per plant, neck thickness and pseudostem diameter, indicating greater diversity for these traits and their further improvement through selection.

High heritability supplemented with high genetic advance as percentage of mean was manifested by bulb yield per plant followed by neck thickness, pseudostem diameter, polar diameter of bulb, number of leaves per

plant at 120 DAT, pseudostem length, plant height at 120 DAT and equatorial diameter of bulb suggested that they can be improved through direct selection.

The association studies indicated that the advantages of upgrading onion genotypes through simultaneous selection for pseudostem length, followed by polar diameter of bulb, plant height at 90 DAT, equatorial diameter of bulb, plant height at 120 DAT, plant height at 60 DAT, pseudostem diameter, neck thickness, number of leaves per plant at 60 DAT and at 30 DAT.

Path coefficient analysis revealed that plant height at 60 DAT had highest positive direct effect followed by pseudostem length, pseudostem diameter, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb were the most important characters contributing towards bulb yield per plant and hence purposeful and balanced selection based on these characters would be made rewarding for improvement of onion. Direct selection of neck thickness, days to maturity and number of leaves per plant should be avoided instead of indirect selection.

Considerable variability was observed among the genotypes for foliage colour, foliage cranking, bulb shape and bulb colour. Foliage colour in green onion and shape and colour of onion bulb are most important characteristics to help customers in choosing cultivars on the market.

6.3 Suggestions for further work

1. Stability of distinct traits of onion should be established over the years.
2. Traits identified for high heritability coupled with high or moderate genetic gain may be considered well in selection for the improvement of crop.

3. Characters having desirable association and direct effects with bulb yield should be given due consideration for genetic improvement in onion.
4. The genotypes showing greater yield potential with other desirable qualities may be tested under different agro climatic conditions and those found suitable could be recommended for general cultivation.

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ABSTRACT

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ABSTRACT

The present investigation “Study on genetic variability and character association in onion (*Allium cepa* L.) genotypes” was carried out during rabi season of 2011-2012 at the Vegetable Research Farm, Department of Horticulture, College of Agriculture, J.N.K.V.V., Jabalpur (M.P.). The experimental material for the present investigation was comprised of 38 genotypes of onion. These genotypes were sown in Randomized Complete Block Design with three replications, to estimate the genetic variability and association analysis (Correlation and Path coefficient). Observations were recorded on the basis of ten random competitive plants selected from each genotype separately for morphological, yield and quality parameters were evaluated as per standard procedure. The variance components and coefficient of variation were determined according to Burton (1952). The heritability (broad sense) and genetic advance was worked out by Hanson *et al.* (1956) and Johnson *et al.* (1955). Correlation coefficient and path coefficient was computed by the formula suggested by Miller *et al.* (1958) and Dewey and Lu (1959).

Analysis of variance revealed highly significant variance for all the traits depicting greater variability in the existing material.

The mean performance of the genotypes revealed a wide range of variability for all the traits. The variation was highest for bulb yield per hectare followed by bulb yield per plant, plant height at 90 DAT, plant height at 60 DAT, plant height at 120 DAT, plant height at 30 DAT, days to maturity and bulb yield per plot.

The PCV was higher than the GCV for all the characters. High PCV and GCV was observed for bulb yield per plant, neck thickness and pseudostem diameter, indicating greater diversity for these traits and their further improvement through selection.

High heritability supplemented with high genetic advance as percentage of mean was manifested by bulb yield per plant followed by neck thickness, pseudostem diameter, polar diameter of bulb, number of leaves per plant at 120 DAT, pseudostem length, plant height at 120 DAT and equatorial diameter of bulb suggested that they can be improved through direct selection.

The association studies indicated that the advantages of upgrading onion genotypes through simultaneous selection for pseudostem length, followed by polar diameter of bulb, plant height at 90 DAT, equatorial diameter of bulb, plant height at 120 DAT, plant height at 60 DAT, pseudostem diameter, neck thickness, number of leaves per plant at 60 DAT and at 30 DAT.

Path coefficient analysis revealed that plant height at 60 DAT had highest positive direct effect followed by pseudostem length, pseudostem diameter, plant height at 90 DAT, polar diameter of bulb, plant height at 120 DAT and equatorial diameter of bulb were the most important characters contributing towards bulb yield per plant and hence purposeful and balanced selection based on these characters would be made rewarding for improvement of onion. Direct selection of neck thickness, days to maturity and number of leaves per plant should be avoided instead of indirect selection.

Considerable variability was observed among the genotypes for foliage colour, foliage cranking, bulb shape and bulb colour. Foliage colour in green onion and shape and colour of onion bulb are most important characteristics to help customers in choosing cultivars on the market.