

**Studies on genetic and association analysis for
yield and its component traits in *Kharif* Onion
(*Allium cepa* L.)**

THESIS

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Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

**In partial fulfillment of the requirements
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**(AGRICULTURE)
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By

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2013

CERTIFICATE- I

This is to certify that the thesis entitled “**Studies on genetic and association analysis for yield and its component traits in *kharif* onion (*Allium cepa* L.)**” 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 (M.P.) is a record of the bonafide research work carried out by Ms. Richa Pyasi 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 her.

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CERTIFICATE-II

This is to certify that the thesis entitled “**Studies on genetic and association analysis for yield and its component traits in *kharif* onion (*Allium cepa* L.)**.” submitted by Ms. Richa Pyasi to the J. N. Krishi Vishwa Vidyalaya, Jabalpur (M.P.) in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN AGRICULTURE, Horticulture (Vegetable Science) in the Department of Horticulture, 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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INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Amyrillidaceae is important bulb vegetable cultivated in more than hundred countries. Onion is grown worldwide throughout the year under various Agro climatic conditions.

It is a high value crop and its market price fluctuates as per supply and availability. Onion is important crop as it earns a major portion of foreign exchange for the country. Irrespective of price, onion remains dominated in the market as it is primarily used in the Indian cuisine. It is an old world crop and it was originated in Central Asia. It is consumed as vegetable as well as an spice. Green leaves, immature bulbs and mature bulbs are preferred by consumers for kitchen purpose.

Onion has many medicinal values and used for preparation of various Homeopathic, Unani and Ayurvedic medicines. Nutritive value of onion varies from variety to variety. Major value of onion lies in its flavour. The pungency in onion is due to sulphur bearing compound allyl propyl disulphide($C_6H_{12}O_2$) in a very small quantity (0.005%) in form of volatile oil. The quality of onion depends on shape, size, colour and pungency of bulbs. Highly pungent Red colour onions are preferred in India, while less pungent yellow or white skinned ones are demanded in European and Japanese market. Shape, size and colour of bulb also determines its market value.

India is second largest producer of onion in world after China. Among the different states in India Maharashtra is the leading state in terms of area and production. Other major onion producing states are Gujrat, Karnataka, Orissa, UttarPradesh, AndhraPradesh, Tamilnadu and Rajasthan. The area of onion production in Madhya Pradesh is 57.30 thousand hectare, total production is 952.30 thousand million tones with productivity of about 16.6 tonnes per hectare (NHB,2011-12). Onion accounts for 70% of our total Foreign exchange earnings from the export of fresh vegetables. Government of India has declared onion as an essential commodity. Looking at 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.

About 70% of the total onion production in India is confined to *rabi* season crop and remaining 30% is associated with *Kharif* season crop. Rainy season onion cultivation is new preface in Eastern India mainly for fresh bulbs in off season.

There is steady increase in onion production in last five years. Due to increase in demand of onion, varietal improvement programs are necessary at present. The knowledge of pattern of inheritance of various characters are important consideration while determining the most appropriate breeding procedures applicable to onion specially *kharif* season. The breeders choice for the material for any improvement work consequently depends on the amount of genetic variability present in the population. The phenotype is often not the true indicator of its genotype, due to the masking effect of environment over genotype. Standardization of varieties for the off season crop is of paramount importance. So to improve the yield through selection, information on nature and magnitude of variability present in population is an important pre requisite for starting any breeding programme.

Attempts have been made to determine the magnitude of heritable and nonheritable components of genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance as percentage of mean in quantitative characters of onion. Knowledge of correlation among various characters and their relative contribution to yield is useful for multiple trait selection.

Identification of superior genotypes among the existing genotypes becomes necessary for promoting production per unit area of this crop. The estimates of correlation coefficient analysis is more useful in estimation of interrelationship among the yield contributing components and onwards. Estimation of path coefficient analysis gives indication of direct and indirect effects themselves.

The present experiment is an attempt to gather information of various genotypes and study the relationships among the different traits of onion to find the direct and indirect effect of these traits on bulb yield.

In view of above aspects the present investigation in onion entitled “Studies on genetic and association analysis for yield and its component traits in *kharif* onion (*Allium cepa* L.)” has been carried out with the following objectives :-

1. To estimate the genetic parameters for yield and associated characters of *kharif* onion.
2. To assess the correlation between yield and its contributing characters.
3. To analyze the path coefficient for selection of suitable *kharif* onion genotypes.

RIVIEW OF LITERATURE

It is necessary to possess the knowledge of researches conducted in past years in the concerned field in order to draw sufficient background for current experiment. 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 Mean performance of the genotypes
- 2.2 Coefficient of variation
- 2.3 Heritability and genetic advance
- 2.4 Correlation coefficient analysis
- 2.5 Path coefficient analysis

2.1 MEAN PERFORMANCE

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 of onion 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 in onion the range of bolting was 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 with significantly high mean yield, 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.

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, 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.

Mohanty and Prusti (2002) found that the varieties N-53, Arka kalyan, Agrifound Dark Red gave significantly high bulb yield. Whereas varieties like Pusa Madhvi, Arka Niketan, Punjab Red Round and Arka

Pitamber produced small to medium sized bulbs there by confirming their better storage quality.

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, Agrifound 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.

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 onion 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 .

Sharma (2009) evaluated five onion cultivars for three years during *kharif and* reported that Basvant-780 was top yielded with a mean bulb production of 230.50q/ha. Agrifound Dark Red and N-53 with a yield potential of 199.40 and 176.50q/ha respectively.

Singh *et al.* (2010) revealed that the wide range of variability was observed in onion for gross yield (301.99q/ha to 387.81q/ha), marketable yield (239.33q/ha to 338.49q/ha), bulb size index (21.31to 23.09cm²) and plant

height (62.73 to 68.43cm). The mean data indicated that the advance line 562 showed highest bulb diameter(5.50), bulb size index (23.09cm²) and weight of 20 bulbs (1.10kg) which was however at par with advance line 627 (5.47cm), (22.75cm²) and (1.03kg) and line 629 (5.40cm), (22.30cm²) and (1.06kg) 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 (1.37cm) 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.

Bharti *et al.* (2011) evaluated sixteen genotypes of onion and revealed that the genotypes Pusa Madhvi, AOSDRB-0919 and AOSDRB-0913 performed better in terms of plant height, bulb size, bulb weight and yield/ha.

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.

2.2 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

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.

Balareddy (1999) recorded low PCV (phenotype coefficient of variation) and GCV (genotype coefficient of variation) for TSS content.

Mohanty (2002) Evaluation of 12 onion cultivars at Bhawanipatna, Orissa, 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) observed maximum phenotypic variability 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.

Gurjar and Singhania (2006) Evaluation of 30 cultivars and local landraces of onion in *Raipur*, Rajasthan, 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.

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 onion 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 showed 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) recorded high Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient Variation (GCV) were for leaf diameter and percentage of bulb sprouting.

Morsy *et al.* (2011) observed that in onion 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.

2.3 Heritability and genetic advance

Right selection of experimental material is the prerequisite for success of any breeding programme. The proper selection depends on the knowledge of heritability. Estimation of genetic advance is an important parameter to evaluate effectiveness of selection.

Mohanty (2001) 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 (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 in onion higher heritability and high genetic advance for the traits like leaves per plant, soluble solids, biological yield per plant and plant height was recorded.

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, 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 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 in onion 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.

Morsy *et al.* (2011) revealed that in onion maximum estimates of heritability in broad sense were obtained for plant weight. Days to maturity and bulb weight gave the lowest genetic advance percentage in the first and second seasons, respectively.

2.4 Correlation coefficient analysis

Correlation studies are of considerable importance as they provide a clear view about the degree of association between two variables under study. The correlations between yields its components give an idea about selection, which could profitably be exercised to obtain an increase in yield. It is necessary to estimate the correlation coefficients to find the true association of genes governing specific character. A brief review is discussed here.

Rajalingam and Haripriya (2000) showed that in onion the yield components, including plant height number of leaves, bulb diameter 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.. 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.

Rahman *et al.* (2002) during the trial found 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 in onion 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) evaluated 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.

Shrivastava *et al.* (2004) revealed that in onion 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.

Trivedi *et al.* (2006) during onion genotype trial found that the yield was positively associated with bulb weight and equatorial bulb diameter.

Trivedi *et al.* (2006a) showed that in onion yield was significantly and positively associated with plant height, 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) evaluated 30 cultivars and local landraces of onion in *Raipur*, Rajasthan, 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.

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 in onion 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 in onion the plant height, bulb diameter and weight of bulb positively correlated to increase for yield.

Singh *et al.* (2010) found that in onion the marketable yield was significantly and positively correlated with plant height, bulb diameter 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..

Hosamani *et al.* (2010) revealed that in onion 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.

Dhotre *et al.* (2010) reported that in onion the bulb yield exhibited positive and significant association with fresh bulb weight, equatorial diameter and TSS

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

Morsy *et al.* (2011) reported that in onion genotypes 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%.

2.5 Path coefficient analysis

The path coefficient analysis helps in analyzing 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 also gives an advantage to find out the true yield determinants for genetic improvement of crop.

Mohanty (2001) revealed that in onion 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 (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 in onion 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

Meena *et al.* (2007) revealed that in onion 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.

Hosamani *et al.* (2010) revealed that in onion 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).

MATERIAL AND METHODS

This chapter deals with the description of the materials used and the methodology adopted during the present investigation entitled “Studies on genetic and association analysis for yield and its component traits in *kharif* onion (*Allium cepa* L.)”.

3.1 Experimental site

The experiment was conducted at Horticulture complex, 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 23.91⁰ North latitude, 79.5⁰ 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 46⁰C and minimum temperature 6.8⁰C. The average annual 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 3.1.

Table 3.1. Meteorological information (week wise) during entire crop season of the year 2012-13 at Jabalpur

Weekly Data of Jabalpur, during the year 2012-13								
Metrological Week	Temperature (°C)		Sun Shine hrs.	Rainfall (mm)	Relative Humidity (%)		Wind Speed (K.m./hrs)	Rainy days
	Max.	Min.			Mor	Eve		
26	37.7	27.0	6.4	0.0	64	42	8.8	0
27	34.5	24.4	5.6	296.8	85	62	6.9	3
28	31.3	23.9	4.7	116.0	88	77	6.3	4
29	32.3	24.1	3.1	117.5	90	76	6.6	3
30	28.2	22.8	3.0	119.9	95	88	6.9	5
31	26.3	22.0	0.0	32.4	94	87	7.6	4
32	27.7	22.7	1.2	145.8	96	88	6.0	5
33	28.2	23.0	0.8	101.8	89	81	5.9	5
34	30.2	22.9	4.9	84.4	92	77	6.3	4
35	31.9	24.2	4.8	3.0	92	69	3.0	0
36	30.8	23.9	2.8	52.2	93	79	5.4	3
37	30.7	23.4	2.8	87.4	91	79	5.1	2
38	30.8	23.1	4.6	11.0	89	69	3.9	1
39	31.9	22.6	8.7	0.0	88	51	3.1	0
40	33.4	21.9	7.3	2.3	91	44	3.3	0
41	32.4	18.5	9.0	0.0	83	35	2.9	0
42	32.5	18.6	9.4	0.0	79	32	2.4	0
43	31.6	15.2	8.4	0.0	82	35	1.9	0
44	27.9	15.6	6.7	0.0	91	51	3.6	0
45	28.2	14.6	7.7	0.0	88	30	3.0	0
46	28.6	10.0	8.4	0.0	85	28	2.7	0
47	27.9	10.6	7.6	0.0	88	29	2.2	0
48	28.4	11.5	8.4	0.0	83	33	2.1	0
49	28.7	10.6	9.0	0.0	85	26	2.1	0
50	29.0	14.0	7.2	3.2	92	41	2.2	1
51	25.3	7.1	8.6	0.0	88	29	2.3	0
52	23.8	5.0	9.1	0.0	90	30	2.2	0
1	23.3	7.2	5.9	0.0	87	42	3.6	0
2	23.0	5.2	9.2	0.0	87	32	2.6	0
3	26.7	10.1	8.1	0.0	84	36	4.0	0
4	21.4	5.1	7.6	0.0	86	36	2.9	0
5	24.6	7.4	7.4	0.0	91	36	2.3	0
6	25.9	11.3	6.2	0.0	88	49	4.4	0
7	25.2	13.0	4.1	0.0	91	60	4.4	0
8	25.0	11.0	9.3	5.4	93	49	3.2	3
9	28.0	9.2	9.8	4.8	87	37	3.1	1
10	30.7	9.9	9.6	00	83	28	2.6	0
11	31.6	14.7	7.4	00	84	39	4.6	2
12	33.5	15.0	8.5	26.1	82	41	4.8	0

Table 3.2. Details of the experiment are given below

1.	Location	:	Horticulture complex, Department of Horticulture, 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	:	33
6.	Total number of plots	:	99
7.	Plot size	:	3.0 x 2.0 m
8.	Spacing	:	15 x 10 cm
9.	Total number of plants per plot	:	400
10.	Net experimental area	:	.594m ²
11.	Number of plants for observation per plot	:	10
12.	Plot to plot distance	:	0.50m
13.	Distance between replication	:	1.0m
14.	Crop	:	Onion
15.	Season	:	<i>Kharif</i> , 2012-2013
16.	Date of transplanting	:	28 August 2012
17.	Manure and fertilizer	:	15 kg FYM, N: P: K: S 80: 60: 50: 50 Kg/ha

3.3 Treatment details

The following thirty three genotypes were under the experimental studies during the trial.

Genotypes

1. ASKO -1201	12. ASKO-1231	23. BSKO-1251
2. ASKO-1203	13. ASKO-1233	24. BSKO-1256
3. ASKO-1207	14. ASKO-1236	25. BSKO-1259
4. ASKO-1210	15. ASKO-1238	26. CSKO-1227
5. ASKO-1213	16. ASKO-1271	27. CSKO-1231
6. ASKO-1215	17. ASKO-1273	28. CSKO-1233
7. ASKO-1217	18. BSKO-1227	29. CSKO-1261
8. ASKO-1220	19. BSKO-1231	30. CSKO-1264
9. ASKO-1222	20. BSKO-1233	31. CSKO-1266
10. ASKO-1224	21. BSKO-1246	32. CSKO-1269
11. ASKO-1227	22. BSKO-1249	33. Agrifound Dark Red

PLAN OF LAYOUT

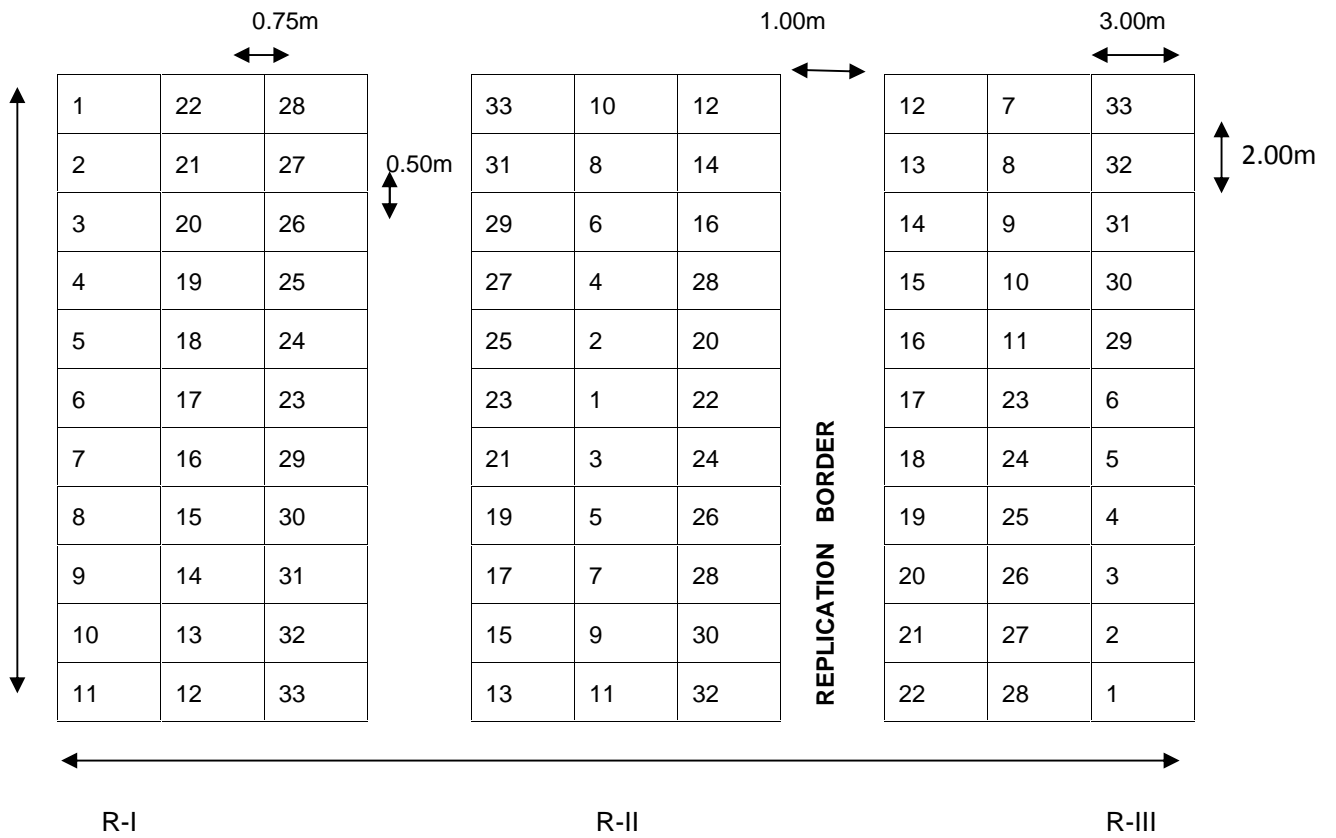
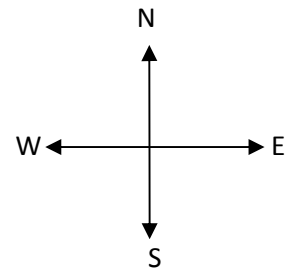


Fig.2 Plan of the layout of the experiment

3.4 Agronomical operation: -

3.4.1 Raising of seedling:

Raised nursery beds were prepared and protected by the cover of polythene sheets for the protection of nursery from the heavy rains. These nursery beds were 1m wide and 3m long and elevated up to 20cm from ground levels. Treated seeds 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 straw. Sprinkling of water was done immediately. After germination of seeds, cover of dry straw was removed. Weeding was done manually when weeds appeared in the nursery .

3.4.2 Land preparation:

The experimental area was ploughed and harrowed in order to bring the soil in good condition. Plots were made according to the layout plan after leveling. Drainage channels were made around the field to remove the excess of water.

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.

3.4.4 Fertilizer application:

A basal dose of 15t FYM along with the 80 kg nitrogen, 60 kg phosphorus, 50 kg potash and 50 kg sulphur were applied in form of urea, single super phosphate and muriate of potash. Full dose of FYM, SSP, MOP were incorporated in field before transplanting whereas nitrogen was applied in three split doses first before transplanting, second at 25 DAT and last one at 50 DAT.

3.4.5 Irrigation:

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

3.4.6 Intercultural operations

The experimental plots were kept weed free. Hand weeding was done timely and whenever needed during the entire crop growth period.

3.5 Sampling

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

3.6 Observations -:

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 taken 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 Collar thickness(cm)

Collar thickness of selected bulbs from each plot and replication were measured with the help of vernier caliper and the mean was taken out.

3.6.4 Neck thickness(cm)

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

3.6.5 Equatorial diameter of bulb (cm)

Equatorial diameter of ten randomly selected bulbs from each plot and replication was recorded with the help of Vernier caliper and the mean equatorial diameter was taken out.

3.6.6 Polar diameter of bulb (cm)

Polar diameter of bulbs from each plot and replication was recorded with the help of Vernier caliper and the mean polar diameter was taken out.

3.6.7 Fresh weight of bulbs

Total yield(Kg) obtained from a plot was divided by total number of bulbs obtained from that plot.

3.6.8 Average weight of marketable bulbs (g)

Marketable bulbs were identified and separated from the total bulbs from each plot and their individual weight was recorded.

3.6.9 % A grade bulbs (on weight basis)

After harvesting total bulbs from each plot, bulbs with bulb diameter between 5.5 - 6.5 cm were separated and weighed as A grade bulbs. Percent 'A' grade bulbs was calculated from total yield obtained

3.6.10 % B grade bulbs (on weight bulbs)

From the total bulbs obtained after harvesting from every plot, bulbs with bulb diameter of 4.5 – 5.5 cm were separated and weighed as B grade bulbs. Percent 'B' grade bulb was calculated from total yield obtained.

3.6.11 % C grade bulbs (on weight basis)

From the total bulbs obtained after harvesting from every plot bulbs with bulb diameter between 3.5 – 4.5 cm were separated and weighted as C grade bulbs. Percent C grade bulbs was calculated from total yield obtained.

3.6.12 % D grade bulbs (doubles)

Total number of Jointed or double bulbs obtained from each plot were separated and weighted as D grade bulb. % D grade bulb was calculated from the total yield obtained.

3.6.13 % Rotting

Number of plants rotted per plot after transplanting were observed and their % rotting was calculated.

3.6.14 % Marketable bulbs (on weight basis)

Sum total weight of A grade bulbs, B grade bulbs and C grade bulbs was considered as total weight of marketable bulbs. Which was converted on percentage basis from the total yield

3.6.15 % Bolting (on weight basis)

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

3.6.16 Marketable yield (q/ha)

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

3.6.17 Total yield (q/ha)

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

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

Total soluble solid was estimated with the help of refractometer.

3.6.19 Dry weight of bulbs

Bulbs were dried in 'hot air oven' at 60⁰c until the constant weight of the bulbs were obtained.

3.6.20 Days to Harvest

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

3.6.21 Incidence of stemphyllium blight and Purple Blotch

Disease occurrence was identified by the presence of symptoms on leaves and stem of plants at (i) 30 days after transplanting (ii) 45 days after transplanting (iii) 60 days after transplanting and (iv) 75 days after transplanting . It was computed on percent basis.

3.6.22 Incidence of Thrips

Number of thrips per plant were counted at (i) 30 days after transplanting (ii) 45 days after transplanting (iii) 60 days after transplanting and (iv) 75 days after transplanting and converted on percent basis.

3.6.23 Bulb colour

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

- Red
- Light Red
- White
- Dark Red

3.6.24 Storage losses

It included the following losses which were observed for the duration for the duration of two months -:

- (i) sprouting percentage in bulbs .
- (ii) Rotting percentage in bulbs.
- (iii) Physiological weight loss of bulbs.

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.

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

Where,

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.

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

$$SE\ m \pm = \sqrt{\frac{EMS}{r}}$$

$$SE\ diff = \sqrt{\frac{2\ EMS}{27\ r}}$$

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

Where,

C.V. = Coefficient of variation

SEm ± = 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,

x_i = The sum of all the observation for ith 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	t ² _e + r . t ² _g
3.	Error	E _i	t ² _e

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

$$t^2_{e_i} = E_i$$

$$t^2_{p_i} = t^2_{g_i} + t^2_{e_i}$$

Where,

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

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

$\sigma^2_{p_i}$ = 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,

\bar{X}_i = General mean of the i^{th} character under consideration

$\sigma^2_{g_i}$ and $\sigma^2_{p_i}$ = Genotypic and phenotypic variance of the i^{th} character, respectively.

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.

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

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 i^{th} character

h_i^2 = Broad sense heritability (fraction) of the i^{th} character

\bar{X}_i = General mean of the i^{th} 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).

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

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.

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

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

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

Testing of correlations:

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

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

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

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 “Studies on genetic and association analysis for yield and its component traits in *Kharif* Onion (*Allium cepa* L.)” 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 Annexure 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, has been of higher magnitude.

**Annexure 4.1: Analysis of variance for various characters in onion
(mean sum of squares)**

Source of variation	D.F	Plant height(cm)				Number of leaves per plant			
		30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
Replication	2	13.16	0.847	15.768	20.328	0.409	0.343	0.373	0.461
Treatments	32	7.43**	12.068**	55.880**	43.312**	1.020**	2.173**	2.387**	5.445**
Error	64	5.786	2.433	4.442	3.330	0.271	0.879	0.492	0.486

Source of variation	D.F	% A Grade bulbs	% B Grade bulbs	% C Grade bulbs	% Bolters	% Marketable yield	Total yield (q/ha)
Replication	2	30.40	66.44	3.925	130.44	8.714	9371.762
Treatments	32	217.345**	293.618**	191.171**	11.001**	209.346**	4121.319**
Error	64	23.466	69.343	73.082	4.643	54.410	634.090

Source of variation	D.F	Marketable yield (q/ha)	Collar thickness (cm)	Neck thickness (cm)	Equatorial diameter (cm)	Polar diameter (cm)	Fresh weight of bulbs (gm)
Replication	2	4897.714	0.167	0.046	0.153	0.588	7.771
Treatments	32	5984.017**	0.020**	0.006**	0.789**	0.490**	35.993**
Error	64	702.946	0.005	0.004	0.089	0.049	2.543

Source of variation	D.F	Average marketable weight of bulbs (gm)	Days to harvest	% Dry weight of bulbs	Sprouting % 15 DAS	Rotting % 15 DAS	Sprouting % 30 DAS
Replication	2	4.574	1.608	0.276	2.496	1.418	2.778
Treatments	32	49.832**	19.214**	14.803**	1.702**	1.898**	1.743**
Error	64	2.056	1.669	0.796	0.573	0.459	0.347

Source of variation	D.F	Rotting % 30 DAS	Sprouting % 45 DAS	Rotting % 45 DAS	Sprouting % 60 DAS	Rotting % 60 DAS
Replication	2	0.320	1.094	2.842	6.072	1.795
Treatments	32	3.865**	3.444**	3.729**	12.657**	8.527**
Error	64	0.454	0.638	1.312	1.829	1.523

Source of variation	D.F	Wt. loss 30 DAS	Weight loss % 60 DAS	Stemphyllium blight % 30 DAT	Stemphyllium blight % 45 DAT	Stemphyllium blight % 60 DAT
Replication	2	0.563	0.769	2.059	110.048	104.527
Treatments	32	4.245**	6.1448**	2.315**	44.096**	52.067**
Error	64	0.171	0.400	0.918	15.162	17.874

Source of variation	D.F	Thrips count 30 DAT	Thrips count 45 DAT	Thrips count 60 DAT	T.S.S %
Replication	2	2.004	0.976	6.299	0.474
Treatments	32**	6.511**	6.161**	5.132**	4.392**
Error	64	0.864	1.203	0.880	0.940

significant at 1% level= **

4.2 Genetic Variability

4.2.1 Range and mean performance of the genotype

Range and mean performance of the thirty three genotypes of onion for all the twenty four characters are depicted in the Table 4.2 a, b and c, d and e.

4.2a: Mean performance of Morphological parameters in onion

Treatment	Plant height (cm) DAT				Number of leaves per plant				Days to harvest
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	
ASKO-1201	18.700	25.833	44.533	52.600	3.567	7.233	10.033	13.733	122.267
ASKO-1203	19.033	26.033	44.067	53.600	3.500	6.167	10.233	13.833	123.833
ASKO-1207	19.400	27.467	40.433	50.733	3.600	6.033	10.100	12.167	121.667
ASKO-1210	17.200	25.200	39.600	50.133	3.300	5.833	9.867	11.667	122.833
ASKO-1213	19.133	25.933	41.100	50.567	4.000	6.167	10.433	14.833	123.733
ASKO-1215	19.600	26.033	40.900	50.800	4.400	6.567	11.533	14.667	121.000
ASKO-1217	20.100	26.967	52.367	52.233	4.567	7.200	10.933	15.833	121.000
ASKO-1220	21.000	28.133	47.767	55.900	4.100	8.067	10.500	14.833	122.367
ASKO-1222	18.633	27.767	49.133	52.900	4.600	8.367	11.167	14.467	125.333
ASKO-1224	19.567	27.267	51.767	56.400	4.833	8.367	11.267	16.167	126.333
ASKO-1227	21.633	26.900	44.433	59.500	4.867	8.500	10.933	15.800	128.667
ASKO-1231	23.133	28.133	43.533	60.667	4.867	8.533	10.867	15.667	127.500
ASKO-1233	20.833	28.200	41.500	51.067	4.767	8.233	11.500	16.533	126.233
ASKO-1236	22.533	29.667	41.967	51.533	5.067	8.533	12.900	17.200	120.833
ASKO1238	19.233	27.367	43.767	53.300	5.167	8.367	12.333	16.833	122.000
ASKO-1271	18.267	27.267	40.333	50.767	3.800	7.833	12.400	16.833	122.100
ASKO-1273	19.000	29.500	40.800	50.500	3.667	7.000	11.200	16.867	122.133
BSKO-1227	18.067	26.833	42.267	52.500	3.900	7.233	11.567	17.000	121.000
BSKO-1231	22.000	29.033	48.067	54.733	5.300	8.300	11.967	15.500	125.333
BSKO-1233	18.900	27.367	50.167	56.667	4.600	8.700	12.400	16.000	126.767
BSKO-1246	19.567	28.567	51.700	58.967	5.033	7.833	10.767	15.833	122.000
BSKO-1249	21.333	28.500	51.000	59.167	5.033	8.700	10.867	16.967	125.367
BSKO-1251	20.567	26.767	50.000	60.933	4.733	7.800	11.200	15.067	121.000
BSKO-1256	20.967	28.033	50.667	61.200	5.067	6.933	10.633	15.733	121.567
BSKO-1259	18.867	27.133	50.700	58.333	4.467	6.867	12.133	15.333	125.000
BSKO-1227	17.967	26.800	49.167	55.900	4.767	8.167	12.400	16.033	121.500
BSKO-1231	20.033	30.433	44.867	51.867	4.533	8.200	12.400	16.133	122.000
CSKO-1233	19.233	32.733	48.433	54.600	5.267	8.333	11.667	16.167	128.333
CSKO-1261	17.567	30.067	49.333	57.533	5.433	8.833	13.367	17.233	126.500
CSKO-1264	19.300	28.667	50.067	59.533	5.100	8.000	12.633	16.000	129.000
CSKO-1266	17.767	32.000	50.967	60.133	4.533	7.867	11.867	16.700	124.500
CSKO-1269	23.367	34.233	52.433	62.067	4.133	7.700	11.367	17.167	125.000
A.D.R (SC)	19.333	27.300	42.400	55.133	4.467	7.567	10.633	14.767	121.500
Mean	19.750	28.120	46.330	55.220	4.500	7.690	11.390	15.620	123.824
C.D.	N/A	2.550	3.446	2.983	0.851	1.533	1.146	1.140	2.112
SE(m)	1.389	0.901	1.217	1.054	0.301	0.541	0.405	0.402	0.746
C.V.	12.178	5.546	4.545	3.304	11.526	12.178	6.153	4.461	1.043

4.2b : Mean performance of sink parameters of onion

Treatment	Neck thickness (cm)	Equatorial diameter (cm)	Polar diameter r(cm)	Total yield q/ha	Marketable yield q/ha	Collar thickness (cm)	Fresh weight of bulb (gm)	Average weight of marketable bulb (gm)	Dry weight of bulbs %
ASKO-1201	0.767	3.333	3.967	228.867	162.633	1.433	35.300	39.100	14.167
ASKO-1203	0.800	3.900	4.067	222.067	128.467	1.433	36.900	37.967	13.067
ASKO-1207	0.700	3.533	4.433	248.867	179.033	1.400	35.533	38.200	11.567
ASKO-1210	0.733	4.067	5.000	277.733	197.733	1.367	34.867	38.200	16.267
ASKO-1213	0.800	3.733	4.533	243.833	171.333	1.433	36.700	40.500	11.700
ASKO-1215	0.700	5.033	4.533	286.067	201.167	1.333	40.533	45.100	14.600
ASKO-1217	0.700	4.233	4.933	212.733	149.767	1.300	31.367	35.767	13.100
ASKO-1220	0.833	3.767	4.467	208.300	128.500	1.433	31.467	35.500	15.533
ASKO-1222	0.733	3.500	4.333	201.633	123.767	1.400	31.500	37.767	14.933
ASKO-1224	0.767	4.133	4.633	243.267	158.267	1.433	37.933	43.700	14.867
ASKO-1227	0.833	4.700	4.867	229.400	176.533	1.533	39.600	44.833	17.700
ASKO-1231	0.800	5.267	4.733	332.200	291.900	1.467	43.167	49.000	18.933
ASKO-1233	0.767	4.400	5.167	257.200	182.033	1.367	38.633	43.100	17.667
ASKO-1236	0.800	4.567	5.167	311.067	254.633	1.333	37.600	43.700	16.900
ASKO1238	0.800	4.900	4.433	222.767	134.133	1.300	31.000	33.767	11.667
ASKO-1271	0.667	4.400	4.033	209.967	115.567	1.200	30.567	33.900	9.933
ASKO-1273	0.733	4.500	4.367	286.067	202.067	1.333	37.100	40.167	16.733
BSKO-1227	0.767	4.233	5.000	243.867	195.967	1.200	35.433	39.233	12.667
BSKO-1231	0.700	4.667	5.200	285.533	225.733	1.367	39.267	46.300	15.133
BSKO-1233	0.800	4.533	5.100	260.533	177.433	1.333	35.267	39.933	14.500
BSKO-1246	0.767	4.200	4.867	271.067	142.667	1.233	35.700	40.833	13.733
BSKO-1249	0.767	4.900	5.300	258.867	169.967	1.267	35.300	41.233	13.800
BSKO-1251	0.800	5.300	4.767	278.300	205.133	1.300	40.067	45.067	15.867
BSKO-1256	0.767	5.500	5.233	363.867	296.900	1.333	40.733	45.200	17.100
BSKO-1259	0.833	4.133	4.867	246.633	164.667	1.167	36.367	40.733	11.367
CSKO-1227	0.833	4.467	5.167	283.867	174.767	1.300	40.867	46.200	12.333
CSKO-1231	0.833	4.933	5.300	293.867	231.333	1.300	38.967	45.833	12.700
CSKO-1233	0.853	4.667	5.333	281.667	216.333	1.300	39.233	45.000	12.633
CSKO-1261	0.767	3.867	4.933	275.533	207.233	1.267	39.933	44.467	11.567
CSKO-1264	0.767	5.000	5.167	293.833	236.933	1.300	41.100	45.733	15.567
CSKO-1266	0.800	4.633	5.167	306.633	230.500	1.300	43.433	48.033	16.700
CSKO-1269	0.767	4.467	5.200	281.100	222.600	1.300	40.667	45.667	15.033
A.D.R (SC)	0.800	5.100	5.033	248.900	187.067	1.267	35.767	40.400	12.300
Mean	0.760	4.400	4.820	263.510	189.170	1.320	37.200	41.820	14.310
C.D.	N/A	0.489	0.362	41.170	43.348	0.112	2.607	2.344	1.459
SE(m)	0.038	0.173	0.128	14.538	15.307	0.040	0.921	0.828	0.515
C.V.	8.565	6.781	4.581	9.556	14.015	5.129	4.286	3.428	6.233

4.2c: Mean performance of various parameters in onion

Treatment	% A grade bulbs	% B grade bulbs	% C grade bulbs	% Marketable bulbs	% Bolters	T.S.S%
ASKO-1201	0.000	33.267	38.067	71.067	3.033	10.567
ASKO-1203	0.000	28.167	30.000	57.933	0.000	13.033
ASKO-1207	0.000	41.667	30.233	71.900	0.000	13.833
ASKO-1210	0.000	43.267	27.867	71.133	6.500	12.167
ASKO-1213	0.000	41.567	29.567	71.133	2.133	12.500
ASKO-1215	0.000	34.900	35.600	70.500	4.067	12.233
ASKO-1217	0.000	35.000	37.767	72.767	0.533	11.367
ASKO-1220	0.000	27.667	33.667	61.333	2.767	14.100
ASKO-1222	0.000	12.800	46.900	62.233	7.700	13.467
ASKO-1224	0.000	27.800	37.067	64.867	0.000	12.700
ASKO-1227	25.133	30.667	25.333	77.633	1.433	12.733
ASKO-1231	26.833	31.200	29.700	87.733	1.367	14.033
ASKO-1233	1.667	31.200	37.767	70.600	12.167	13.400
ASKO-1236	11.000	29.467	41.200	81.667	3.067	11.533
ASKO1238	0.000	0.000	60.700	60.700	0.000	12.967
ASKO-1271	0.000	0.000	55.533	55.533	1.800	10.600
ASKO-1273	0.000	36.067	34.700	70.767	1.567	10.933
BSKO-1227	0.000	44.300	35.467	79.767	2.200	12.200
BSKO-1231	15.500	24.600	38.633	78.733	2.400	14.233
BSKO-1233	0.000	24.333	43.933	68.267	0.000	14.167
BSKO-1246	0.000	20.000	37.667	53.433	1.333	11.500
BSKO-1249	0.000	34.400	35.033	63.733	2.100	11.667
BSKO-1251	16.800	32.267	24.800	73.867	1.733	12.100
BSKO-1256	9.667	29.533	42.433	81.633	0.733	13.933
BSKO-1259	0.000	24.533	41.867	66.400	0.000	12.167
CSKO-1227	0.000	26.167	36.633	61.100	4.167	12.300
CSKO-1231	18.967	30.167	29.767	78.767	1.700	14.600
CSKO-1233	5.333	32.600	39.600	77.533	0.000	15.000
CSKO-1261	0.000	30.333	45.367	75.700	0.967	13.100
CSKO-1264	17.667	33.667	29.433	80.733	0.900	12.867
CSKO-1266	6.167	31.367	37.767	75.300	0.000	12.433
CSKO-1269	15.567	35.533	28.067	79.167	4.600	13.000
A.D.R (SC)	17.867	27.567	29.667	75.100	2.700	14.300
Mean	5.700	32.310	36.600	71.170	1.920	12.730
C.D.	7.920	13.615	13.977	12.060	3.523	1.585
SE(m)	2.797	4.808	4.936	4.259	1.244	0.560
C.V.	84.955	28.445	23.357	10.364	107.363	7.613

4.2d: Mean performance of disease and insect in onion

Treatment	Stemphylium blight % 30 DAT	Stemphylium blight % 45 DAT	Stemphylium blight % 60 DAT	Thrips count per plant 30 DAT	Thrips count per plant 45 DAT	Thrips count per plant 60 DAT
ASKO-1201	3.733	13.967	18.500	5.567	10.867	14.500
ASKO-1203	4.167	10.533	13.900	5.633	10.167	14.367
ASKO-1207	4.033	10.000	11.467	3.633	11.633	15.333
ASKO-1210	4.400	8.767	13.833	2.433	10.600	16.233
ASKO-1213	3.300	5.733	8.600	5.633	11.500	16.833
ASKO-1215	5.167	13.233	17.433	4.967	13.900	16.767
ASKO-1217	4.800	14.000	16.900	4.200	14.033	17.933
ASKO-1220	6.200	16.400	21.067	7.833	14.133	18.060
ASKO-1222	3.333	16.200	20.167	6.433	10.333	17.233
ASKO-1224	5.367	15.167	19.967	4.533	10.133	17.433
ASKO-1227	3.767	14.500	17.300	5.733	9.667	16.033
ASKO-1231	5.933	15.400	19.867	5.467	9.367	16.633
ASKO-1233	5.533	16.333	25.433	5.067	9.567	15.900
ASKO-1236	6.500	22.500	25.767	7.500	12.160	16.533
ASKO1238	4.367	7.033	13.400	6.367	8.900	14.933
ASKO-1271	4.500	10.500	19.000	4.567	10.200	12.900
ASKO-1273	5.767	11.300	13.700	3.333	9.733	14.400
BSKO-1227	5.033	10.867	14.933	2.267	10.433	16.400
BSKO-1231	5.200	20.333	22.600	2.000	8.767	12.6
BSKO-1233	5.167	15.233	18.733	2.967	10.067	14.933
BSKO-1246	5.433	12.400	14.200	4.133	10.100	14.367
BSKO-1249	5.333	18.167	22.000	3.433	12.133	16.200
BSKO-1251	6.400	17.567	21.000	5.333	10.033	17.433
BSKO-1256	5.467	6.333	8.867	5.400	9.133	15.800
BSKO-1259	3.700	8.767	11.600	5.600	11.167	15.933
CSKO-1227	6.067	10.833	14.867	6.133	11.267	17.267
CSKO-1231	5.700	12.500	15.100	5.600	12.400	15.233
CSKO-1233	3.900	12.000	16.133	3.467	11.100	15.600
CSKO-1261	4.267	11.300	15.400	2.633	12.900	16.000
CSKO-1264	5.167	12.800	16.933	3.667	9.767	15.900
CSKO-1266	4.733	17.133	20.267	3.233	10.133	17.333
CSKO-1269	5.267	11.600	14.567	5.167	11.767	16.567
A.D.R (SC)	5.000	12.200	15.633	3.533	11.433	15.833
Mean	4.93	13.01	16.94	4.65	10.89	15.90
C.D.	1.567	6.366	6.912	1.519	1.793	1.533
SE(m)	0.553	2.248	2.441	0.537	0.633	0.541
C.V.	19.435	29.772	24.952	19.983	10.068	5.897

4.2e: Mean performance of Storage losses in onion

Treatment	Sprouting % 15 DAT	Sprouting % 30 DAT	Sprouting % 45 DAT	Sprouting % 60 DAT	Rotting % 15 DAT	Rotting % 30 DAT	Rotting % 45 DAT	Rotting % 60 DAT	Physiological weight loss % 30 DAT	Physiological weight loss % 60 DAT
ASKO-1201	5.600	7.167	7.700	10.80	3.933	6.033	7.600	9.167	2.667	5.567
ASKO-1203	4.100	6.900	7.867	10.667	5.233	7.167	8.500	11.633	4.533	7.767
ASKO-1207	5.333	8.333	9.733	10.833	6.300	7.133	7.833	13.600	2.033	5.167
ASKO-1210	6.200	8.700	10.400	12.533	6.433	8.300	9.000	15.600	2.400	6.967
ASKO-1213	4.033	8.700	9.267	14.967	4.500	6.733	8.400	14.567	2.233	7.367
ASKO-1215	3.900	7.933	8.433	13.633	4.000	7.267	9.333	13.167	3.400	6.700
ASKO-1217	4.567	8.300	9.167	14.000	5.100	8.800	9.800	15.100	7.500	10.067
ASKO-1220	5.067	8.533	9.100	13.700	6.533	8.900	10.767	14.367	4.200	6.367
ASKO-1222	5.567	8.067	8.900	15.500	6.667	9.067	10.967	16.400	4.933	6.800
ASKO-1224	4.700	7.033	7.867	13.367	6.000	6.367	8.733	13.300	3.400	8.033
ASKO-1227	4.733	8.567	10.733	12.200	5.900	9.933	9.833	12.733	4.200	8.600
ASKO-1231	4.133	8.867	7.867	12.667	6.567	8.767	10.800	11.500	3.133	6.200
ASKO-1233	5.167	9.600	10.167	16.300	6.167	7.433	11.433	13.933	3.267	5.933
ASKO-1236	4.667	8.43	10.633	15.700	5.033	7.433	10.567	13.500	3.933	8.233
ASKO-1238	5.733	9.267	10.967	14.667	5.333	8.200	9.800	16.367	3.567	9.233
ASKO-1271	6.200	9.700	11.400	17.600	5.233	9.833	11.000	15.633	3.200	5.600
ASKO-1273	6.100	9.100	9.800	15.533	6.000	7.700	9.767	13.300	3.833	7.900
BSKO-1227	5.467	9.467	10.867	16.000	6.033	9.500	11.300	15.000	5.800	9.400
BSKO-1231	6.000	9.200	9.967	16.167	5.067	8.967	10.533	14.700	5.300	6.700
BSKO-1233	6.067	8.600	10.167	12.033	5.233	9.133	11.267	13.533	4.267	8.700
BSKO-1246	6.133	8.500	9.333	14.067	4.767	8.767	10.333	15.000	5.433	7.600
BSKO-1249	5.200	8.900	10.300	15.567	5.700	9.567	11.133	15.100	2.933	5.967
BSKO-1251	6.167	8.833	10.133	14.233	6.967	10.400	11.900	16.967	3.433	8.200
BSKO-1256	4.500	8.633	10.567	12.633	5.567	9.667	11.533	14.200	6.000	9.167
BSKO-1259	5.533	9.133	9.800	15.567	6.333	7.767	10.567	15.400	3.433	5.733
CSKO-1227	4.933	7.700	8.633	14.100	5.733	7.533	11.267	14.600	4.867	7.667
CSKO-1231	5.400	8.133	8.833	11.533	4.500	7.600	9.967	13.533	5.033	7.533
CSKO-1233	5.633	9.200	9.667	11.867	4.133	7.933	10.333	14.767	3.767	9.233
CSKO-1261	4.033	7.833	8.033	12.033	5.200	6.767	9.033	11.833	3.700	9.067
CSKO-1264	5.100	7.800	8.367	11.033	5.033	7.500	9.867	13.200	4.133	5.800
CSKO-1266	5.167	7.967	9.000	14.433	5.833	8.200	9.500	15.800	3.833	8.867
CSKO-1269	5.767	8.533	9.100	12.033	5.733	9.000	9.267	14.400	2.767	8.133
A.D.R (SC)	3.667	6.700	7.467	8.600	4.833	6.667	8.967	10.967	2.833	5.733
Mean	5.160	8.430	9.400	13.53	5.500	8.180	10.020	14.020	3.390	7.470
C.D.	1.238	0.963	1.306	2.211	1.108	1.101	1.872	2.017	0.677	1.034
SE(m)	0.437	0.340	0.461	0.781	0.391	0.389	0.661	0.712	0.239	0.365
C.V.	14.648	6.980	8.498	9.995	12.311	8.230	11.421	8.797	10.507	8.464

4.2.1.1 Plant Height (cm)

Plant height varied showed large variation with respect to genotypes at each growth phase of 30, 60, 90, and 120 DAT. Table 4.2a showed that plant height reached to a mean level of 55.22cm at 120 DAT with a range between 50.13cm to 62.06cm. Genotype CSKO- 1269 was recorded highest plant height 62.06 cm, however, genotype ASKO-1210 recorded lowest plant height 50.13cm at 120 DAT.

4.2.1.2 Number of leaves per plant

A similar trend in case of number of leaves per plant was obtained. There was continuous increase in number of leaves per plant at 30, 60, 90, and 120 DAT. At 120 DAT the range of number of leaves per plant was 11.66 to 17.23 in genotype CSKO-1261 with mean of 15.62.

4.2.1.3 Collar thickness (cm)

Collar thickness varied from 1.15 to 1.56 cm with an average performance of 1.32 cm. The genotype ASKO- 1227 was recorded with the maximum collar thickness 1.56 cm . While it was found minimum 1.15 cm in genotype BSKO-1259 .

4.2.1.4 Neck thickness (cm)

Neck thickness varied from 0.66 to 0.83 with an overall mean performance of 0.76 cm. Genotype CSKO- 1233 was recorded with the maximum neck thickness 0.83 cm. Whereas, minimum 0.66 cm was observed in genotype ASKO-1201.

4.2.1.5 Equatorial diameter (cm)

Equatorial diameter lied between 3.34 and 5.31cm with an average being 4.40 cm. Genotype ASKO-1201 was recorded with minimum equatorial diameter of 3.34 cm, while it was recorded maximum 5.31cm in BSKO-1256 .

4.2.1.6 Polar diameter (cm)

Polar diameter ranged between 3.96 and 5.49 cm with an overall mean of 4.82 cm. Genotype ASKO-1201 was recorded with the minimum 3.96 cm & CSKO-1231 recorded with the maximum polar diameter 5.49 cm.

4.2.1.7 Fresh weight of bulbs (g)

Genotype CSKO-1266 was recorded with the maximum fresh weight of bulb 43.43 gm. Whereas, genotype ASKO-1271 was recorded with minimum 30.56 gm. Fresh weight of bulbs lied between 30.56 and 43.43 gm, with a mean of 37.20 gm of all genotypes.

4.2.1.8 Average weight of marketable bulb (g)

It ranged between 33.76 and 49 gm, with a mean performance of 41.82 gm. Highest average marketable weight of bulbs 49 gm was obtained in genotype ASKO- 1231, followed by genotype CSKO-1266 i.e. 48.03 gm and it was recorded lowest 33.76 gm in genotype ASKO-1238.

4.2.1.9 Percentage ‘ A’ grade bulbs

The overall mean value of all genotypes for ‘A’ grade bulbs was 5.70%. Genotype ASKO-1231 was recorded with maximum 26.83 percentage of A grade bulbs. However, there were certain genotypes in which ‘A’ grade bulbs were not found these are ASKO-1201, ASKO- 1203, ASKO-1207, ASKO-1238, ASKO-1271, BSKO-1249 etc.

4.2.1.10 Percentage ‘B’ grade bulbs

It ranged from 24.3 to 44.3 percentage, with an overall mean of 32.31 percentage. Maximum ‘B’ grade bulbs 44.3 percentage were obtained in genotype BSKO- 1227 whereas, minimum 24.3 percentage were obtained in genotype BSKO-1233.

4.2.1.11 Percentage ‘C’ grade bulbs

The overall mean performance of percent ‘C’ grade bulbs was 36.6 percentage. It varied from 24.8 to 60.7 percentage in all genotypes. Maximum ‘C’ grade bulbs 60.7 percentage were obtained in genotype ASKO-1238, whereas it was recorded minimum 24.8 percentage in genotype BSKO-1251.

4.2.1.12 Percentage 'D' grade bulbs (doubles)

Percentage 'D' grade bulbs were not obtained during the experiment work.

4.2.1.13 rotting Percentage

Rotting was not observed in the field during the experimental duration.

4.2.1.14 Percentage Marketable bulbs

Percentage marketable bulbs ranged from 53.4 to 87.7 %. Genotype ASKO-1231 was recorded with the maximum 87.7 % of marketable bulbs followed by ASKO-1236 86.66 % & BSKO-1256 81.63 %. While genotype BSKO-1246 was recorded with minimum 53.4 %bulbs. The overall mean performance of percent marketable bulbs was 71.17%.

4.2.1.15 Percentage Bolters

It varied from 0 to 7.7 percentage percent , with an overall mean performance of 1.920 %. Maximum % bolters 7.7 were observed in genotype ASKO-1222, whereas, there were many genotypes in which bolting was not found such as ASKO- 1203, ASKO-1207, BSKO- 1233, BSKO-1259, CSKO-1233 etc .

4.2.1.16 Marketable yield (q/ha)

Marketable yield varied from 115.67 to 296.9 q/ha, with an overall mean performance of 189.17 q/ha . Genotype BSKO-1256 was recorded with the maximum marketable yield of 296.9 q/ha followed by genotype ASKO-1231 i.e.291.1q/ha. Whereas, genotype ASKO-1271 was recorded with minimum marketable yield i.e. 115.67 q/ha.

4.2.1.17 Total yield q/ha

Genotype BSKO-1256 was recorded with the maximum yield of 363.86 q/ha followed by ASKO-1231 332.20q/ha, whereas, genotype ASKO-1222 recorded minimum yield of 201.63 q/ha, with an overall average performance of 263.51q/ha.

4.2.1.18 Percentage dry weight of bulbs

It lied between 9.93 and 18.93%, with an overall average of 14.31%. Maximum dry weight 18.93% was found in genotype ASKO-1231. Whereas, minimum 9.93% was observed in genotype ASKO-1222.

4.2.1.19 Total soluble solid (TSS)

TSS ranged from 10.56 & to 16% with an overall mean value of 12.73%. The maximum 15% TSS was obtained in genotype CSKO-1233. Whereas, minimum TSS 10.56% was obtained in genotype ASKO-1201.

4.2.1.20 Days to harvest

The average days for harvest after maturity ranged from 120.83 to 129 day. Early maturity was recorded in genotype ASKO-1236 (120.83) days, followed by BSKO-1251 (121) days & CSKO-1227 (121.5) days. However, late maturity was observed in genotype CSKO-1264 (129 days).

4.2.1.21 Incidence of Stemphyllium blight & incidence of Purple blotch

Incidence of Stemphyllium blight disease varied from 3.3 to 6.5, 5.73 to 22.5, & 8.60 to 25.76 percentage with an overall mean performance of 4.93, 13.01 & 16.94 percentage at 30, 45 & 60 DAT respectively. Maximum occurrence of Stemphyllium blight was found in genotype ASKO-1236 (6.5, 22.5, & 25.76 percentage). However, it was minimum in genotype ASKO-1213 (3.3, 5.7 & 8.60 percentage) at 30, 45, 60 DAT respectively. Whereas, incidence of Purple blotch disease was not found.

4.2.1.22 Incidence of Thrips

Thrips incidence ranged from 2.00 to 7.83, 8.76 to 14.13, 12.6 to 18.06 per plant with over all mean performance of 4.65, 10.89 & 15.90 at 30, 45 & 60 DAT. Highest Thrips count per plant 7.83, 14.13 & 18.06 was found in genotype ASKO-1220. However Minimum 7.83, 14.13 & 18.06 was found in genotype BSKO-1231 at 30, 45 & 60 DAT respectively.

4.2.1.23 Storage losses in onion bulbs :-

4.2.1.23a: Sprouting percentage in bulbs

Sprouting percentage in bulbs during storage period varied from 3.6 to 6.2, 6.7 to 9.7, 7.46 to 11.4 & 8.6 to 17.6 percentage, with a grand mean of 5.16, 8.43, 9.40 & 13.53 at 15, 30, 45 & 60 days after storage. Agrifound Dark Red was noticed with minimum sprouting percentage i.e. 3.66, 6.70, 7.40 & 8.60. Whereas genotype ASKO-1271 showed maximum sprouting i.e. 6.2, 9.7, 11.4 & 17.6 percent at 30, 45 & 60 days after storage, respectively.

4.2.1.23b: Rotting percent in bulbs

During storage it was observed that rotting percent varied from 3.93 to 6.96, 6.03 to 10.40, 7.60 to 11.90 & 9.16 to 16.96 with an overall mean performance of 5.50, 8.18, 10.02 & 14.02 at 15, 30, 45 & 60 days after storage. Minimum rotting percent was found in genotype ASKO-1201 i.e. 3.93, 6.03, 7.6 & 9.16., whereas maximum rotting was noticed in genotype BSKO-1251 i.e. 6.96, 10.40, 11.9 & 16.96 at 15, 30, 45 & 60 days after storage, respectively.

4.2.1.23c: Physiological weight loss percent

It varied from 2.03 to 7.5 & 5.16 to 10.06 percent with an overall mean performance of 3.39 & 7.47 percent at 30 & 60 days after storage. Minimum weight loss percent was observed in genotype ASKO-1207 i.e. 2.03 & 5.16 percent. Whereas, maximum was observed in genotype ASKO-1217 i.e. 7.5 & 10.06 percent at 30 & 60 days after storage, respectively.

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 studied (table 4.3). Results 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 & genotypic coefficient of variation varied from 2.2 to 26.37% & 1.95 to 22.49% respectively. The high PCV was recorded for marketable yield (26.37%). However, it was exhibited low for character viz; days to harvest (2.21%), plant height 120 DAT (7.3%), collar thickness (7.66%), neck thickness (8.10%), leaves per plant at 90 DAT (9.43%) & polar diameter (9.48%). Whereas, it was observed moderate for characters like dry weight of bulbs (16.37%) & T.S.S (14.52%), & average weight of marketable bulbs (10.13%).

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. It was partitioned as high (70 to 90%), medium (50-70%) and low (less than 50%).

Results revealed that the heritability estimates were high for average weight of marketable bulbs (88.56%) followed by T.S.S (85.15%) & fresh weight of bulbs (81.31%), dry weight of bulbs (85.6%), plant height 120 DAT (79.17%) days to harvest (77.78%) & marketable yield (72.70%). However, medium heritability was observed in polar diameter (66.33%) followed by equatorial diameter (65.06%), collar thickness (59.25%) & leaves per plant 90DAT (56.25%). Whereas, low heritability was recorded in neck thickness (11.87%).

4.2.4 Genetic advance

The high estimate of genetic advance as percentage of mean was recorded i.e. 39.50% in marketable yield followed by dry weight of bulbs (28.86%) & T.S.S (25.47%). Whereas, Average weight of marketable bulbs (18.49%), fresh weight of bulbs (16.65%), equatorial diameter (15.6150), polar diameter (12.955), plant height (12.01%), number of leaves per plant 90 DAT (10.90%) & collar thickness (9.35%) exhibited moderate value for the same. While days to harvest (3.54%) & neck thickness (1.98%) showed the lowest estimate.

Table 4.3

Genetic Parameters in Twelve characters in onion.

Characters	Grand mean	Range		Coefficient of variations		Heritability %	Genetic Advance	GA as % of mean
		Min.	Max.	Phe.	Gen.			
Plant height 120 DAT	55.246	50.13	62.06	7.36	6.55	79.17	6.63	12.01
Leaves per plant 90 DAT	11.398	9.86	13.36	9.43	7.06	56.25	1.24	10.90
Collar thickness (cm)	1.327	1.15	1.56	7.66	5.90	59.25	0.12	9.35
Neck thickness (cm)	0.763	0.66	0.83	8.10	2.79	11.87	0.01	1.98
Polar diameter (cm)	4.785	3.96	5.49	9.48	7.72	66.33	0.62	12.95
Equitorial diameter (cm)	4.481	3.34	5.31	11.65	9.39	65.06	0.70	15.61
T.S.S%	14.439	10.56	16	14.52	13.40	85.15	3.67	25.47
Days to harvest	123.824	120.83	129	2.21	1.95	77.78	4.39	3.54
Fresh weight of bulb(gm)	37.209	30.56	43.43	9.94	8.96	81.31	6.19	16.65
Dry weight of bulbs %	14.318	9.93	18.93	16.37	15.14	85.60	4.13	28.86
Marketable yield q/ha	188.831	115.67	296.9	26.37	22.49	72.70	74.59	39.50
Average weight of marketable bulb (gm)	41.822	33.76	49	10.13	9.542	88.56	7.73	18.49

(Table 4.4) Estimates of genotypic and phenotypic correlation coefficients among Average weight of marketable bulbs (g) and its contributing characters.

Characters		Plant height (cm)120 DAT	Leaves per plant 90 DAT	Collar thickness (cm)	Neck thickness	Polar diameter (cm)	Equatorial diameter (cm)	T.S.S%	Days to harvest	Fresh weight of bulb (gm)	Dry weight of bulbs%	Marketable yield (q/ha)	Average Weight of Marketable Bulbs / plant (g)
Plant height (cm)120 DAT	G		0.089	-0.077	0.085**	0.240**	0.177	0.428**	0.445**	0.566**	0.356**	0.389**	0.572**
	P		0.097	-0.046	0.280**	0.145	0.130	0.328**	0.370**	0.421**	0.272**	0.318**	0.469**
Leaves per plant 90 DAT	G			-0.589**	0.317**	0.362**	0.094	0.203*	0.267**	0.224*	-0.227*	0.175	0.298**
	P			-0.366**	0.216*	0.282**	0.133	0.154	0.110	0.151	-0.166	0.186	0.220*
Collar thickness (cm)	G				0.398*	-0.381	-0.088	-0.293**	0.220*	0.167	0.602**	0.031	0.129
	P				0.065	-0.199*	-0.042	-0.225	0.202*	0.119	0.398**	0.028	0.075
Neck thickness(cm)	G					0.527**	0.130	0.325**	0.446**	0.671**	0.233*	0.330**	0.733**
	P					0.228*	0.199*	0.109	0.364**	0.255*	0.042	0.178	0.213*
Polar diameter(cm)	G						0.448**	0.574*	0.164	0.373**	0.142	0.540**	0.507**
	P						0.443**	0.364**	0.107	0.248*	0.094	0.318**	0.384**
Equatorial diameter(cm)	G							0.329**	0.047	0.486*8	0.309**	0.625*	0.474**
	P							0.224*	0.015	0.363*8	0.191	0.370*	0.353**
T.S.S%	G								0.276**	0.452**	-0.07	0.141	0.475**
	P								0.254*	0.3728*	-0.047	0.156	0.406**
Days to harvest	G									0.370**	0.276**	0.145	0.475**
	P									0.318**	0.251*	0.156	0.406**
Fresh weight of bulb (gm)	G										0.482**	0.807**	0.981**
	P										0.423**	0.644**	0.916**
Dry weight of bulbs%	G											0.510**	0.487**
	P											0.397**	0.459**
Marketable yield (q/ha)	G												0.807**
	P												0.669**
Average weight of marketable bulbs/ plant (gm)	G												
	p												

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

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 120 DAT (cm)

Plant height at 120 DAT expressed high significant & positive association with neck thickness (0.280), T.S.S (0.328), Days to harvest (0.370), fresh weight of bulb (0.421), dry weight of bulb (0.272), marketable yield (0.318) & average weight of marketable bulbs (0.469).

Number of leaves per plant 90 DAT

Number of leaves per plant at 90 DAT exhibited positive correlation & significance with the neck thickness (0.213), polar diameter (0.282) & average weight of marketable bulb(0.469).

Collar thickness (cm)

Collar thickness had high significant & positive correlation with the days to harvest (0.202), dry weight of bulbs (0.398).

Neck thickness (cm)

Neck thickness showed significant & positive association with the polar diameter (0.228), equatorial diameter (0.325), fresh weight of bulbs (0.255) & average weight of marketable bulbs (0.213).

Polar diameter (cm)

Polar diameter had highly significant & positive correlation with equatorial diameter (0.443), T.S.S (0.364), fresh weight of bulbs(0.248), marketable yield (0.318) & average weight of marketable bulb (0.384).

Equatorial diameter (cm)

Equatorial diameter showed significant & positive correlation with T.S.S (0.224) , fresh weight of bulbs (0.363), marketable yield (0.370) average weight of marketable bulb (0.353).

Total soluble solids (T.S.S)

It had highly significant & positive correlation with days to harvest (0.254), fresh weight of bulbs (0.318) , dry weight of bulb (0.251) & average weight marketable bulb (0.916).

Dry weight of bulbs (%)

Significant & positive correlations were recorded with dry weight of bulbs (0.423), marketable yield (0.397) & average weight of marketable bulb (0.459).

Marketable yield q/ha

Marketable yield showed highly significant & positive correlation with average weight of marketable bulbs (0.669).

(Table 4.5) : Estimates of genotypic and phenotypic path coefficient analysis showing Direct and indirect effect on average weight of marketable bulb.

Characters		Plant height (cm)120 DAT	Leaves per plant 90 DAT	Collar thickness (cm)	Neck thickness	Polar diameter (cm)	Equatorial diameter (cm)	T.S.S%	Days to harvest	Fresh weight of bulb (gm)	Dry weight of bulbs%	Marketable yield (q/ha)
Plant height (cm)120 DAT	G	-0.0897	-0.0085	0.0137	0.0513	0.0688	-0.0008	-0.0977	0.0325	0.6986	0.0305	-0.1268
	P	0.07533	0.0068	-0.0006	-0.0193	0.02260	-0.00675	0.01250	0.01067	0.3187	0.02264	0.0268
Leaves per plant 90 DAT	G	-0.0079	-0.0956	0.1055	0.0192	0.1039	-0.0004	-0.0463	0.0195	0.2762	-0.0194	-0.0570
	P	0.00729	0.07059	-0.0054	-0.0149	0.04409	-0.00691	0.00588	0.00316	0.1143	-0.0137	0.0157
Collar thickness (cm)	G	0.0068	0.05630	-0.1793	0.0242	-0.1094	0.0004	0.0668	0.0160	0.2057	0.0516	-0.0100
	P	-0.0034	-0.0258	0.01482	-0.0045	-0.0.031	0.00218	-0.0085	0.00582	0.0897	0.03313	0.0023
Neck thickness	G	-0.0757	-0.0303	-0.0713	0.0608	0.1512	-0.0006	-0.0741	0.0326	0.8283	0.02001	-0.1070
	P	0.02110	0.01523	0.00096	-0.0691	0.03555	-0.01033	0.00415	0.00426	0.0929	0.00349	0.0150
Polar dia. (cm)	G	-0.0215	-0.0346	0.0684	0.03205	0.28690	-0.00222	-0.1309	0.0120	0.4606	0.0121	-0.1753
	P	0.01091	0.01994	-0.0029	-0.0157	0.15610	-0.02303	0.01386	0.00307	0.1876	0.00785	0.0268
Equatorial diameter(cm)	G	-0.0159	-0.0089	0.0157	0.0079	0.1285	-0.0049	-0.0752	0.0034	0.6005	0.0265	-0.2037
	P	0.00978	0.00939	-0.0006	-0.0137	0.06914	-0.05199	0.00854	0.0004	0.2745	0.0158	0.0312
T.S.S%	G	-0.0384	-0.0194	0.0525	0.0197	0.1645	-0.0016	-0.2282	0.02022	0.5582	-0.0063	-0.045
	P	0.02470	0.01090	-0.0033	-0.0075	0.05676	-0.01165	0.03810	0.00733	0.2816	-0.0039	0.0131
Days to harvest	G	-0.0399	-0.0255	-0.0394	0.0271	0.0470	-0.0002	-0.0630	0.0731	0.4564	0.0236	-0.047
	P	0.0278	0.0077	0.00299	-0.0102	0.01663	-0.00076	0.00969	0.02882	0.2402	0.02087	0.0082
Fresh weight of bulb (gm)	G	-0.0507	-0.0214	-0.0298	0.0407	0.1070	-0.0024	-0.1031	0.0270	1.2350	0.0413	-0.262
	P	0.03175	0.01067	0.0017	-0.0176	0.03873	-0.01887	0.01419	0.0916	0.7562	0.03520	0.0543
Dry weight of bulbs%	G	-0.0319	0.0217	-0.1079	0.0141	0.0406	-0.0015	0.0169	0.0201	0.5952	0.0858	-0.166
	P	0.0204	-0.0117	0.00590	-0.0029	0.0147	-0.0099	-0.0017	0.0072	0.3199	0.08321	0.0335
Marketable yield (q/ha)	G	-0.0349	-0.016	-0.0056	0.0200	0.1549	-0.0030	-0.0322	0.01060	0.9963	0.04379	-0.3257
	P	0.0239	0.0131	0.0004	-0.0123	0.0496	-0.01924	0.0059	0.00280	0.4873	0.03307	0.0843

Phenotypic residual are 0.10845, Genotypic residual are 0.00354

4.4 Path coefficient analysis

To measure to direct as well as indirect association of one variable on the other path coefficients were calculated at both genotypic levels as well as phenotypic levels for all the yield attributing traits(table 4.5).

The observed correlation coefficients of yield with its contributing traits were partitioned into direct effects and indirect effects. In the present investigation, average weight of marketable bulb/plant has been considered as dependable variable with the other traits. Here both genotypic path as well as phenotypic paths have been discussed and the results obtained from them are presented as under.

Direct effects

Path coefficient analysis of different characters contributing towards average weight of marketable bulb/plant showed that high positive genotypic direct effect was exerted through fresh weight of bulb (1.2350), polar diameter (0.2863) dry weight of bulb (0.0858) and neck thickness (0.0608), whereas negative direct effect was excreted through marketable yield (-0.03257), TSS (-0.2282), collar thickness (-0.1793), leaves per plant 90 DAT (-0.0956) of plant height 120 DAT (-0.0956) & plant height 120 DAT (-0.0897) & equatorial diameters (-0.0049)

High positive direct phenotypic effect was exerted through fresh weight of bulb (0.7562), polar diameter (0.1561), marketable yield (0.0843) dry weight of bulb (0.08321), plant height (0.07533), leaves per plant 90 DAT (0.07059), TSS (0.0381), days to harvest (0.02882), and collar thickness (0.01482) whereas, negative phenotypic direct effect was visible through neck thickness (-0.0691) and equatorial diameter(-0.0519).

Indirect effects

1. Plant height 120 DAT

It exerted high genotypic positive indirect effect via fresh weight of bulb (0.6986), polar diameter (0.0688), days to harvest (0.0325), dry weight of bulb (0.0305), collar thickness (0.0137). But it had negative indirect effect on marketable yield (-0.1268), TSS(-0.0977), leaves per plant 90 DAT (-0.0085), and equatorial diameter (-0.008).

Whereas it exerted high phenotypic positive indirect via fresh weight of bulb (0.3187), marketable yield (0.0268), dry weight of bulb (0.0226), polar diameter (0.0226), TSS (0.0125), leaves per plant 90 DAT (0.0068). It had negative indirect effect an on thickness (-0.0193), equatorial diameter (-0.0067), and collar thickness (-0.0006).

2. Leaves per plant 90 DAT

It exerted high positive genotypic indirect effect in fresh weight of bulb (0.2762), collar thickness (0.1055), polar diameter (0.1039), days to harvest (0.0195), neck thickness (0.0192). But it laid negative indirect effect on marketable yield (-0.0570), TSS(-0.0463), dry weight of bulb (-0.0194) and plant height 120 DAT (-0.0079).

Whereas leaves per plant 90 DAT exerted high positive phenotypic indirect effect via fresh weight of bulb (0.1143), polar diameter (0.14409), marketable yield (0.0157), plant height at 120 DAT (0.0072), TSS (0.0058), days to harvest (0.0031),. And it laid negative indirect effect ton neck thickness (-0.0143), dry weight of bulb (-0.0137) equitable diameter (-0.0137) and collar thickness (-0.0054).

3. Collar thickness

It exerted positive genotypic indirect effect via, fresh weight of bulb (0.2057), TSS(0.0668), dry weight of bulb (0.0516), TSS (0.668), neck thickness (0.0242) leaves per plant (0.0563), days to harvest (0.0160), plant height 120 DAT (0.0068) and equatorial diameter (0.004). but it laid negative indirect effect on polar diameter (-0.1094) and marketable yield (-0.0100).

Whereas collar thickness had positive phenotypic indirect effect via fresh weight of bulb (0.0897), dry weight of bulb (0.0331), days to harvest (0.0058), equatorial diameter (0.0021), marketable yield (0.0023).

But negative indirect effect was observed on polar diameter (-0.0311), leaves per plant 90DAT (-0.0258), TSS (-0.0258), neck thickness (-0.0045), and plant height at 120 DAT (-0.0034).

4. Neck thickness

It laid positive genotypic indirect effect via fresh weight of bulb (0.08283), polar diameter (0.1512), days to harvest (0.0326) and dry weight of bulb (0.0200). But it exerted negative indirect effect on marketable yield (-0.1070) plant height 120 DAT(- 0.0757) TSS(-0.0741), collar thickness (-0.0713), leaves per plant 90 DAT (-0.0303) and equatorial diameter (-0.0006).

While positive phenotypic indirect effect was exerted on fresh weight of bulbs (0.0929), polar diameter (0.0355), plant height at 120 DAT (0.0211), leaves per plant 90 DAT(0.0152),marketable yield (0.0150), TSS (0.0041), days to harvest (0.0042), dry weight of bulb (00.0034), whereas negative indirect effect was observed on equatorial diameter (-0.0103).

5. Polar diameter (cm)

It exerted high genotypic positive indirect effect via; fresh weight of bulb (0.4606), collar thickness (0.0684), neck thickness (0.03205), dry out of bulb (0.0121), days to harvest (0.0120), whereas it had negative indirect effect on marketable yield (-0.1753), TSS (-0.1309), plant height 120 DAT (-0.0215) and equatorial diameter (-0.0022).

While it had phenotypic positive indirect effect via; fresh out of bulb (0.1876), marketable yield (0.0268), leaves per plant 120 DAT (0.0199), Plant height 120 DAT (0.0109) TSS (0.0138), days to harvest (0.0030), whereas negative indirect effect was visible on equatorial diameter(-0.0230), neck thickness (-0.0157), caller thickness (-0.0029).

6. Equatorial diameter (cm)

It exerted high positive genotypic indirect effect via; fresh weight of bulbs (0.6005), marketable yield (-0.2037) polar diameters (0.1285), dry weight of bulb (0.0265), collar thickness (0.0157), days to harvest (0.0034) and neck thickness (0.0079). whereas negative indirect effect was visible on TSS (-0.00752), plant height 120 DAT (-0.0159), leaves per plant (-0.0089) and equatorial diameter (-0.0049).

Equatorial diameter exerted high phenotypic indirect effect via; fresh weight of bulb (0.2745), polar diameter (0.0614), dry weight of bulb (0.0158) marketable yield (0.0312), plant height 120 DAT (0.00978), leaves per plant go DAT (0.00939), TSS (0.00854) and days to harvest (0.0004) whereas it had negative phenotypic indirect effect on neck thickness (-0.0137), and collar thickness (-0.0006)

7. TSS %

It had exerted high genotypic positive indirect effect via; fresh weight of bulb (0.5582), collar thickness (0.0525), polar diameter (0.1645), days to harvest (0.0202) and neck thickness (0.0197) however it had negative indirect effect on marketable yield (-0.045), plant height 120 DAT (-0.0384), leaves per plant 90 DAT (-0.0194) and dry weight of bulb (-0.0063).

TSS exerted positive phenotypic indirect effect via; fresh cut of bulb (0.2816), polar diameter/0.05676), plant height 120 DAT (0.0247), leaves per plant 90 DAT (0.0109), marketable yield (0.0131) and day to harvest (0.0073). But it had negative indirect effect on equatorial diameter (-0.01165), neck thickness (-0.0075) dry weight of bulb (-0.0039) collar thickness (-0.0033).

8. Days to harvest

It exerted positive genotypic indirect effect fresh weight of bulb (0.4564), polar diameter (0.470), neck thickness (0.0275) and dry weight of bulb (0.0236), whereas negative indirect effect on TSS (-0.0630) marketable yield (-0.047), collar thickness (-0.0394), plant height 120 DAT (-0.0399), leaves per plant (-0.0255) and equatorial diameter (-0.0002).

It had high positive phenotypic indirect effect via; fresh weight of bulb (0.2402), plant height 120 DAT (0.0278,), dry weight of bulb (0.02087), polar diameter (0.0166), TSS (0.00969), marketable yield (0.0082), collar thickness (0.00299) and leaves per plant 90 DAT (0.0077). However negative indirect effect was visible on neck thickness (-0.0102) equatorial diameter (-0.00076).

9. Fresh weight of bulb

It had high positive genotype indirect effect on polar diameter (0.1070) dry weight of bulb (0.0413), neck thickness (0.0407) and days to harvest (0.0270). Negative indirect effect was on marketable yield (-0.262), TSS (-0.1031), plant height 120 DAT (-0.0507), collar thickness (-0.0298) and leaves per plant 90 DAT (-0.0298).

However positive phenotypic indirect effect was on days to harvest (0.0916) marketable yield (0.0543), polar diameter (0.03873) dry cut of bulb (0.03520) plant height (0.03175) TSS (0.01415), leaves per plant (0.01067) of collar thickness (0.0017). negative indirect effect on equatorial diameter (-0.01887) and neck thickness (-0.0176).

10. Dry weight of bulb

It had positive genotypic indirect effect via; fresh cu weight of bulb (0.5952), polar diameter (0.0406), days to harvest (0.0201), leaves per plant (0.0217), TSS (0.0169) and neck thickness (0.0141). Negative indirect effect on marketable yield (-0.166), plant height 120 DAT(-0.0319), collar thickness (-0.1079) and equatorial diameter (-0.0015).

Phenotypic positive indirect effect via; fresh weight of bulb (0.3199), marketable yield (0.0335), plant height 120 DAT (0.0204) polar diameter(0.0147), days to harvest (0.0072), and collar thickness (0.0059). Negative indirect effect on leaves per plant (-0.0117), equatorial diameter (-0.0099), neck thickness (-0.0029) and TSS (-0.0017).

11. Marketable Yield

It exerted high positive genotypic indirect effect via; fresh weight of bulb (0.9963) polar diameter (0.1549) dry weight of bulb (0.0437), neck thickness (0.0200) and days to harvest (0.0106). Negative indirect effect on marketable

yield (-0.3257) leaves per plant 90 DAT (-0.016) collar, thickness (0.0056), equatorial diameter (-0.0030).

Phenotypic indirect positive effect was visible through fresh weight of bulb (0.4873), polar diameter (0.0196), dry weight of bulb (0.03307), plant height 120 DAT (0.0239), leaves per plant 90 DAT (0.0131), TSS (0.0059) & collar thickness (0.0004). However negative indirect effect was on equatorial diameter (-0.01924) and neck thickness (-0.0123).

4.5 Bulb colour

Variability were observed for bulb colour viz; light red, red, white and dark red. Light red colour was visible in genotypes ASKO-1201, ASKO-1203, ASKO-,1217, ASKO-1222,ASKO-1224, ASKO-1231, ASKO-1231, ASKO-1233, BSKO-1227, BSKO-1231, BSKO-1233, BSKO-1251, BSKO-1256, BSKO-1259, CSKO-1227, CSKO- 1231, CSKO- 1233 , CSKO-1269. White colour was visible in genotypes ASKO-1215, ASKO- 1236, ASKO-1238, ASKO- 1273, ASKO-1246, BSKO-1246, BSKO-1249, CSKO-1264. Red colour was observed in ASKO-1207, ASKO-1210, ASKO-1213, ASKO-1220, ASKO-1227, ASKO-1271,CSKO-1261,CSKO-1264. And dark red colour was observed in Agrifound Dark Red. Colour categorization in genotypes is given in(Table 4.6).

Table 4.6 Categorization of onion genotypes based on bulb colour

Light red	Red	White	Dark red
ASKO-1201, ASKO-1203, ASKO-1217, ASKO-1222, ASKO-1224, ASKO-1231, ASKO-1233, BSKO-1227, BSKO-1231, BSKO-1233, BSKO-1251 BSKO-1256, BSKO-1259, CSKO-1227, CSKO-1231, CSKO-1233, CSKO-1269.	ASKO-1207, ASKO-1210, ASKO-1213, ASKO-1220, ASKO-1227, ASKO-1271, CSKO-1261, CSKO-1266.	ASKO-1215, ASKO-1236, ASKO-1238, ASKO-1273, BSKO-1246, BSKO-1249, CSKO-1264.	Agrifound Dark Red

DISCUSSION

The experimental findings of the present investigation “Studies on genetic and association analysis for yield and its component traits in *Kharif* Onion (*Allium cepa* L.)” have been discussed on the following heads with the relevance to the available literature.

5.1 Genetic variability

5.1.1 Range and mean performance

5.1.2 Coefficient of variation

5.1.3 Heritability and genetic advance

5.2 Association analysis

5.2.1 Correlation coefficient analysis

5.2.2 Path coefficient analysis

5.1 Genetic variability

5.1.1 Range and Mean performance of the genotypes

The mean performance of the genotypes (Table 4.2) revealed a wide range of variability for all the characters. The variation was highest for marketable yield (115.67 to 296.9 q/ha.) followed by average weight of marketable bulbs (33.76 to 49 g), plant height at 90 DAT (39.6 to 52.43 cm), plant height at 120 DAT (50.13 to 62.06 cm), days to harvest (120.83 to 129 days). The existence of variability was due to diverse genotypes. The findings were quite similar to as reported by Mohanty (2001), Jansi Rani and Thangaraj (2004), Sharma (2009), Singh *et al.* (2010) and Hosamani *et al.* (2010).

The results obtained for neck thickness 0.66 to 0.83 cm, collar thickness 1.15 to 1.56 cm and bolters 1.6 to 7.7 % were very relevant to findings of Bal and Sidhu (1995).

Equatorial diameter lied between 3.34 to 5.31 cm and polar diameter 3.96 to 5.49 cm these results are similar to results obtained by Thamburaj et.al. (1995), Mohanty and Prusti (2002), Jansi rani and Thangaraj (2004), Singh and Bhonde (2009).

The variations in mean performance of dry weight and TSS(Total soluble solids) were relevant to Sharma et.al. (1996), Verma et.al. (1999) and Mahanthesh et.al.(2009).

5.1.2 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 2.2% to 26.37% and 1.95% to 22.49% respectively. The high PCV and GCV were recorded for marketable yield q/ha and dry weight of bulbs . The high values of GCV and PCV showed greater phenotypic and genotypic variability among the genotypes and responsiveness of the attributes for making further improvement by selection. The results are close to the findings of Dehdari *et al.* (2001), Trivedi *et al.* (2006a), Gurjar and Singhania (2006), and Singh *et al.* (2010) for marketable yield and fresh weight of bulbs, while Mohanty (2002) and Gurjar and Singhania (2006) for neck thickness and fresh weight of bulbs.

However, it was exhibited low for characters viz., days to harvest, collar thickness, neck thickness, number of leaves per plant at 90 DAT, plant height at 120 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).

Rest of the characters i.e. polar diameter of bulb, equatorial diameter of bulb, and TSS exhibited moderate phenotypic and genotypic coefficient of variation. The finding of Singh *et al.* (2010) was similar to the present finding which indicated that there is limited scope for further improvement in the material.

5.1.3 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, high (more than 70- 90%), medium (50-70%) and low (less than 50%).

High heritability was recorded in the characters viz., average weight of marketable bulbs, TSS, fresh weight of bulbs, dry weight of bulbs, days to harvest, plant height at 120 DAT and marketable yield. 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 Mohanty (2001), Krishna Prasad *et al.* (2005), Melke and Ravishankar (2006) for plant height and TSS, Pramoda and Gangaprasad (2007) for plant height and yield, Mohanty (2004) for average weight of bulbs, Gurjar and Singhanian (2006) for plant height, bulb weight, bulb yield and days to maturity and Hayder *et al.* (2007) for plant height and bulb yield, and Yaso (2007) for days to maturity, and Trivedi *et al.* (2006) for TSS.

However, it was recorded moderate for number of leaves per plant at 90 DAT, polar diameter, equatorial diameter and collar thickness. The findings were relevant to Mohanty (2001) for number of leaves per plant. Low estimate of heritability was recorded in neck thickness.

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 marketable yield q/ha, dry weight of bulbs and TSS. The results were in consonance with Mohanty (2001a), Gurjar and Singhania (2006) and Trivedi *et al.*(2006) for bulb yield, Hayder *et al.* (2007), Yaso (2007) for marketable yield, Hayder *et al.* (2007) and Hosmani *et al.*(2010) for bulb yield per hectare. Hence selection for these characters is likely to be more effective, as high heritability values were associated with high genetic advance. This could be due to additive gene effects.

Plant height at 120 DAT, number of leaves per plant at 90 DAT, average weight of marketable bulbs, fresh weight of bulbs, equatorial diameter, polar diameter and collar thickness exhibited moderate value of genetic advance as percentage of mean. The findings were in close relation to the findings of Mohanty (2001) and Mohanty (2004) for number of leaves per plant. Gurjar and Singhania (2006) obtained moderate genetic gain for plant height, number of leaves per plant and equatorial diameter of bulb.

High heritability coupled with high genetic advance for traits like marketable yield q/ha followed by dry weight of bulbs, fresh weight of bulbs, & TSS. 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 (2001a), Melke and Ravishankar (2006) and Hayder *et al.* (2007) for number of leaves per plant and Gurjar and Singhania (2006) for bulb yield per plant, Mohanty and Prusti (2001), Mohanty (2001) and Gurjar and Singhania (2006) for neck thickness,

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

Moderate heritability supplemented with moderate genetic advances as percentage of mean was manifested by, number of leaves per plant at 90 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 harvest which revealed the predominance of non-additive gene action in the expression of these characters. The findings were in agreement to the findings of Gurjar and Singhania (2006) and Yaso (2007) for days to harvest.

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

5.2 Association analysis

5.2.1 Correlation coefficient analysis

A wide range of variation in quantitative characters is the pre-requisite for selection in any plant breeding programme. The knowledge of association among the characters is useful to the breeder for improving the efficiency of selection. Correlation coefficient analysis and 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 view 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.

Correlation coefficient of average weight of marketable bulb was recorded positive and significant with plant height 120 DAT, number of leaves per plant 90 DAT, neck thickness, polar diameter, equatorial diameter, TSS, Days to harvest, fresh weight of bulbs, dry weight of bulb marketable yield indicating that these characters were the primary yield determinant in onion. These findings corroborated the earlier findings of Mohanty (2001), Mohanty (2004), Gurjar and Singhania (2006) and Meena *et al.* (2007) Rajalingam and Haripriya (2000), Mohammed *et al.* (2000), Mohanty (2001), Mohanty (2004), Shrivastava *et al.* (2004), Trivedi *et al.* (2006), Trivedi *et al.* (2006a), Gurjar and Singhania (2006) and Meena *et al.* (2007).

Plant height 120 DAT and number of leaves per plant 90 DAT were found to be significant & positively associated at both levels, genotypic phenotypic with average weight of marketable bulbs, polar diameter, fresh weight of bulb, neck thickness, days to harvest & TSS. From the above results obtained it is clear that with increase in plant height & number of leaves, there is more photosynthesis in plants. So, these photosynthetic get accumulated in bulbs there by increasing the weight and size of the bulbs. These finding were found to be similar with Rajalingam & Haripriya (2000), Mohanty (2001), Rahman *et al.* (2002), Mohanty (2002) and Singh *et al.* (2010). But negative association with collar thickness indicated that with increase in plant height and number of leaves there is gradual decrease in collar thickness.

Polar diameter and equatorial diameter were found to be significantly and positively associated with average weight of marketable bulb, fresh weight of bulb, marketable yield and TSS at both genotypic and phenotypic level. It is clear that polar diameter and equatorial diameter of bulb are size determinants of bulb. So, when these two variables increase, weight of marketable bulb and marketable yield also increases simultaneously. These finding were close to Mohanty (2004), Shrivastava *et al.* (2004), Gurjar and Singhania (2006), Trivedi *et al.* (2006), Hayder *et al.* (2007), Singh and Bhonde (2009) and Singh *et al.* (2011).

TSS was found to be positively associated with average weight of marketable bulb, marketable yield fresh weight of bulb and days to harvest at both genotypic and phenotypic levels. This finding indicates that with increase in weight of bulbs, the total soluble solids of the bulbs also increase. Similarly as number of days to maturity increases it leads to occurrence of more TSS in bulbs. Similar findings were obtained by Dhotre et.al (2010) and Morsy et al. (2011).

Fresh weight of bulbs was found to be closely associated to average weight of bulb, marketable yield, dry weight of bulb at both genotypic and phenotypic level this clearly indicates that as fresh weight of bulb increase it simultaneously increase the average marketable weight of bulb and marketable yield. The similar findings were obtained by Mohanty (2001), Mohanty (2004) and Gurjar and Singhania (2006).

Neck thickness was positively associated to average weight of marketable bulb, genotypic and phenotypic level. Results were relevant to the findings of Gurjar and Singhania (2006) and Hosmani et. al (2010).

Marketable yield was positive and significantly correlated to plant height at 120 DAT, number of leaves 90 DAT, neck thickness, polar diameter, average weight of marketable bulb, equatorial diameter, fresh weight of bulb and dry weight of bulb at both genotypic and phenotypic level. These result shown that all these variables directly contribute toward increase in marketable yield. Similar findings were obtained by Rajalingam and Haripriya (2000), Rahman et al (2002), Trivedi et al(2006a), Gurjar and singhana (2006), Meena et al. (2007) and Morsy et al (2011).

5.2.2 Path coefficient analysis

The path coefficient analysis provides an effective measure of direct and indirect effect on character association and depicts the relative importance of each factor involved in contributing to the desired product.

The present investigation revealed that plant height 120 DAT, fresh weight of bulb polar diameter, marketable yield, leaves per plant 90 DAT, TSS and days to harvest had highest positive direct effect an average weight of marketable bulb. While equatorial diameter and neck thickness exerted

negative direct effect which could be compensated by the positive direct effect of other characters and influenced the maximum average weight of marketable bulb. These results are in accordance with the findings reported by Mohaty (2001), Dehdari et al. (2002) Gurjar and Singhania (2006). Plant height 120 DAT and number of leaves per plant 90 DAT shown positive indirect effect via; fresh weight of bulb, polar diameter, days to harvest and percent dry weight of bulb at both genotypic and phenotypic level while the negative indirect effect was shown via; equatorial diameter and marketable yield at genotypic level. However, the character involved in the negative indirect effect shown positive correlation with plant height 120 DAT and number of leaves per plant 90 DAT. Thus resulting in the improvement of average weight of marketable bulb within the genotypes studied. These findings are in line with the results obtained by Mohanty (2002) and Mohanty (2004).

collar thickness exerted positive indirect effect via; fresh weight of bulb, equatorial diameter days to harvest and dry weight of bulb at both genotypic and phenotypic level while the negative indirect effect was shown via; polar diameter, plant height 120 DAT and number of leaves per plant 90 DAT. Polar diameter and equatorial had shown positive indirect effect via; fresh weight of bulb, days to harvest and dry weight of bulb at both genotypic and phenotypic level while the negative indirect effect was exerted via; plant height 120 DAT, number of leaves 90 DAT, TSS and marketable yield at genotypic level. However, the characters showing negative indirect effect had positive correlation with polar diameter and equatorial diameter. Thus, leading to an increase in average weight of marketable bulb. the results obtained above are in confirmation with the findings of Mohanty (2001), Dehdari et.al (2002), Mohanty (2004) and Gurjar and Singhania (2006).

TSS had exerted positive indirect effect via; fresh weight of bulb, days to harvest and polar diameter at both genotypic and phenotypic level, whereas negative indirect effect was shown via; equatorial diameter and dry weight of bulb. However, these characters had positive correlation with TSS and ultimately resulting in improvement of average weight of marketable bulb among the genotypes under consideration.

Neck thickness and days to harvest exerted positive indirect effect via; fresh weight of bulb, dry weight of bulb, days to harvest and polar diameter at both genotypic and phenotypic levels. But it laid negative indirect effect via; plant height, number of leaves, collar thickness, equatorial diameter TSS and marketable yield at genotypic level however, characters showing negative indirect effect had shown positive correlation with neck thickness and finally leading to an increase in average weight of marketable bulb.

Fresh weight and dry weight of bulb exerted positive indirect effect via; polar diameter and days to harvest at both genotypic and phenotypic level but exerted negative indirect effect via; plant height 120 DAT, equatorial diameter and marketable yield at genotypic level. However the characters showing negative indirect effect had positive correlation with fresh weight and dry weight of bulbs, leading to an improvement in average weight of marketable bulb. These results are in accordance with the finding reported by Mohanty (2001) and Gurjar and Singhania (2006).

Marketable yield had shown positive indirect effect via; polar diameter, fresh weight of bulb, days to harvest and dry weight of bulb at both genotypic and phenotypic level. While the negative indirect effect was shown via; plant height 120 DAT, and number of leaver per pant 90 DAT, collar thickness, TSS and equatorial diameter at genotypic level. However the characters showing negative indirect effect had shown positive correlation with average weight of marketable bulb. The results obtained from study are in confirmation with Mohanty (2001), Dehdari et al. (2002) and Meena et. al (2007).

SUMMARY, CONCLUSION AND SUGGESTION FOR FURTHER WORK

6.1 Summary

The present investigation entitled "Studies on genetic and association analysis for yield and its component traits in *Kharif* onion (*Allium cepa* L.)" was carried out during *kharif* season 2012-13 at the Horticulture Complex, Department of Horticulture, College of Agriculture, JNKVV, Jabalpur (M.P.). The experimental material for the present investigation was comprised of 33 genotypes of onion. These genotypes were sown in randomised complete Block design with three replication 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 genotypes separately for morphological, yield, disease & insect and quality parameters for evaluation as per standard procedures.

The data observed were subjected to proper analysis as per the formula suggested by various scientist. The estimates of means sum of squares 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 marketable yield (q/ha) followed by average weight of marketable bulb, % A grade bulb, plant height 120 DAT. Genotypes BSKO-1256 performed best in terms of yield and gave marketable yield of 296.90 q/ha followed by genotype ASKO-1231, 291.90 q/ha and genotype CSKO-1266, 230.50 q/ha. Whereas genotypes ASKO-1231 & CSKO-1266 also gave highest average weight of marketable bulb of 49.00 & 48.03 g respectively. Genotype ASKO-1213 was minimum affected by incidence of stemphyllium blight 8.68% at 60 DAT whereas genotype BSKO-1231 had shown lowest thrips count per plant 12.00 at

60 DAT. So these genotypes can be further exploited in selection programmes of disease & insect resistance. Agrifound Dark Red & ASKO-1201 were recorded with minimum sprouting % and rotting % in bulb at 60 days after harvest respectively.

The present study described that the phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the traits under study which might be due to interaction of genotypes with the environment and influenced the expression of these characters. High phenotypic and genotypic coefficient of variation was observed for marketable yield. High value of GCF & PCB suggested greater variability among genotypes. Whereas the low value of GCV & PCB were recorded in days to harvest, plant height 120 DAT, collar thickness & neck thickness indicated that those characters are less suitable for selection and need to be further improvement.

High estimates of heritability were recorded obtained for the character like average weight of marketable bulb, plant height 120 DAT, TSS, days to harvest, fresh weight of bulb & marketable yield. High values of broad sense of heritability for these characters expressed that they were least influenced by environmental modifications. It reflected that the phenotypes were the true representative of their genotypes and their selection based on phenotypic performance would be reliable.

High heritability coupled with high genetic advance was observed in marketable yield followed by dry weight of bulb & TSS. It suggested the action of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters were governed by additive gene actions. High heritability coupled with moderate genetic advance as percentage of mean were manifested by plant height 120 DAT, leaves per plant 90 DAT & fresh weight of bulb. Our estimates of heritability coupled with low genetic advance as percentage of mean was recorded in neck thickness indicated that these

character was highly influenced by environment effects and consequently its selection would be ineffective.

The genotypic correlation coefficient were higher in magnitude than their corresponding phenotypic one, indicating there exists a strong inherent association between different traits studied. The highest positive and significant correlation coefficient of average weight of marketable bulb was noted with fresh weight of bulb followed by marketable yield, neck thickness, plant height 120 DAT, dry weight of bulb, TSS & days to harvest which indicated that these characters contributed maximum towards increase in average weight of marketable bulb. Plant height at 120 DAT and number of leaves at 90 DAT had significant & positive correlation with average weight of marketable bulb, marketable yield, days to harvest, polar diameter & fresh weight of bulb but showed negative correlation with collar thickness. Collar thickness showed positive & significant correlation with dry weight of bulb, neck thickness & days to harvest. But negative correlation with TSS & polar diameter. Neck thickness had positive correlation with average weight of marketable bulb, polar diameter, days to harvest & fresh weight of bulb. Polar diameter equatorial diameter had positive & significant correlation with TSS, average weight of marketable bulb, equatorial diameter & marketable yield. TSS had significant correlation with average weight of marketable bulb, fresh weight of bulb and days to harvest. Days to harvest showed significant positive correlation with average weight of marketable bulb, fresh weight of bulb & dry weight of bulb. Fresh weight of bulb, dry weight of bulb had significant & positive correlation with average weight of marketable bulb, marketable yield & dry weight of bulb.

Path coefficient analysis of various characters contributing towards average weight of marketable bulb showed that fresh weight of bulb had highest positive direct effect followed by polar diameter, marketable yield, dry weight of bulb, plant height at 120 DAT, leaves per plant 90 DAT, TSS & days to harvest. This indicates the true relationship of these traits with average weight of

marketable bulb and direct selection of these traits would result in higher breeding efficiency for improving the yield. Whereas, equatorial diameter & neck thickness had the negative direct effect on average weight of marketable bulb. Whereas these or characters were positively correlated to it. This indicates that negative effect was nullified by positive effect exerted by them. Plant height at 120 DAT exerted highest positive effect via fresh weight of bulb, marketable yield & polar diameter. Polar diameter & equatorial diameter exerted indirect effect via. fresh weight of bulb, days to harvest, TSS, dry cut of bulb & marketable yield. Days to harvest exerted indirect effect through fresh weight of bulb & polar diameter. Whereas, fresh weight of bulb exerted positive indirect effect via. plant height at 120 DAT, leaves per plant 90 DAT, days to harvest, dry weight of bulb & marketable yield. Simultaneous selections can be made for these traits for improvement of yield & marketable weight of bulbs. Considerable variability was observed among the genotypes for bulb colour & following bulb colours were obtained.

1. Red
2. Light Red
3. White
4. Dark Red

6.2 Conclusion

High heritability coupled with high genetic advance was observed in marketable yield followed by dry weight of bulb & TSS suggested that they can be improved by direct selection.

The estimates of means due to genotypes were highly significant for all the characters, indicating the presence of genetic diversity in the existing material. The mean performance of genotypes showed a wide range of variability for all the traits. The variation was highest for marketable yield, followed by average weight of marketable bulb, % A grade bulb. Genotypes BSKO-1256 performed best in terms of yield and gave marketable yield of 296.90 q/ha followed by genotype ASKO-1231, 291.90 q/ha and genotype CSKO-1266, 230.50 q/ha. Whereas genotypes ASKO-1231 & CSKO-1266 also gave highest average weight of marketable bulb of 49.00 & 48.03 g respectively Genotype

ASKO-1213 was minimum affected by incidence of stemphyllium blight 8.68% at 60 DAT whereas genotype BSKO-1231 had shown lowest thrips count per plant 12.00 at 60 DAT. So these genotypes can be further exploited in selection programmes of disease & insect resistance. Agrifound Dark Red & ASKO-1201 were recorded with minimum sprouting % and rotting % in bulb at 60 days after harvest respectively.

The association analysis revealed that onion genotypes can be improved by simultaneous selection of traits like plant height at 120 DAT leaves per plant 90 DAT, collar thickness, polar diameter & equatorial diameter, fresh weight of bulb, TSS & days to harvest.

Path coefficient analysis revealed that fresh weight of bulb, polar diameter, marketable yield, dry weight of bulb, plant height, 120 DAT, leaves per plant 90 DAT, TSS & days to harvest had highest positive direct effect on average weight of marketable bulb and hence purposeful selection based on these traits would help in improvement of onion genotypes.

6.3 Suggestions for further work

- Maintenance of traits giving stable performance should be considered for any breeding programme.
- Further evaluation should be tried at different locations and environment for their stable performance.
- Good performing genotypes could be used in various crossing programmes for disease and insect resistance development.

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