GENETIC VARIABILITY STUDIES IN ONION (*Allium cepa* L.) GERMPLASM UNDER CENTRAL DRY ZONE OF KARNATAKA

BEERESHA, D. C.

MH2TAC030

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, MUDIGERE - 577 132
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA

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BEERESHA, D.C.

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, MUDIGERE - 577 132
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA

AUGUST, 2015

Affectionately Dedicated

to

Ever loving Parents

With my lovely Sisters
and brothers

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, MUDIGERE-577132
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES, SHIVAMOGGA

CERTIFICATE

This is to certify that the thesis entitled **"GENETIC VARIABILITY STUDIES IN ONION (*Allium cepa* L.) GERMPLASM UNDER CENTRAL DRY ZONE OF KARNATAKA"** submitted in partial fulfillment of the requirement for the award of degree in **MASTER OF SCIENCE (Horticulture) in VEGETABLE SCIENCE** to the University of Agricultural and Horticultural Sciences, Shivamogga is a record of *bonafide* research work carried out by **Mr. BEERESHA, D. C.,** ID No. **MH2TAC030** under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or any other similar titles.

MUDIGERE
AUGUST, 2015

(P. UMAMAHESWARAPPA)
Major Advisor

APPROVED BY:

Chairperson : --
(P. UMAMAHESWARAPPA)

Members : 1. --
(V. SRINIVASA)

2. --
(H. CHANDRAPPA)

3. --
(B. N. HARISH BABU)

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AUGUST, 2015

Beeresha

(BEERESHA, D. C.)

GENETIC VARIABILITY STUDIES IN ONION (*Allium cepa* L.) GERMPLASM UNDER CENTRAL DRY ZONE OF KARNATAKA

BEERESHA, D. C. (MH2TAC030)

ABSTRACT

An investigation on genetic variability studies in onion germplasm was carried out in randomized complete block design with three replications in the experimental block at ZAHRS Hiriyur during 2014. Significant difference among genotypes were observed for all the characters under study. High heritability (>60 %) in association with high genetic advance over mean (> 20 %) was observed for per cent less than C grade bulbs, total yield, marketable yield and average bulb weight, due to predominance of additive component. Thus, there is ample scope for improving these characters through direct selection. High genotypic (>20.1%) and phenotypic co-efficient variation (>20.1%) was observed for less than C grade bulbs and the same character recorded higher range of variation and there is a better scope of improvement through selection.Total bulb yield was found to have highly significant and positive correlation with number of leaves at 90 DAT, collar thickness, polar diameter, equatorial diameter, neck thickness, shape index, per cent A grade bulbs, per cent B grade bulbs, per cent bolter bulbs, marketable yield and average bulb weight. Results of screening for purple blotch incidence revealed that, genotypes such as Arka Kalyan, Bhima Shakti and Bhima Kiran were found to be moderately susceptible, the per cent leaf area infection ranged from 21-40 per cent in these cultivars. Considering the growth, yield and quality performances the cultivars, each varieties *viz.*, Arka Kalyan, PKV-White, Bhima Super, Bhima Shubra, Bhima Kiran and Arka Bindu are suitable for late Kharif season cultivation.

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Department of Vegetable Science
College of Horticulture,
Mudigere-577132.

Dr. P. Umamaheswarappa
(Major Advisor)

ಕರ್ನಾಟಕದ ಮಧ್ಯ ಒಣ ಪ್ರದೇಶದಲ್ಲಿ ಈರುಳ್ಳಿ (*ಅಲಿಯಮ್ ಸಿಪಾ ಎಲ್.*) ವಂಶವಾಹಿ ರೂಪಗಳ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸ ಅಧ್ಯಯನ

ಬೀರೇಶ, ಡಿ. ಸಿ. (ಎಮ್‌ಹೆಚ್‌೨ಟಿಎಸಿ೦೩೦)

ಸಾರಾಂಶ

ಇಪ್ಪತ್ತೂರು ಈರುಳ್ಳಿ ವಂಶವಾಹಿ ರೂಪಗಳ ಅನುವಂಶಿಕ ವ್ಯತ್ಯಾಸದ ಅಧ್ಯಯನವನ್ನು ೨೦೧೪ ರ ಅವಧಿಯಲ್ಲಿ ವಲಯ ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕಾ ಸಂಶೋಧನಾ ಕೇಂದ್ರ, ಬಬ್ಬೂರ್ ಫಾರಂ ಹಿರಿಯೂರಿನಲ್ಲಿ ನಡೆಸಲಾಯಿತು. ಮೂರು ಪ್ರತಿಕೃತಿ ಜೊತೆಗೆ ಯಾದೃಚ್ಛಿಕ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ಎಲ್ಲಾ ವಂಶವಾಹಿ ರೂಪಗಳಲ್ಲಿ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗು ಗುಣಮಟ್ಟಕ್ಕೆ ಸಂಬಂಧಿಸಿದ ಗುಣಗಳಲ್ಲಿ ವೈವಿಧ್ಯಮಯ ವ್ಯತ್ಯಾಸವಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಅಧಿಕ ಅನುವಂಶಿಕತೆ (>೬೦%) ಜೊತೆಗೆ ಹೆಚ್ಚು ಅನುವಂಶಿಕ ಮುಂಗಡ ಸರಾಸರಿಯು (>೨೦%) ಶೇಕಡ 'ಸಿ' ದರ್ಜೆಗಿಂತಲೂ ಕಡಿಮೆ ಗೆಡ್ಡೆ, ಒಟ್ಟು ಇಳುವರಿ, ಮಾರುಕಟ್ಟೆ ಇಳುವರಿ, ಸರಾಸರಿ ಗೆಡ್ಡೆಯ ತೂಕ ಅಂಶಗಳಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಆದ್ದರಿಂದ ಈ ಮೇಲ್ಕಂಡ ಗುಣಲಕ್ಷಣಗಳು ನೇರ ಆಯ್ಕೆಗೆ ಸೂಕ್ತವಾಗಿದೆ. ಹೆಚ್ಚು ವಂಶವಾಹಿ (>೨೦%) ಹಾಗೂ ಬಾಹ್ಯಗುಣಾಂಕ ವ್ಯತ್ಯಾಸವು ಶೇಕಡ 'ಸಿ' ದರ್ಜೆಗಿಂತಲೂ ಕಡಿಮೆ ಗೆಡ್ಡೆಗಳಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಆದ್ದರಿಂದ ಈ ಗುಣಲಕ್ಷಣವು ಹೆಚ್ಚಿನ ವ್ಯಾಪ್ತಿಯ ವ್ಯತ್ಯಾಸ ಹೊಂದಿದೆ ಮತ್ತು ಆಯ್ಕೆಗೆ ಸೂಕ್ತವಾಗಿದೆ. ಅತ್ಯಂತ ಗಮನಾರ್ಹ ಮತ್ತು ಗುಣಾತ್ಮಕ ಸಂಯೋಗವನ್ನು ಒಟ್ಟು ಇಳುವರಿಯ ಜೊತೆಗೆ ೯೦ ದಿನಗಳ ನಂತರದ ಎಲೆಗಳ ಸಂಖ್ಯೆ, ಕತ್ತಿನ ದಪ್ಪ, ದ್ರುವದ ವ್ಯಾಸ, ಸಮಭಾಜಕದ ವ್ಯಾಸ, ಕುತ್ತಿಗೆಯ ದಪ್ಪ, ಆಕಾರದ ಸೂಚ್ಯಾಂಕ, ಶೇಕಡ 'ಎ' ದರ್ಜೆಯ ಗೆಡ್ಡೆ, ಶೇಕಡ 'ಬಿ' ದರ್ಜೆಯ ಗೆಡ್ಡೆ, ಶೇಕಡ ಹೂ ಬಿಟ್ಟ ಗೆಡ್ಡೆ, ಮಾರುಕಟ್ಟೆ ಇಳುವರಿ ಮತ್ತು ಸರಾಸರಿ ಗೆಡ್ಡೆಯ ತೂಕದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಅರ್ಕಾ ಕಲ್ಯಾಣ್, ಭೀಮಾ ಶಕ್ತಿ ಮತ್ತು ಭೀಮಾ ಕಿರಣ್ ತಳಿಗಳು ನೇರಳೆ ಮಚ್ಚೆ ರೋಗಕ್ಕೆ ಮಧ್ಯಮ ಪ್ರಭಾವಕ್ಕೆ ಒಳಗಾಗುತ್ತವೆ. ಈ ತಳಿಗಳು ಮೂರರ ದರ್ಜೆಯ ಪ್ರಮಾಣದ ಜೊತೆಗೆ ಶೇಕಡ ಎಲೆಯ ವಿಸ್ತೀರ್ಣದಲ್ಲಿ ಸೋಂಕು ತಗುಲಿದ ವ್ಯಾಪ್ತಿಯು ಶೇಕಡ ೨೧-೪೦ ರಷ್ಟು ಹೊಂದಿವೆ. ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟದ ಪ್ರದರ್ಶನವನ್ನು ಪರಿಗಣಿಸಿದಾಗ ಅರ್ಕಾ ಕಲ್ಯಾಣ್, ಪಿಕೆವಿ-ವೈಟ್, ಭೀಮಾ ಸೂಪರ್, ಭೀಮಾ ಶುಭ್ರ, ಭೀಮಾ ಕಿರಣ್ ಮತ್ತು ಅರ್ಕಾ ಬಿಂದು ಮಳೆಗಾಲದ ಬೇಸಾಯಕ್ಕೆ ಸೂಕ್ತವಾಗಿವೆ.

ಆಗಸ್ಟ್-೨೦೧೫
ತರಕಾರಿ ವಿಜ್ಞಾನ ವಿಭಾಗ
ತೋಟಗಾರಿಕಾ ಮಹಾವಿದ್ಯಾಲಯ,
ಮೂಡಿಗೆರೆ-೫೭೭೧೩೨.

ಡಾ. ಪಿ. ಉಮಾಮಹೇಶ್ವರಪ್ಪ
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

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INTRODUCTION

I. INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important commercial vegetable cum spice crops of India and it belongs to the family Alliaceae with diploid chromosome number of 2n=2x=16. The onion has been cultivated since 4700 years or more and does not exist as a wild species. Onion was probably first domesticated in the mountainous regions of Turkmenistan and North Iran bordering the ancient advanced civilization of the Near East (Sumerian). Therefore, South-West Asia is regarded as the primary centre of domestication and variability. Other regions of great diversity like Mediterranean is considered as secondary centre (Fritschan and Friesen, 2002). The nearest wild relative in the subgenus *cepa* section is *A. vavilovii* (Klass and Friensen, 2002), which is found in the Koppet Dag mountains of Turkmenistan. It has a hollow scape with a bubble-like swelling, but the leaves are completely flat. Recent molecular studies have shown that *A. asarense* is basal to the group, which includes *A. cepa* and *A. vavilovii* (Fritschan and Friesen, 2002).

Onion is a biennial herb with a characteristic smell. The leaves are tubular and the bulbs are formed by the attachment of swollen leaf bases to underground part of stem which is small and rudimentary. Flowering structure is called an umbel which is an aggregate of many small inflorescences of 5-10 flowers. The flowers are hermaphrodite they are cross pollinated due to protandry. Cross pollination is achieved by honey bees when they visit flower for nectar. Stigma becomes receptive 3-4 days after shedding of pollen grains (Gopalakrishnan, 2007).

Onion is popularly known as Pyaz in Hindi and Ullagaddi or Irulli in Kannada. It is used as salad, cooked vegetable in the preparation of pickles dehydrated white & yellow onion is used for preparation of flour, flakes, paste etc. It is a rich source of major minerals like calcium (180 mg/100 g), phosphorus (50 mg/100 g), iron (0.7mg), carbohydrates (11.0 g), protein (1.2g), dietary fibre (0.6 g), vitamin C (11 mg) and minerals (0.4 g). Pungency in onion is mainly due to sulphur containing compound called allyl propyl disulphide (Gopalakrishnan, 2007).

Onions possess several medicinal and therapeutic properties and is effective against common cold, diabetes, heart disease, osteoporosis and has diuretic, aphrodisiac properties and helps in prevention of other diseases. Onion is known for anti-platelet aggregation, anti-rheumatic and a fibrinolytic effect as well as it lowers the blood sugar. Also contains a chemical compound, quercetin, believed to have anti-inflammatory, anti-cholesterol, anti-cancer and anti-oxidant properties. Bulb juice is very useful in faintness, infantile convulsions, headache and epileptic. The hot juice is dropped into the ear to relieve ear pain. It is applied in eyes in dimness of vision, to allay irritation of insect bites, scorpion stings and also in skin diseases. It can also used as a good antidote for tobacco poisoning. (Gopalakrishnan, 2007).

Onion is grown worldwide on an area of 3,971.51 (thousand hectares) with production of 75,977.21 (thousand metric tons) and having an average productivity of 19.1 tons per hectare. China (20,507.76 Thousand metric tons) and India (16,813 thousand metric tons) are the major onion producers followed by Turkey (1,900 thousand metric tons) (Anon., 2011).

In India, onion occupies an area of 1051.5 (thousand hectares) with a total production of 16,813 (thousand metric tons). Maharashtra, Karnataka, Gujarat, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and Tamil Nadu are the major onion growing states. In Karnataka, onion is grown in an area of 159.60 (thousand hectares) with a total production of 2395.90 (Thousand metric tons) and productivity of 15 tons per hectare (Anon., 2013).

Although, India is the second largest producer of onion in the world, productivity is much lower (16 t/ha) than top ranking countries (20.80 t/ha.). In temperate regions, long day onions are grown, which enjoys congenial climate and as a result the bulking of onion is very high, which in turn enhances productivity but in India grows short day onions, which has inherent low yield potential and further, tropical climate limits the productivity. Poor yielding tropical genotypes, use of land races for large-scale production, susceptibility to diseases and pests and shortage of irrigation water at critical growth stages reduces productivity in India. Besides these factors, sharp fluctuations in prices in market disturb the attitude of farmers towards adoption of production techniques and good management practices.

Many varieties and pre-breeding lines are developed by different breeding centres in India and local cultivars grown by farmers in different agro-climatic zones are need to be evaluated at different locations as the response is location specific. Onion being highly cross pollinated crop, high variation in genetic components can be seen. This genetic variability can be exploited in development of varieties or lines for different breeding objectives.

To improve the bulb yield of varieties through selection the information on the nature and magnitude of variability for yield, pests and disease resistance and other quantitative and qualitative characters present in the population owing to its genetic causes play an important role and as such it is a basic pre-requisite for any systematic breeding programme. The crop yield being complex in nature largely depends on its contributing characters and their interactions.

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

Keeping these in view, many locally cultivated cultivars and released varieties were collected and the study was undertaken with the following objectives.

1) Exploration and collection of onion germplasm.
2) To assess the genetic variability in onion germplasm for morphological and yield traits.
3) To assess the incidence of purple blotch in onion germplasm.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Vegetable breeder is primarily concerned with the improvement of both qualitative and quantitative characters. Hence, adequate knowledge on genetics of various traits is very essential in vegetable breeding programme for obtaining desired results in succeeding generations. However, the success of vegetable breeding depends on the extent and the magnitude of variability existing in the germplasm. At the same time, improvement is possible on the basis of heritable variation. In the present investigation, an attempt has been made to study genetic variability and heritability in onion. The available literature pertaining to the investigation on onion and related crops have been presented in this chapter under different headings.

2.1 Survey and collection of onion germplasm

About 212 germplasms of onion and garlic were collected, which included 109 red onion, 57 white onion and 46 garlic germplasms from Karimnagar, Nizamabad and Adilabad districts of Andhra Pradesh; Garchiroli, Chandrapur, Yavatmal and Nanded districts of Maharashtra and Narainpur, Bastar and Dantewada districts of Chhattisgarh (Anand, 2013).

Rouamba and Currah (1998) surveyed and collected twenty-four accessions of onion from eighteen places of Africa. The largest collection of onion was held at CERRA, Maradi, in Niger (16) and the largest regional collection was done at the station Cote de Ivoire (38).

Kale and Warade (2013) surveyed in the traditional and non-traditional onion growing areas of the state Maharashtra and collected 148 red-skin and 33 white-skin types of onion. These landraces are being maintained and evaluated for their growth and yield characters.

Kamala *et al.* (2014) surveyed in eastern Vidarbha region in peninsular India during May 2009 in collaboration with directorate of Onion and Garlic Research, Pune. Ninety-two onion samples (bulbs-91; seeds-1) were collected from 25 villages and 15 mandals. Wide range of variation were observed for bulb shape, colour, size and total soluble solids. These accessions hold potential for utilization in breeding programmes for further genetic improvement in onion.

2.2 Genetic variability, heritability and genetic advance

The magnitude of variability and its genetic components are the most important aspects of breeding material. Hence, basic understanding of the genetic variability is a prerequisite for the planning of breeding programme. A great deal of information has been generated on genetic variability of various components of onion. Generally, genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are measured to study the variability. Literature pertaining to genetic variability and its components has been collected and presented in this chapter.

Galton (1889) observed that a part of continuous variation is due to heredity. The study of heritable and non-heritable component of variability has its inception in the finding of Johannsen (1909). The degree to which the variability of quantitative character is transmitted to the progeny is referred as heritability.

The genetic and environmental components of variation were described in the early part of this century by Johannsen (1909) who attributed the variation in segregating population to both heritable and non-heritable factors and the variation in a pure line due to only environmental factors. Charles and Smith (1939) and Powera *et al.* (1950) partitioned genetic variance from total variance in non-segregating populations. The heritable variation was further divided into additive and non-additive components and the latter fraction included dominance and inter-allelic interaction (Falconer, 1981).

Genetic advance is the measure of improvement that can be achieved by practicing selection in a population. Since, the estimates of heritability give no indication of the amount of progress expected from the selection, they are the most meaningful when accompanied by estimates of genetic advance. High genetic advance coupled with high heritability is an indication of more additive gene action (Panse, 1957).

2.2.1 Growth parameters

2.2.1.1 Plant height

Mohanty (2001) reported the significant variation in plant height among 12 varieties of onion. Range is varied between 30.25 cm to 42.62 cm, recorded moderate GCV (14.96%) and low PCV (9.01%) with moderate genetic advance over percentage of mean (11.27%) and moderate heritability (36.2%) for the trait.

Prasad *et al.* (2005) reported significant variation in plant height among 209 onion lines. Which is having high heritability (65.2%) associated with low genetic advance over percentage of mean (6.23%).

Golani *et al*. (2006) reported that, the significant difference in onion for plant height indicating existence of genetic difference among the 32 genotypes. It ranged from 49.91 cm to 59.49 cm, recorded low GCV (3.96%) and PCV (7.90%), low heritability (25.50%) coupled with low genetic advance over percentage of mean (4.08%).

Haydar *et al.* (2007) observed that, plant height with the mean of 44.05 cm in onion and also recorded the high GCV (47.24%) and PCV (61.28%), high heritability (78.06%) with moderate genetic advance over percentage of mean (18.96%).

Sendek *et al*. (2008) reported wide variability in shallot for plant height with the range 18.6-31.05 cm, moderate PCV (12.69%) and low GCV (8.05%), moderate heritability (40%), genetic advance (3.12%) with moderate genetic advance over percentage of mean (18.96%).

Dhotre (2009) reported lesser variation in plant height among 14 onion genotypes range varied between (40.39-52.17 cm), low GCV (6.46%) and PCV (8.33%), high heritability (61.34%) coupled with low genetic advance over percentage of mean (6.25%).

Hosamani *et al*. (2010) reported the significant difference for this character indicating existence of genetic difference among the 21 onion genotypes. Plant height ranged from 23.33 cm (Agrifound White) to 32.00 cm (PRO-6) with a mean of 27.70 cm. Low GCV (7.34%) and moderate PCV (10.69%), moderate heritability (49.09%) associated with moderate genetic advance over percentage of mean (10.36%).

Singh and Dubey (2011) reported lesser variability for plant height ranged from 56.58-65.96 cm in onion. They also reported low GCV (3.24%) and PCV (3.87%), high heritability (70%) with low genetic advance over percentage of mean (5.58%).

Ram *et al*. (2011) observed that, all the varieties of onion showed significant differences for plant height studied, moderate GCV (11.57%) and PCV (12.00%) with high heritability (93.00%), genetic advance (11.38%) associated with high genetic advance over percentage of mean (22.99%).

Ashok and Netrapal (2013) reported that, all the varieties of onion showed significant differences for the characters studied. Highest plant height was observed for Pusa Madhavi (54.8 cm), highly significant differences in values indicated great amount of variation among the treatments. The large amount of variation existed in the varieties/ lines revealed that considerable improvement can be made in this crop.

2.2.1.2 Number of leaves

Vidyasagar and monika (1993) observed low heritability in combination with low genetic advance over percentage of mean for number of leaves per plant. Non-significant variation among 106 genotypes of onion for number of leaves per plant was reported by Monpara *et al*. (2005). Whereas, Patil (1997) recorded wide range between 4.00-15.6 with high PCV (35.05%) and GCV (43.28%) and high heritability (65.60%) for number of leaves per plant in onion.

Mohanty (2001) reported significant variation in onion for number of leaves per plant ranged between 7.30-16.90, PCV was high (24.06%), moderate GCV (19.00%) and moderate values of heritability (41%), associated with high genetic advance over percentage of mean (44.27%).

Golani *et al.* (2006) observed significant differences among the 32 onion genotypes for number of leaves per plant and noticed low heritability (8.00%) coupled with low genetic advance over percentage of mean (1.35%) for this trait.

Significant differences among the 10 onion varieties for number of leaves per plant also noticed moderate GCV (10.63%) and PCV (15.63%), high heritability (66.78%) coupled with high genetic advance over percentage of mean (24.09%) for this trait by (Haydar *et al.*, 2007).

Sendek *et al*. (2008) reported wide variability in shallot for number of leaves per plant ranged from 14.35-48.90, high PCV (27.33%) and moderate GCV (13.08%), high heritability (65.1%) coupled with high genetic advance over percentage of mean (21.09%) for this trait.

Dhotre (2009) reported the wide variability in number of leaves among 14 onion genotypes ranged from 5.93 to 12.73, moderate GCV (11.46%) and PCV (15.28%) and moderate heritability (55.82%) coupled with moderate genetic advance over percentage of mean (17.64%).

Hosamani *et al*. (2010) observed wide variability in onion for number of leaves per plant which was ranged from 5.00 to 8.33 with moderate GCV (13.37%) and high PCV (21.91%), moderate heritability (37.33%) and moderate genetic advance over percentage of mean (16.84%). Whereas, significant differences for number of leaves among the 30 onion genotypes range lies between 7.90 to 12.10, low GCV (7.33%) and PCV (8.84%) associated with high heritability (75.6%) (Rashid *et al*., 2012).

Singh *et al*. (2010) reported lesser variability in onion for number of leaves ranged from 8.40-9.70, low PCV (5.73%) and GCV (3.41%), moderate heritability (35.53%) coupled with low genetic advance over percentage of mean (4.18%).

Ram *et al.* (2011) reported significant variation in onion for the number of leaves per plant ranged between 8.00 to 9.77, low GCV (4.70%) and PCV (6.50%) and high heritability (63.8%) associated with genetic advance (0.16%) coupled with moderate genetic advance over percentage of mean (11.85%).

Singh and Dubey (2011) reported lesser variability for number of leaves ranged from 2.26 to 8.5 in onion. Low genotypic (5.34%) and phenotypic (5.61%) coefficient of variations and high value of heritability (90.30%).

Abubakar and Ado (2013) reported that, in onion number of leaves per plant recorded higher genotypic variance (2.47%) than the environmental variance (2.37%).

2.2.1.3 Foliage colour

Jelica *et al*. (2013) reported that, in onion genotypes foliage colour ranged from green to bluish green with most of the genotypes having dark green leaves.

Brown (2013) evaluated the onion varieties for foliage colour, the varieties Calibra, Sarape Café and Red Defender had the glossiest foliage, while Madras, Patterson and Yankee had the bluest foliage.

Ali *et al.* (2014) reported that, green colour leaf in all new varieties of onion was different from cultivar BHP (light), two varieties had very light colour (MA and Z6), three had medium colour (G502, RA and G6) and two were characterized by a dark colour (YD and KR).

Shree *et al*. (2014) reported that, the leaf colour of garlic genotypes were light green, medium green and green. Only two genotypes Faizabad-6 and Akola garlic-43 showed the green colour leaves, while Akola white and NG-45 having light green colour leaves.

2.2.1.4 Days to maturity

Patil (1997) observed significant variation among the onion genotypes for number of days to maturity and recorded low PCV (7.80%) and GCV (7.66%). High estimates of heritability (96.40%) coupled with high genetic advance over percentage of mean (20.59%) were noticed.

Haydar *et al*. (2007) observed significant variation for days to maturity among ten onion varieties with a mean of 161.70 days and recorded the highest genotypic (89.33%) and phenotypic coefficient of variation (357.3%). Low heritability (25.00%) coupled with low genetic advance over percentage of mean (7.65%).

Sendek *et al*. (2008) reported lesser variability in shallot for days to maturity ranged from 71.00-84.50 days with low GCV (2.65%) and PCV (5.91%) with low heritability (20.2%).

Dhotre (2009) reported lesser variability in onion for number of days to maturity and it was ranged between 128.3 to 148.3 days, low GCV (3.55%) and PCV (4.95%), moderate heritability (51.30%) associated with low genetic advance over percentage of mean (5.24%).

Yadav *et al.* (2009) evaluated the eight cultivars of onion and reported minimum days to harvest was recorded in cultivar Sindhudurg Local (100.67 days) followed by Alibag Local (106.0 days) and Phule Safed (108.0 days) while maximum days taken to harvest was found in N-2-4-1 (120.67 days) followed by Baswant-780 (119.0 days).

Singh *et al*. (2010) observed that, moderate to low range of variability for days to maturity in onion which was ranged from 110.33-114.33 days, high heritability (87.50%) coupled with genetic advance (3.15%).

Abubakar and Ado (2013) reported that, higher genotypic variance was recorded in onion for all the characters under consideration than the environmental variance, in the combined analysis across seasons and days to maturity recorded relatively high genotypic co-efficient of variation (24.29%).

Panse *et al*. (2013) reported that, days to maturity in garlic ranged from 135.0 to 165.33 days, higher GCV (50%) and PCV (52.16%), high heritability (95.85%) associated with moderate genetic advance over percentage of mean (14.26%) for this trait.

2.2.1.5 Neck thickness

The onions with thin neck are known to store better when compared to those with thick neck (Kepkova and Unioka, 1970 and Jones and Mann, 1963).

Less variation among 25 onion genotypes for neck thickness, estimates of genotypic (0.02%) and phenotypic (0.08%) variance, moderate GCV (10.35%) and high PCV (20.35%). Lower heritability (25.40%) with moderate genetic advance over percentage of mean (10.48%) (Patil,1997). Whereas, Dhotre (2009) reported wide variability in neck thickness and the range varied between 9.50 to 13.40 mm and moderate PCV (14.24%), moderate heritability (55.82%) associated with moderate genetic advance over percentage of mean (16.89%).

Mohanty (2002 and 2004) reported significant variation among 12 onion varieties and high GCV (22.25%) and PCV (27.8%) for neck thickness and the heritability (66.89%) was estimated to be highest.

Ananthan and Moorthy (2007) reported a wide range of variation in onion bulbs for neck thickness. However moderate estimates of genotypic coefficient of variation (16.28%) and phenotypic coefficient of variation (16.40%) with high heritability (98.52%) coupled with low genetic advance over percentage of mean (0.27%) for this trait.

Hosamani *et al*. (2010) reported that, the wide range of variation in onion bulbs for neck thickness with the mean of 1.10 cm and range varies from 0.47 to 1.37 cm. Moderate estimates of genotypic coefficient of variation (17.01%) and high phenotypic coefficient of variation (25.57%), moderate heritability (50.00%) with high genetic advance over percentage of mean (23.64%) for this trait. Whereas, Ram *et al*. (2011) observed that, the high heritability (63.80%) and genetic advance 0.63 per cent among 16 onion genotypes for neck thickness.

Singh *et al*. (2010) reported, moderate to low variability of neck thickness in onion which is ranged from 1.46-1.61cm. Also recorded genetic advance (0.03%) and low heritability (22.60%).

Singh and Dubey (2011) observed lesser variability in onion for neck thickness which was ranged from 1.36 to 1.72 cm with a mean of 1.52 cm. The estimate of GCV (5.39%) and PCV (6.29%) were low, associated with high heritability (73.60%) with low genetic advance over percentage of mean (9.86%).

Singh *et al*. (2012) reported high value of heritability in garlic for neck thickness (77.6%) coupled with genetic advance (0.14%).

Tripathy *et al*. (2013) reported that, for better keeping quality the cultivar should have minimum neck thickness a desirable parameter in onion. In the present study, significantly lowest neck thickness was observed in Arka Niketan (0.42 cm) than rest of the tested advance lines or cultivars. However, statistical parity was recorded with the cultivars such as Bhima Super, NRCWO-4, RO-282, NOL-103, NOL-115, Bhima Raj, Bhima Red, N-2-4-1 and L-28 (0.42 to 0.62 cm) with Arka Niketan.

2.2.1.6 Collar thickness

Singh *et al*. (2013) reported wide variability in onion for collar thickness which ranged from 11.13 to 17.11 mm with a mean of 14.46 mm and the estimate of standard deviation (1.50%) and moderate genotypic coefficient of variation (10.37%).

Tripathy *et al*. (2013) reported significant variations among the onion varieties, advanced lines with respect to bulb quality (TSS) and collar thickness ranges from 12.21 mm (COLL 652) to 18.31 mm (Sel-397) among the tested lines.

Shree *et al.* (2014) indicated that, the garlic germplasms differed significantly to the different morphological attributes, Collar thickness ranges from 12.21 cm (COLL 652) to 18.31 cm (Sel-397) among the tested lines. However, statistically parity was recorded with NRCRO-4, VG-18, Syn-06, Soyal-2009 and RO-252.

2.2.2 Bulb parameters

2.2.2.1 Polar and equatorial bulb diameter

This character is directly related to bulb yield. Bulb diameter (polar and equatorial) showed very low heritability (Madalgeri, 1983, Patil *et al.*, 1986, Sidhu *et al*., 1986 and Vidyasagar and monika, 1993) while high heritability coupled with genetic advance, indicating non-additive gene action. It also showed wide variation among genotypes (Sidhu *et al*., 1986).

Patil (1997) reported that, in onion polar and equatorial diameter ranged between 3.99 to 6.46 cm with a mean of 6.08 cm, while GCV (6.32%) and PCV (12.34%) was low to moderate and high heritability (65.2%) associated with moderate genetic advance over percentage of mean (13.56%) for this trait.

Mohanty (2001) reported that, in onion variability for polar diameter ranged between 4.55-6.47 cm. Low GCV (7.91%) and moderate PCV (10.66%), moderate heritability (55.1%) coupled with moderate genetic advance over percentage of mean (12.05%).

Findings of Monpara *et al*. (2005) revealed that, phenotypic coefficient of variation was observed to be higher than the corresponding genotypic coefficient of variation in onion. High heritability coupled with high genetic advance over percentage of mean for characters like equatorial diameter of bulb.

Dhotre (2009) reported a significant variation for polar and equatorial diameter in onion and it ranged between 38.2 to 47.8 mm. while low GCV (8.49%) and PCV (9.38%), high heritability (80.88%) associated with moderate genetic advance over percentage of mean (15.74%) for diameter of bulb.

Hosamani *et al.* (2010) noticed significant variation among 21 onion genotypes for polar diameter and it ranged from 3.33 to 6.20 cm with a mean of 4.53 cm. The estimate of GCV (14.38%) and PCV (19.07%) were moderate. Heritability was moderate (57.33%) coupled with high genetic advance over percentage of mean (22.30%).

Singh and Dubey (2011) observed less variability in onion for diameter of bulb which ranged from 5.14 to 5.62 cm with the mean of 5.37 cm. The estimate of GCV (1.56%) and PCV (2.94%) were low. Heritability was low (28.20%) with low genetic advance over percentage of mean (1.67%).

Ram *et al*. (2011) reported that, in onion, bulb diameter was ranged from 4.84 to 6.12 cm. The estimate of GCV (5.65%) and PCV (8.32%) were low. Heritability was moderate (46.2%) with low genetic advance over percentage of mean (7.85%).

Panse *et al*. (2013) reported that, in garlic, equatorial diameter of bulb shown significant variation. The line JAS-27 was recorded maximum equatorial diameter while the minimum equatorial diameter of bulb was found in line JAS-3.

Singh *et al*. (2013) reported that, the greater part of the variation was accounted in onion for the diameter. The lowest values of standard deviation were recorded in the case of the equatorial diameter of the bulb (0.49%) followed by the polar diameter of the bulb (0.61%).

Chattopadhyay *et al.* (2013) reported that, the low GCV (8.38%) and moderate PCV (16.91%) values for polar and equatorial bulb diameter in onion. Low heritability (24.58%) associated with high genetic advance over percentage of mean for all the traits except polar diameter (8.56%) of bulb was indicative of additive gene action.

Mushtaq *et al*. (2013) reported that, onion cultivars showed significant variation for bulb diameter. Data showed largest bulb diameter (73.22 mm) for Phulkara followed by Mirpur Khas (61.96 mm), Dark Red (61.52 mm) and Desi Red (61.17 mm), respectively. It was on the lower side (52.00 mm) in VRIO-6, differences in bulb diameter were mainly due to variation in the genetic makeup of varieties.

2.2.2.2. Shape index

Ananthan and Moorthy (2007) evaluated 12 genotypes of onion for both *Rabi* and *Kharif* season at TNAU, Coimbatore. The pooled mean analysis revealed that the maximum bulb shape index was recorded in genotype ACC.7 (1.293) which was on par with ACC.17 (1.280) followed by ACC.29 (1.057) and minimum bulb shape index was observed in ACC.12 (0.823).

Dhotre (2009) evaluated *Kharif* onion and reported that, the genotypes exhibited wider variability for shape index with a range from 0.86 to 1.19. The maximum bulb shape index was recorded in genotype Bidar Local (1.19), whereas minimum bulb shape index was observed in Kohinoor-9 (0.86).

Camen *et al.* (2011) reported that, shape index most of the populations in shallot presented the elongated shape. Populations Rudna 101 and Giera 6 had the longest bulbs, meanwhile populations Dolat 1261, Dolat 198 and Dolat 244 had ovoid oblate shaped bulbs.

2.2.2.3 Per cent Bolter bulbs

Patil (1997) estimated wide variability in onion for bolting per cent which was ranged from 0.00 to 98.33 per cent with a mean of 33.1 per cent. High estimate of GCV (78.63%) and PCV (79.62%), high heritability (97.70%) associated with high genetic advance over percentage of mean (160.19%) for this trait.

Singh and Dubey (2011) reported significant variation among 26 onion genotypes for bolting ranged from 1.07 to 14.73 per cent, high GCV (66.71%) and PCV (81.25%). high heritability (67.40%) associated with high genetic advance over percentage of mean (113.00%).

Mushtaq *et al.* (2013) reported that, bolting percentage depicted significant variability among onion cultivars and it was maximum in Desi Red (46.67%). However, minimum bolting percentage (13.33%) was observed in both Faisal Red and in VRIO-6. This variation in bolting percentage between onion cultivars could be attributed to differences in their genetic makeup.

Ibrahim *et al.* (2013) reported the moderate GCV (16.10%) for bolting in onion with moderate PCV (19.23%) and low heritability (13.01%).

2.2.2.4 Per cent A, B, C grade bulbs

Trivedi and Dhumal (2010) reported that, four accessions of onion (NRCOG-574, 588, Hy-3667 and B-780) had high per cent of A grade and B grade bulbs, three were (NRCOG-551, 568 and 577) having high per cent of C grade bulbs, five accessions (NRCOG-574, 577, 588, Hy-3667 and B780) having high marketable yield and showed supremacy in respective attributes studied.

Trivedi and Dhumal (2010) reported that, A grade bulb and yield was negatively correlated with dry matter and doubles of bulb in onion. Bulb yield had a positive significant association with plant height, equatorial diameter, bulb weight, percentage of A grade bulbs.

Anand (2013) reported that the variety Local white gave significantly the highest A grade onion bulbs during the years 2003-04 and 2004-05 as compared to variety Agrifound Light Red during 2003-04 and 2004-05. On the other hand the variety Agrifound Light Red registered significantly higher values for B and C grades of onion bulbs as compared to variety Local White during the years 2003-04 and 2004-05.

Ahmed and Sharma (2014) reported that, 32 long day onion varieties with two check varieties *i.e.* Brown Spanish and Corel Red were evaluated for yield, quality and resistance to different insect and diseases. Genotypes CITH-O-12, CITH –O-30, CITH –O-1, CITH-O-3, CITH-O-28, CITH-O-23 and CITH-O-6 produced maximum A and B Grade bulbs as compared to control.

2.2.3 Quality parameters

2.2.3.1 Total soluble solids (TSS ^{o} Brix)

Patil (1997) reported that, the TSS range varies between 9.50 to17.6 ° Brix in onion. Genotypic (12.04%) and phenotypic (13.89%) coefficients of variation were observed to be moderate for TSS with higher heritability (75.10%) and genetic advance (2.68%).

Golani *et al*. (2006) reported the range of TSS in onion from 12.60 to 16.02 ° Brix, genotypic (4.62%) and phenotypic (9.92%) coefficient of variation were low with high heritability (74.2%) associated with low genetic advance over percentage of mean (4.43%).

Ananthan and Moorthy (2007) reported moderate genotypic coefficient of variation (11.92%) and phenotypic coefficient of variation (12.02%) with high heritability (98.40%) coupled with high genetic advance over percentage of mean (24.37%) for total soluble solids in onion.

Khar *et al.* (2007) reported that, among the ten onion lines along with five checks evaluated, the accession No. 671 had recorded the highest TSS (14.17 %) and was on par with the accession No. 650 (13.81 %) and accession No. 592 (13.80 %) followed by accession No. 597 (13.51 %), whereas least TSS registered in accession No. 651 (11.44 %).

Sendek *et al.* (2008) reported wide variability in shallot for total soluble solids ranged from 9.90 to 16.30 ° Brix, with moderate PCV (10.94%), low GCV (6.70%) and moderate heritability (37.5%).

Dhotre (2009) observed a wide range of TSS in onion varied from 10.40 to 18.7 ° Brix and reported moderate genotypic coefficient of variation (14.87%) and phenotypic coefficient of variation (16.45%), high heritability (82.28%) coupled with high genetic advance over percentage of mean (23.68%).

Hosamani *et al.* (2010) reported the significant difference among the onion genotypes for TSS with a range of 9.20 to 12.23 °Brix, low GCV (6.58%) and PCV (7.66%), higher heritability (74.24%) associated with moderate genetic advance over percentage of mean (11.68%).

Trivedi and Dhumal (2010) reported that, among the eighteen onion genotypes and four varieties evaluated during *Kharif* season at NRCOG, Pune, the genotype

NRCOG-596 had recorded the highest TSS (15.17 %), while DPS-1029 had registered the lowest TSS (9.0 %).

Singh *et al*. (2010) reported moderate to low variability for total soluble solids in onion ranged from 11.41-12.83 ° Brix, low phenotypic coefficient of variation (6.08%), low heritability (19.48%) coupled with low genetic advance over percentage of mean (2.36%).

The genotypic (3.87%) and phenotypic (6.87%) coefficients of variation were observed to be lowest and moderate heritability (32.20%) coupled with low genetic advance over percentage of mean (4.53%) for TSS in onion (Singh and Dubey, 2011).

Ram *et al.* (2011) evaluated sixteen genotypes of onion under Lucknow conditions, where AOSDRB-0922 recorded the highest TSS (13.27 %) and it was at par with AOSDRB-0913 (13.31 %), followed by AOSDRB-0910 (12.97 %) whereas AOSDRB-0920 marked the lowest TSS (11.38 %).

Ashok and Netrapal (2013) reported that, all the varieties of onion showed significant differences in total soluble solids. Maximum values for TSS were recorded for Sel 126. Reducing sugars ranged from 2.1 per cent (Sel 383) to 3.61 per cent (Early Grano). Sel 126 possessed highest non-reducing sugars while the lowest was found in Early Grano.

Tripathy *et al*. (2013) reported that, TSS in onion was ranges from 8.83 per cent (Soyal-2009) to 11.33 per cent (Arka Niketan). The lines such as Bhima Super, VG-18 and Syn-06 recorded significantly higher TSS except the highest value of Arka Niketan which was statistically at par.

2.2.3.2 Per cent of double bulbs

Khar *et al.* (2007) reported that, the least percentage of double bulbs was observed in onion cultivar Baswant-780 (4.11%) followed by accession no. 592 (8.16 %), whereas the highest percentage of double bulbs was recorded in the cultivar Agrifound Light Red (25.04 %).

Yadav *et al*. (2009) reported that, onion cultivars Baswant-780, Phule Swarna, Phule Safed and Phule Samarth were recorded zero percentage of double bulbs followed by Alibag Local (1.29%). Whereas cultivar Sindhudurg Local recorded the maximum double bulb percentage of 22.17 per cent.

Trivedi and Dhumal (2010) evaluated the eighteen onion genotypes and four check varieties among them, genotypes NRCOG-574 and Baswant-780 recorded least double percentage (11.54 % each), followed by NRCOG-568 and Hy-3667 (18.29 % each), while NRCOG-539 recorded highest percentage of double bulbs (50.30 %).

2.2.3.3 Uniformity of bulb shape

Rivera *et al.* (2005) reported that, the analysis of variance (ANOVA) for morphological quantitative characters showed highly significant differences between lines of onion for all of the traits under study these corresponded to lines with rhombic bulb shape like in Ribadeo, Oimbra, Vilagarcía,Outes and Cea whereas transverse narrow elliptic shape in Betanzos, Xulián, Mondoñedo, Chata-Miño and Pontearnelas and lines with bulb shapes ranging from transverse elliptic to transverse narrow elliptic shape in Ameixenda, Baldaio, Caldas, Arcade, Ponteareas and Garda.

Mallor *et al.* (2011) reported great variability in bulb shape for most accessions of onion (87.2%) *i.e*. flat, flat globe, rhomboid or broad oval bulbs with BSI value lower than 1, while the 3.5 per cent and 9.3 per cent corresponded to globe bulbs (BSI=1) and elongated bulbs (BSI>1), respectively.

Jelica *et al*. (2013) reported that, high variability have been established for bulb shape in onion. Flat to flat globe bulbs were found in domestic populations (Kol-NK-1, Kol-NK-2, Kol-79, Kol-153, Kol-154, Kol-166, Kol-57, Kol-62, Kol64, Kol-67), which originated in Serbia.

Ali *et al.* (2014) studied the morphological characteristics of the eight varieties of onion bulbs. Four shapes of bulb were observed which were different from cultivar BHP. With the shape of (Transverse narrow elliptic), circular shape in (YD and RA), rhombic shape in varieties like (Z6, G6 and KR), broad ovate in (G502) and broad elliptic shape in (MA).

2.2.3.4 Uniformity in bulb colour

Yadav *et al.* (2009) evaluated eight varieties of onion under Konkan agro-climatic conditions of Maharashtra and reported that the bulb skin colour of the cultivars based on visual observations, cultivars Phule Samarth and Nasik Red found to be red skinned, Baswant-780, N-2-4-1 and Sindhudurg Local registered medium red skin colour, Phule Safed and Alibag local recorded white colour, whereas the variety Phule Swarna marked Yellow skin colour.

Mallor *et al*. (2011) reported that, there was great variability in onion bulb skin with colour appearing white, yellow, brown and violet bulbs with different shades were recorded except green. Most of the bulbs were brown (53.5%), violet (25.6%) and white (16.3%).

Jelica *et al*. (2013) reported that, high variability in onion have been established for bulb skin colour and bulb flesh colour. Eighteen genotypes they differed in bulb colour from white to brown while most of them were yellow and light brown.

Shree *et al*. (2014) reported that, variability observed among the garlic genotypes in respect of clove skin colour varied from silky white, snow white and light cream.

Ali *et al.* (2014) studied the morphological characteristics of the bulb in eight varieties of onion. Two colours of skin other than cultivar 'BHP' grey colour was detected, brown in MA and Z6 and pink colour in the other varieties.

2.2.4. Yield parameters

2.2.4.1 Average bulb weight

Golani *et al*. (2006) noticed significant differences among 32 onion genotypes for bulb weight and reported low genotypic and phenotypic coefficient of variation. Patil (1997) also reported the same results.

Haydar *et al*. (2007) showed significant variation among 10 onion varieties and they reported high genotypic (142.41%) and phenotypic coefficient of variation (291.32%) associated with moderate heritability (48.88%) for this trait.

Dhotre (2009) reported the average bulb weight ranges from 31.32 to 93.86 g, high estimates of genotypic coefficient of variation (31.32%) and phenotypic coefficient of variation (32.58%) and high heritability (92.37%) with high genetic advance over percentage of mean (62.02%) for this trait in onion.

Hosamani *et al*. (2010) reported the range of average bulb weight in onion between 26.67-84.00 g, high estimates of genotypic coefficient of variation (28.92%) and phenotypic coefficient of variation (35.97%) and high heritability (64.64%), with high genetic advance over percentage of mean (47.88%) for this trait.

Bharti *et al*. (2011) reported average bulb weight of onion ranged from 81.33 to 128.44 g with a mean of 97.31g, moderate GCV (11.57%) and PCV (14.27%) have high heritability (65.7%) coupled with moderate genetic advance over percentage of mean (19.32%). High heritability (80.80%) with high genetic advance over percentage of mean (23.05%) for the average bulb weight was reported by Mohanty (2001).

Tripathy *et al*. (2013) indicated significant variations among the tested lines or cultivars of onion. The average bulb weight (ABW) varies from 26.39 g (Soyal-2009) to 82.33 g (NRCWO-3). Significantly highest bulb weight of 82.33 g was recorded in NRCWO-3 than rest of the tested lines except Bhima Super, NRCRO-4 and VG-19 (74.94 g to 79.47 g) which were statistically at par.

Mushtaq *et al*. (2013) reported that, onion cultivars showed significant variation for average bulb weight. Before curing the cultivar Phulkara (156.92 g) and Dark Red (154.33 g) yielded the highest bulb weight, while it was lowest (66.65 g) in VRIO-7. Similarly bulb weight after curing was maximum in Phulkara (148.43 g) and Dark Red (145.88 g) while it was minimum (62.63 g) in VIRO-7.

Singh *et al*. (2013) reported that, the average onion bulb weight of the hybrids ranged from 0.093 to 0.123 kg the noteworthy hybrids being Serena F1 and Mata Hari, which had significantly higher values of 0.123 and 0.122 kg respectively.

2.2.4.2 Marketable yield

Sendek *et al.* (2008) reported that, a wide range of genetic variability was obtained for all the traits in shallot with high PCV (40.38%) and GCV (27.95%) for marketable yield. Moderate heritability (48.3%), coupled with high genetic advance over percentage of mean were observed (36.59%).

Singh *et al*. (2010) reported that, wide range of variability in onion for marketable yield ranged from 239.33-338.49 q ha^{-1}, moderate magnitude of genotypic coefficient of variation (10.18%) coupled with high heritability (80.49%) and high genetic advance over percentage of mean (23.88 %).

Singh and Dubey (2011) observed wide variability in onion for marketable yield which ranged from 62.40–183.58 q ha^{-1}, moderate genotypic (17.78%) and higher phenotypic (20.15%) coefficients of variations. High value of heritability (77.80%) and genetic advance (46.31%) were also observed.

Singh *et al*. (2012) reported that, a wide range of variability in garlic was recorded for marketable yield (62.40–183.58 q ha^{-1}), genotypic and phenotypic coefficients of variations were moderate to high (17.78– 20.15%). High value of heritability (77.8%) and high genetic advance over percentage of mean (32.32%) were also observed.

Chattopadhyay *et al*. (2013) reported that, wide range of variability in onion for marketable yield ranged from 6.77 to 11.85 q ha^{-1}. Moderate GCV (16.78%) and PCV (17.18%), high heritability (95.39%) with high genetic advance over percentage of mean (33.76%) was observed.

Tripathy *et al*. (2013) reported that, in onion significant variations among the tested lines or cultivars for yield attributing traits. Marketable bulb yield varies from 25.58 q ha^{-1} (Soyal-2009) to 241.28 q ha^{-1} (Arka Niketan) with a mean value of 129.22

q ha^{-1}. The check variety, Arka Niketan recorded significantly highest marketable bulb yield (241.28 q ha^{-1}) than rest of the lines tested. However, statistical parity was observed with Bhima Super (240.02 q ha^{-1}) and NRCWO-3 (226.33 q ha^{-1}).

2.2.4.3 Total yield

Mohanty (2001) reported that, in onion the range of total yield was 30.29-35.53 q ha^{-1}, low GCV (3.34%) and PCV (5.99%) with moderate heritability (31%).

Sendek *et al*. (2008) reported that, a wide range of genetic variability was obtained for all the traits in shallot, high PCV (41.57%) and GCV (32.32%) for total yield. Moderate heritability (40.8%) coupled with genetic advance (32.96%).

Singh *et al*. (2010) reported lesser range of variability for total yield in onion ranged from 301.99-387.81 q ha^{-1}, lower magnitude of genotypic coefficient of variation was recorded for marketable yield (9.13%), which was followed by gross yield (9.16%), genetic advance (17.62 %) with high heritability (87.28%).

Singh *et al*. (2012) reported that, a wide range of variability was recorded in garlic for total yield (106.91–263.58 q ha^{-1}), genotypic (22.7%) and phenotypic (24.30%) coefficients of variations were high for total yield coupled with high heritability (87.80%),

Singh *et al*. (2013) reported that, in onion the range of total yield was 136.220 to 491.000 qha^{-1}, highest standard deviation (80.19%) with highest genotypic coefficient of variation (22.49%).

Tripathy *et al*. (2013) reported the total bulb yield of onion indicated significant variations among the tested lines or varieties of onion which vary from 88.24 q ha^{-1} (Soyal-2009) to 376.00 q ha^{-1} (Bhima Super) with an average value of 212.42 q ha^{-1} under Odisha condition. Significantly highest total bulb yield was recorded in Bhima Super (376.00 q ha^{-1}), closely followed by NRCRO-4 (337.12 q ha^{-1}), NRCWO-3 (328.96 q ha^{-1}) and Arka Niketan (325.41 q ha^{-1}) than rest of the tested lines or cultivars.

Mushtaq *et al*. (2013) reported that, all onion cultivars showed significant variation with respect to total bulb yield ha^{-1}. The highest yield (21.90 t ha^{-1}) was recorded in Phulkara while it was lowest (10.48 t ha^{-1}) in VRIO-6. This may be due to superiority of genotype and suitability to the local conditions.

2.3 Correlation studies

Association of economically important quantitative characters which is statistically determined by correlation coefficient has been quite useful as a basis of selection. Correlation studies provide information about the selection for one character will result in progress for all correlated characters.

2.3.1 Correlation of bulb yield with growth parameters

Bharti *et al*. (2011) reported that, onion bulb size had positive and highly significant correlation with bulb diameter, plant height at genotypic and phenotypic level. Bulb yield showed significant and positive association with most of the morphological characters. Positive association of plant height with bulb yield has been reported by Vidyasagar and Monika (1993); Mohanty (2004); Ananthan and Moorthy (2007); Netrapal *et al*. (1988). However, Mohanty, (2001) showed a negative association of plant height with the bulb yield. Whereas no association was reported between plant height and bulb yield (Patil, 1997). Aliyu *et al*. (2007) also found significant positive correlation of bulb yield with plant height and number of leaves per plant. Whereas, Hosamani *et al*. (2010) reported negative relationship between vegetative charecters like number of leaves per plant with bulb yield.

Number of leaves have both positive and negative association with bulb yield. The positive association was reported by Mohanty (2001); Mohanty (2004). Mahanthesh *et al*. (2007) and Netrapal *et al*. (1988).

Whereas, negative correlation for number leaves with bulb yield was reported by Padda *et al*. (1973). Bharti *et al*. (2011) observed bulb diameter showed positive and highly significant association with number of leaves per plant, plant height and neck thickness at genotypic and phenotypic level.

2.3.2 Correlation of bulb yield with bulb and quality characters

The relationship between bulb yield and various bulb characters have been reported by Netrapal *et al*. (1988); Vidyasagar and Monika (1993); Ananthan and Moorthy (2007); Mahanthesh *et al*. (2008), Mohanty (2004) and Hosamani *et al*. (2010).

Netrapal *et al*. (1988) observed that, positive association of onion bulb yield with polar diameter and equatorial diameter. Patil (1997) reported that, the onion bulb yield was negatively correlated with bulb shape index. Bulb exhibited positive and significant association with equatorial bulb diameter and average weight of bulb (Mohanty, 2002).

Bulb diameter showed to be positively correlated with bulb yield (Pavlovic *et al*., 2007; and Mohanty, 2004). Monpara *et al*. (2005) reported that the chief yield attributing factor, bulb weight was positively associated with polar and equatorial diameter of bulb. Positive and significant association of bulb yield with bulb weight has also been reported by Mahanthesh *et al*. (2007) and Mahanthesh *et al*. (2008). Several workers have also reported positive association between number of rings per bulb and the bulb yield (Vidyasagar and Monika, 1993 and Mahanthesh *et al*., 2008).

Onion bulb yield was significantly and highly positive correlated with equatorial bulb diameter, marketable yield and polar bulb diameter. It also had a positive relationship with the number of rings per bulb and bulb neck thickness. Sprouting and split percentage in bulb production were negatively correlated with bulb yield (Ibrahim *et al*., 2000).

Golani *et al.* (2006) observed that, the bulb yield in onion showed significant and positive association with number of leaves per plant, bulb length, and bulb girth also bulb weight at phenotypic and genotypic levels.

Haydar *et al*. (2007) noticed that, the onion bulb yield had strong positive genotypic correlation with plant height, days to harvest, bulb length and bulb diameter. Bulb yield was found to be positively and significantly correlated with fresh weight (0.877), TSS (0.560) and equatorial diameter (0.569) it was also found to be positively but negatively correlated with plant height (0.298), number of leaves (0.336), neck thickness (0.308), days to maturity (0.302) and polar diameter (0.494), While negative association was observed only with doubles/split bulb percentage (-0.294) reported by Dhotre (2009).

Hosamani *et al*. (2010) showed that, the yield of onion was negatively associated with TSS in both phenotypic and genotypic correlations. Days to maturity described by positive association with bulb yield (Sidhu *et al*., 1986 and Patil, 1997) but negative association with the bulb yield was reported (Monpara *et al*., 2005).

Hosamani *et al*. (2010) observed the interrelationship in onion with bulb yield having positive association with bulb diameter, bulb neck thickness and average bulb weight. Whereas, for phenotypic level, bulb length and average bulb weight were significant for bulb yield. Bharti *et al*. (2011) noticed that the bulb diameter had positive and highly significant correlation with bulb diameter, number of leaves per plant at genotypic and phenotypic level.

Trivedi and Dhumal (2010) reported that, polar diameter of onion had a significant positively association with average bulb weight, A grade bulb and total yield. It was also same for equatorial diameter. Bulb weight had positive significant association with A grade bulbs and yield.

Bharti *et al*. (2011) reported that, neck thickness had positive and significant association with plant height at genotypic level only. Similarly neck thickness also showed to be associated positively with bulb yield (Mahanthesh *et al*., 2008) whereas, some workers (Mohanty, 2001; Mohanty, 2002 and Mohanty, 2004) reported that, the bulb neck thickness was negatively associated with the bulb yield. Patil (1997) reported no association between neck thickness and bulb yield.

2.4 Screening of genotypes for disease

2.4.1 Purple blotch (*Alternaria porri*) incidence

Efforts have been made to locate sources of resistance for this disease in onion and garlic by few workers in India (Raju and Raj, 1979 and Sandhu and Korla, 1982). Sandhu *et al.* (1981) tested 49 lines over two years by inoculation with *Alternaria porri* in the field, Red Creole, 33-2, New-selection and VL 167 proved moderately resistant.

Bhangale and Joi (1985) screened 74 cultivars of onion against this disease under field conditions and reported that no cultivar was resistant. Whereas, Gupta and Pathak, (1988) screened 21 indigenous and exotic cultivars at two locations in India under artificial inoculations. All the exotic lines except two from Sudan were highly resistant to *Allium porri* while all the indigenous lines were susceptible.

Dhiman *et al*. (1986) evaluated 18 genotypes of onion against infestation of purple blotch disease under natural conditions. No genotype was found resistant, whereas, two genotypes VL-1 and Sel-2-4-1 were found moderately resistant and three genotypes were found highly susceptible.

Pathak *et al*. (1986) evaluated 36 lines of onion against purple blotch in order to locate the source of resistance to disease and only one line IHR-56 was found resistant while, five lines were moderately resistant.

Sugha *et al.* (1992) evaluated 94 genotypes of onion for their performance against the purple blotch. The lines 1C-39178 and IC49371 were resistant where ADR, RED Giobe, IC-33671, IC-43130, IC48001 and IC48045 were found to be moderately resistant.

Sindhu *et al.* (1994) reported that, Punjab Naraya a new and red skinned onion variety was less susceptible to purple blotch than Punjab red round and Punjab selection.

Sharma *et al*. (1997) evaluated 94 genotypes of onion for their performance against the purple blotch. The lines IC39178 and IC49371 were resistant while Agrifound

Dark Red, Red Globe, IC33671, IC43130, IC48001 and IC48045 were found to be moderately resistant.

Mathur *et al.* (2006) indicated that, Ro 59 variety was resistant to purple blotch with 8.2 per cent disease index (PDI), while other two varieties *viz.*, Ro 1 and N-53 were moderately resistant and susceptible with 11.2 and 23 PDI, respectively.

Upmanyu and Sharma (2007) evaluated eight genotypes of red onion against purple blotch disease to locate the source of resistance to the disease. All the eight genotypes onion were susceptible with disease severity ranging between 18.4 and 52.5 per cent, among these genotype-409 exhibited minimum (18.4 %) disease severity and genotype-432 exhibited maximum (52.5 %) while remaining genotypes exhibited intermediate values of apparent infection rate.

Prem *et al.* (2007) revealed that, two sprays of Bavistin @ 0.2% had lowest PDI value but at par to other different number of sprays of different fungicides except no spray of fungicide. Bulb yield of garlic was highest in two sprays of Dithane M-45 @ 0.3% followed by two sprays of Krinoxyl @ 0.15% and three sprays of Blitox-50 @ 0.3%.

Kumar and Palakshappa (2008) reported that, among the eight treatments, T7 (Mancozeb-3 sprays @ 0.2%) recorded least per cent index of (52.44%) and it was most effective in controlling the incidence of purple blotch in onion and resulted in high yield of 14.44 t ha^{-1} at 105 DAS.

Mishra *et al.* (2009) revealed that, out of twenty one garlic promising lines, Line G-54 was found moderately susceptible, line G-222 was moderately resistant and rest of lines were found to be resistant against purple blotch.

Chethana *et al*. (2011) reported that, screening of onion genotypes for purple blotch under field condition revealed that, the genotype Arka Kalyan was found moderately resistant while the genotypes *viz.*, Rampur Rose, Agrifound Rose, Arka

Pragati, Arka Niketan, Arka Pitamber and Arka Bindu were found moderately susceptible to purple blotch.

Kumari, *et al.* (2011) reported among 310 onion genotypes screened against purple blotch disease, none of them were found resistant or immune, while four genotypes *viz*. Arka Kalyan, AK-171, AK-172, Ak-173 and MSPBR-120 were found moderately resistant with grade scale of 2 and the per cent of leaf area infection ranged from 11 to 20 per cent.

Madhavi *et al.* (2012) reported that, Czapek-Dox medium amended with nutrients like lactose, urea, diammonium hydrogen orthophosphate, ammonium sulfate and pH 5.0 supported good growth of the pathogen. Mancozeb and extracts from the plant species, *Mentha Arvensis* were effective in controlling the growth of *A. porri*.

Abubakar and Ado (2013) reported that, in onion estimates the components of variation indicate that disease incidence and disease severity recorded higher genotypic variance (519.24%) than the environmental variance (18.07%).

Tripathy *et al*. (2013) indicated significant variations among the tested cultivars in onion with respect to purple blotch disease with the range of 42.83 to 63.97 per cent and average of 54.75 per cent. The cultivar, NRCWO-3 recorded significantly lowest incidence of disease (42.83%) than rest of the cultivars except NRCRO-3, NRCRO-4, NRCWO-4, VG-19, Syn-6, RO252 and Arka Niketan.

Behera *et al.* (2013) reported that, none of the 22 onion varieties, screened against purple blotch, there were significant variations were existed among the varieties under study. Results revealed that, only one variety *viz.,* VG-18 performed best among all the tested cultivars by displaying resistant and moderately resistance to purple blotch while its comparative yield (288.18 q/ha) also remained at top. 12 varieties were moderately resistant and nine varieties are moderately susceptible.

Agarwal and Tiwari, (2013) reported that, nine genotypes of garlic *viz*., G-1, G-50, G-323, PGS-4, PGS-14, G-313, PGS-99-1, PGS-98 and PGS-99-2 fell into the category of resistant, five showed moderately resistant reaction to disease (PGS-13, PGS-17, KGS-1, HG-17 and PGS-99-3), four were mild susceptible (G-41, DG-2, DARL-52 and DARL-53) whereas three (G-282, DG-1 and RAUC-5) were susceptible. A strong and negative correlation was observed between purple blotch incidence and bulb weight.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The studies on "Genetic variability studies in Onion (*Allium cepa* L.) germplasm under central dry zone of Karnataka" was undertaken during the year 2014-2015. The details of the experiment with respect to material used and techniques adopted during the present investigation are presented in this chapter.

3.1 Experimental site

The field experiment on "Genetic variability studies in Onion (*Allium cepa* L.) germplasm under central dry zone of Karnataka" was conducted at Zonal Agricultural and Horticultural Research Station Hiriyur, University of Agricultural and Horticultural Sciences, Shivamogga.

3.1.1 Location and climate

ZAHRS Hiriyur is situated in Central dry zone (Zone-4) 13^{o}57'32" North latitude and 70^{o}37'38" East longitude at 606 meters above Mean Sea Level (MSL). Among the agro-climatic zones of Karnataka, Hiriyur has benefits of both South-West and North-East monsoons. The annual average rainfall for last 35 years is 567 mm per year. The maximum and minimum temperature in a year ranges between 31.49 $^{\circ}$C and 20.91 $^{\circ}$C respectively. The annual relative humidity of location is 77.76 per cent and 61.74 per cent in morning and evening, respectively. The meteorological data recorded at the meteorological observatory of the Zonal Agricultural and Horticultural Research Station, Hiriyur is presented in Appendix I.

3.2 Exploration and collection of onion germplasm

An exploration was under taken to collect onion germplasm from different research stations in Karnataka and Maharashtra as well as onion growing areas in Chitradurga district. Seven genotypes were procured from Directorate of Onion and Garlic Research (DOGR), Pune. Five genotypes were collected from Indian Institute of Horticulture Research (IIHR), Hesaraghatta, Bengaluru. The National Horticultural Research and Development Foundation (NHRDF), Nasik, Maharashtra has spared 4 genotypes and Mahathma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra has contributed 2 genotypes. In addition, three local cultivars consisting of 2 lines from Maharashtra and one local collection from Chitradurga, (Molakalmur area) Karnataka as well as two genotype from private seed company *viz*., East West seeds. Pvt. Ltd were collected and used in the present investigation. The list of these genotypes and their source of collection are presented in the Table 1.

3.3 Details of the experiment

3.3.1 Design and experimental layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replication, plan of layout is depicted in Figure 1. The treatments in each replication were allotted randomly. General view of the experimental plot is depicted in Plate 1.

The experimental details are as follows:

Number of genotypes: 23

Replications: 3

Season: *Kharif* 2014-15

Plot size: 3 m × 2 m

Spacing: 15 cm x 10 cm

Number of plants per plot: 300

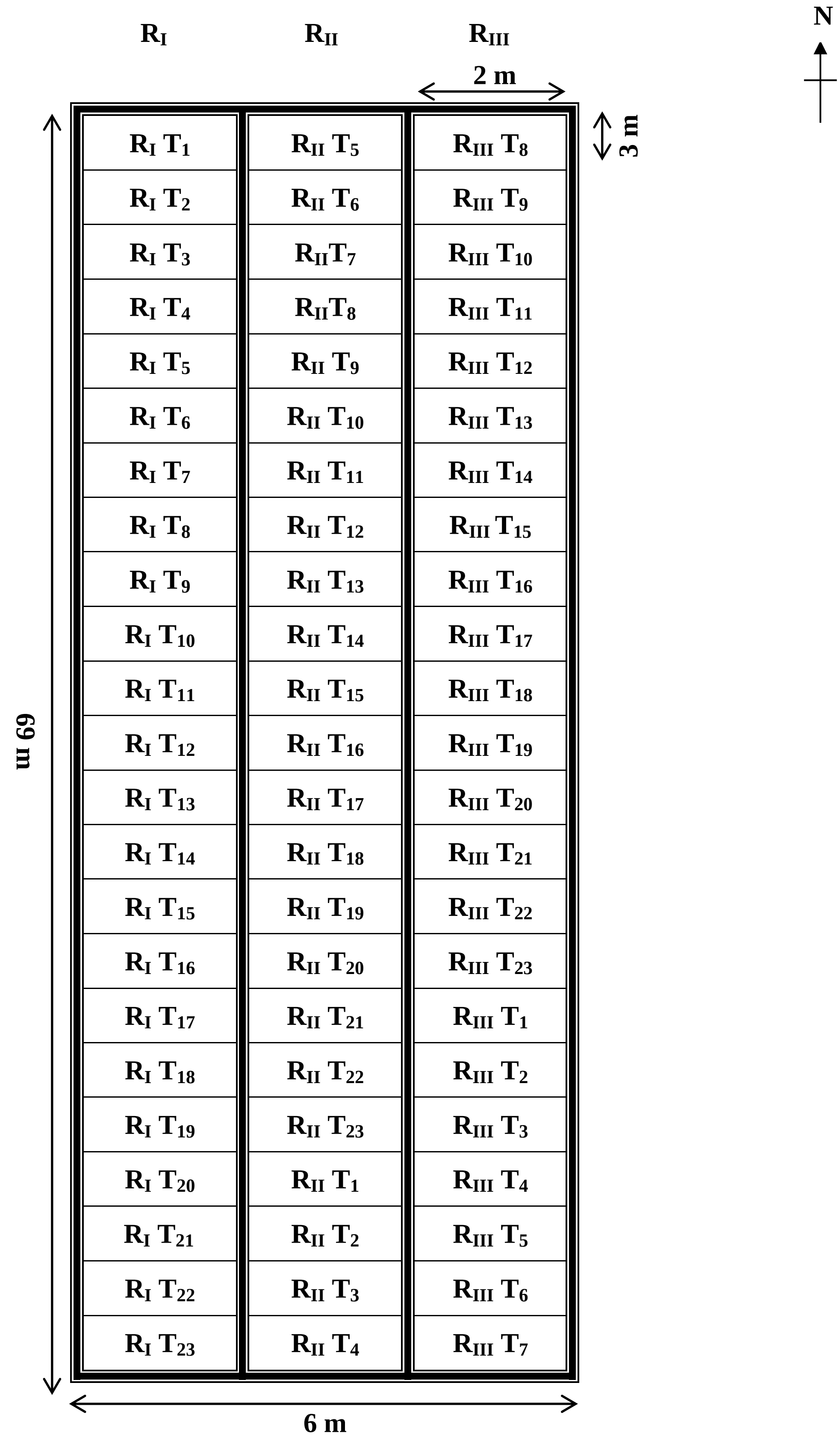


Fig. 1: Plan and layout of experimental plot

Plate 1. General view of experimental plot

Table 1. Different onion cultivars used in the experiment and their sources of collection

Sl. No.	Cultivars	Source
1.	Agrifound Dark Red	NHRDF, Nasik
2.	Agrifound Light Red	NHRDF, Nasik
3.	Agrifound White	NHRDF, Nasik
4.	Light Red	NHRDF, Nasik
5.	Arka Bindu	IIHR, Bengaluru
6.	Arka Kalyan	IIHR, Bengaluru
7.	Arka Pragati	IIHR, Bengaluru
8.	Arka Niketan	IIHR, Bengaluru
9.	Arka Keerthiman	IIHR, Bengaluru
10.	N-53	MPKV, Rahuri
11.	PKV-White	MPKV, Rahuri
12.	Bhima Super	DOGR, Pune
13.	Bhima Shubra	DOGR, Pune
14.	Bhima Shakti	DOGR, Pune
15.	Bhima Kiran	DOGR, Pune
16.	Bhima Red	DOGR, Pune
17.	Bhima Shweta	DOGR, Pune
18.	Bhima Raj	DOGR, Pune
19.	Prema-178	East West seeds. Pvt. Ltd
20.	Prerana	East West seeds. Pvt. Ltd
21.	Mahalakshmi	Molakalmur, local
22.	Poona Pursangi	Local collection form Maharashtra
23	Sataara Garva	Local collection form Maharashtra

NHRDF- National Horticulture Research and Development Foundation, Nasik

IIHR- Indian Institute of Horticultural Research, Bengaluru

3.3.2 Treatment details

T_1 –Agrifound Dark Red	T_9 –Arka Keerthiman	T_{17}–Bhima Shewtha
T_2 –Agrifound Light Red	T_{10} –N-53	T_{18}–Bhima Raj
T_3 –Agrifound White	T_{11}–Bhima Super	T_{19}–Prema-178
T_4 –Sataara Garva	T_{12}–Light Red	T_{20}–Mahalakshmi
T_5 –Arka Bindu	T_{13} –Bhima Shubra	T_{21}–Prerana
T_6 –Arka Kalyan	T_{14}–Bhima Shakthi	T_{22}–Poona Pursangi
T_7 –Arka Pragathi	T_{15} –Bhima Kiran	T_{23}–PKV-White
T_8 –Arka Niketan	T_{16}–Bhima Red	

3.4 Cultural practices

3.4.1 Soil and its characteristics

The soil of the experimental site comprised of black soil. Before sowing a composite soil sample was drawn from experimental area to a depth of 0-30 cm and analysed for chemical properties and the values obtained are furnished in Appendix II.

3.4.2 Sowing and raising of seedlings in nursery

Sowing was done on 19th April 2014 and seedlings of all the 23 genotypes were raised in protrays using recommended nursery practices at ZAHRS, Hiriyur. Recommended cultural practices were followed before and after sowing of seeds. Protrays were watered morning and evening regularly. Seedlings were transplanted to main plot at forty five days after sowing.

3.4.3 Field preparation

The experimental plot was ploughed and brought to a fine tilth and applied the recommended dose of NPK at the rate of 120:50:160 kg/ha and farm yard manure (FYM) at the rate of 20 tons per hectare. (Gopalakrishnan, 2007).

3.4.4 Planting

The seedlings of all the cultivars were planted on 5th June 2014. The seedlings raised in portrays were uprooted cultivar wise separately and immediately transplanted in the main field in plots at row of spacing of 15 cm and plant spacing of 10 cm within each row in irrigated plots.

3.4.5 Irrigation and weeding

The plots were irrigated at 10 days interval depending on climatic conditions. The experimental plots were kept free from weeds by hand weeding once in 15 days.

3.4.6 Plant protection measures

The crop was sprayed with mixture of spray solution containing Phosphomidon (0.25%) and Mancozeb (0.25%) seven weeks after sowing. The second spray was given using Dimethoate (0.17%) and Mancozeb (0.25%) twelve weeks after transplanting. The third spray was given using Confidor (0.25%) and Mancozeb (0.25%) ten days after the second spray as a prophylactic measure to control thrips and purple blotch disease. However, in a separate block wherein the plots were subject to the screening for purple blotch incidence were not sprayed with any of the plant protection chemicals.

3.4.7 Harvesting

The bulbs were harvested at proper maturity stage separately for each treatment. The plants were uprooted from the individual plot and then dried under shade for curing of the bulbs.

3.5 Observations recorded

Five representative plants were selected randomly from each genotype per replication and were tagged for identification. Average from these five plants was worked out for the statistical analysis and further used for the genetic variability studies. The details of the observations recorded and the techniques adopted to record each observation are given below.

3.5.1 Growth parameters

3.5.1.1 Plant Height

The plant height was measured from the ground to the tip of longest leaf (when held vertically) at 90 days after transplanting. The mean of the five plants in a treatment per genotype was worked out and expressed in centimetre.

3.5.1.2 Number of leaves per plant

The numbers of fully grown, green and photo synthetically active leaves were recorded and average number of leaves per plant was worked out from the five randomly selected tagged plants and expressed in numbers.

3.5.1.3 Foliage colour

Foliage colour was recorded by visual observation at 30 days after transplanting like light green, green and dark green.

3.5.1.4 Days to maturity

Days to maturity was recorded from individual plot after neck fall or when the leaves start drying.

3.5.1.5 Collar thickness

The collar thickness at harvest was measured using Vernier calipers and the measurement was made in centimetres below the joint of leaf lamina, the observations recorded on five plants were averaged to get mean value and expressed in centimetre.

3.5.1.6 Neck thickness

The neck thickness after curing was measured using Vernier calipers and the measurement was made in centimetres below the joint of leaf lamina, the observations recorded on five plants were averaged to get mean value and expressed in centimetre.

3.5.2 Bulb parameters

3.5.2.1 Polar bulb diameter

The length between two polar ends of the bulb was recorded with the help of Vernier calipers and mean diameter was worked out from all the five bulbs in each plot. It was expressed in centimetre.

3.5.2.2 Equatorial bulb diameter

The equatorial diameter of bulb at the middle of the polar length was measured with the help of Vernier calipers and the mean was calculated from all the five bulbs in each plot. It was expressed in centimetre.

3.5.2.3 Shape index

The bulb shape index was determined by dividing the polar diameter of bulb with equatorial diameter of the bulb. The bulb with 1.0 index was considered as globular, those with less than 1.0 as flat and those with more than 1.0 as torpedo types.

$$\text{Bulb shape index} = \frac{\text{Polar diameter of bulb}}{\text{Equatorial diameter of bulb}} \times 100$$

3.5.2.4 Bolter bulbs

It refers to the emergence of seed stalk prior to time of their bulb formation and the percentage of bolting was worked out for each genotype or plot.

$$\text{Bolting per cent} = \frac{\text{Number of bolting plants}}{\text{Total number of plants}} \times 100$$

3.5.2.5. A Grade bulbs

A grade bulbs were recorded after harvesting in field. Those bulbs with more than 5.5 cm diameter using vernier callipers are considered as A grade bulb and the number of bulbs was converted into percentage and the mean values were calculated.

3.5.2.6. B Grade bulbs

B grade bulbs were recorded after harvesting in field. Those bulbs with 4.5 to 5.5 cm diameter are considered as B grade bulb using vernier callipers and the number of bulbs was converted into percentage and the mean values were calculated.

3.5.2.7. C Grade bulbs

C grade bulbs were recorded after harvesting in field. Those bulbs with 3.5 to 4.5 cm diameter are considered as C grade bulb using Vernier callipers and the number of bulbs was converted into percentage and the mean values were calculated.

3.5.2.8. Less than C grade bulb

Less than C grade bulbs were recorded after harvesting in field and those bulbs with less than 3.5 cm diameter are considered as Less than C grade bulbs using Vernier callipers and the number of such bulbs was converted into percentage and the mean values were calculated.

3.5.3 Yield parameters

3.5.3.1 Total yield

Total yield was recorded after harvest by weighing the bulbs in the plot. It was expressed in tons per hectare.

$$\text{Total bulb yield (t/ha)} = \frac{\text{Area of 1 ha x Bulb yield (kg/plot)}}{\text{Plot size (6 m}^2\text{) x 1000}} \times 100$$

3.5.3.2 Marketable yield

Marketable yield was recorded after harvest by weighing the bulbs of A+B+C grade bulbs only. It was expressed in tons per hectare.

$$\text{Marketable bulb yield (t/ha)} = \frac{\text{Area of 1 ha x Marketable bulb yield (kg/plot)}}{\text{Plot size (6 m}^2\text{) x 1000}} \times 100$$

3.5.3.3 Average bulb weight

The bulbs from five randomly tagged plants were weighed individually in an electronic balance and the average bulb weight was recorded and expressed in grams (g).

3.5.4 Quality parameters

3.5.4.1 Total soluble solids (TSS)

Total soluble solids were recorded with the help of Refractometer and average was worked out from all the five bulbs and expressed in percentage.

3.5.4.2 Uniformity in bulb colour

Uniformity in bulb colour was recorded by visual observation after curing in open field like Dark red, Red, Light red, Yellow and White.

3.5.4.3 Uniformity in bulb shape

Uniformity in bulb shape was recorded by visual observation after curing in open field like Flat/Globular/Oval/Round.

3.5.4.4 Double bulbs

The bulbs having splits or doubles were recorded after the harvest. Then the percentage of doubles or splits was worked out for each plot.

$$\text{Percentage of double bulbs} = \frac{\text{Number of double bulbs}}{\text{Total number of bulbs}} \times 100$$

3.5.5 Screening of genotypes for disease

The seedlings were transplanted in the plots with a spacing of 15 cm between plants and 10 cm within rows. Out of three replications, one replication was not sprayed by any chemicals so as to facilitate the incidence of purple blotch disease. The genotypes were randomised within each replication.

3.5.5.1 Purple blotch (*Alternaria porri*) *incidence*

The disease scoring was done after 70 days after transplanting. The development of the symptoms and the severity of the disease were recorded by observing all the plants in each treatment and the per cent disease incidence (PDI) was worked as per the formula given by Dhiman *et al.* (1986).

$$PDI = \frac{Scr}{N \times 5} \times 100$$

Where, Scr = Sum of all class ratings,

n = number of leaves examined, and

5 = maximum class rating in the scale.

The lines were placed in different categories of resistance and susceptibility and scored on the basis of 0-5 scale given by Bhangale and Joi (1985).

0 = Immune (No disease)

1 = Resistant (1-10%)

2 = Moderately resistant (11-20%)

3 = Moderately susceptible (21-40%)

4 = Susceptible (41-60%)

5 = Highly susceptible (61% & above)

3.6 Statistical Analysis

The data collected from the experiment was subjected to various statistical analysis to draw the suitable inference. The details of the statistical procedure followed are given below.

3.6.1 Analysis of variance

Analysis of variance was done separately for each character for all treatments.

The model of analysis of variance was given below.

Source	**D.F**	**SS**	**MSS**	**Cal. F**
Replication	r-1	RSS	RSS/(r-1)	TMSS/EMSS
Treatments	t-1	TSS	TSS/(t-1)	
Error	(r-1)(t-1)	ESS	ESS/(r-1)(t-1)	
Total	(rt-1)	TSS		

Where,

t = Number of treatments (genotypes)

r = Number of replications

The standard error was calculated as,

S.Em ± = $\sqrt{\mathrm{EMSS}/\mathrm{r}}$

Critical difference, CD = $\sqrt{2 \text{ x S.Em x t } (\alpha, \mathrm{Edf})}$

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

Edf – Error degrees of freedom.

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

3.6.2 Mean, Range and Variance

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

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

Range = The minimum and maximum values for each trait.

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

Where,

Xi = Individual value

$\overline{X}$ = Population mean

n = Number of observations

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

3.7 Estimation of genetic parameters

In order to identify and ascertain the genetic variability among genotypes and to assess the extent of environmental effect on various characters, different genetic parameters were estimated by using formulae as given below.

3.7.1 Genotypic and phenotypic variance

These were calculated according to the formula given by Chaudhary and Prasad (1968).

$$\text{Genotypic variance } (\sigma g^2) = \frac{\text{MSS (treatment)} - \text{MSS (error)}}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma p^2) = (\sigma g^2 + \text{MSS (error)})$$

3.7.2 Phenotypic and Genotypic Coefficient of variation

The coefficient of variation both at phenotypic and genotypic levels for all the characters were computed by applying the formula as suggested by Burton and Devane (1953).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma g}{\overline{X}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma p}{\overline{X}} \times 100$$

Where,

$\overline{X}$ = grand mean of the character

σ_p = phenotypic standard deviation

σ_g = genotypic standard deviation

PCV and GCV were classified into low, moderate and high as suggested by Sivasubramanian and Menon (1973)

0 – 10 % : Low

10.1 – 20 % : Moderate

20.1 % and above: High

3.7.3 Heritability (h^2) in broad sense

Heritability in broad sense for all the characters was computed by the formula suggested by Hanson *et al.* (1956).

$$\text{Heritability } (h^2_{bs}) = \frac{\sigma g^2}{\sigma p^2} \times 100$$

Where,

h^2_{bs} =heritability (broad sense)

σ^2_g= genotypic variance

σ^2_p= phenotypic variance

Heritability was classified into low, moderate and high as suggested by Robinson *et al.* (1949).

Where,

0 – 30 % : low

30.1 – 60 % : moderate

60.1 % and above: high

3.7.4 Genetic Advance (GA)

The predicted genetic advance was estimated according to the formula given by Johnson and Robinson (1955).

$$GA = h^2_{bs} \times K \times \sigma_P$$

Where,

h^2_{bs} = heritability in broad sense

K= selection differential at given intensity

σ_P= phenotypic standard deviation

3.7.5 Genetic advance as per cent mean (GAM)

This was calculated using the formula given below.

$$GAM = \frac{GA}{\overline{X}} \times 100$$

Where,

GA = Genetic advance

$\overline{X}$ = General mean

The genetic advance as per cent of mean was categorized into low, moderate and high as suggested by Johnson and Robinson (1955).

0 – 10 %	: Low
10.1 – 20 %	: Moderate
> 20.1 and above	: High

3.7.6 Correlation analysis

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

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

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

Where,

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

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

$V_x(G)$ = Genotypic variance of character 'x'

$V_x(P)$ = Phenotypic variance of character 'x'

$V_y(G)$ = Genotypic variance of character 'y'

$V_y(P)$ = Phenotypic variance of character 'y'

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

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Investigations on the genetic variability for growth, yield and quality parameters as well as purple blotch tolerance in 23 onion genotypes were conducted at Zonal Agricultural and Horticultural Research Station (ZAHRS) Hiriyur, during the year 2014-15. The results obtained in the present investigation are presented in this chapter.

4.1 Exploration and Collection of onion germplasm

In order to collect the onion germplasm for the present investigation, an exploration was under taken to visit various research stations in Karnataka and Maharashtra as well as onion growing areas in Chitradurga district. Seven genotypes were procured from Directorate of Onion and Garlic Research (DOGR), Pune which includes Bhima Super, Bhima Shubra, Bhima Shakti, Bhima Kiran, Bhima Red, Bhima Shweta and Bhima Raj. Five genotypes *viz*., Arka Bindu, Arka Kalyan, Arka Pragati, Arka Niketan and Arka Keerthiman were collected from Indian Institute of Horticulture Research (IIHR), Hesaraghatta, Bengaluru. The genotypes contributed by National Horticultural Research and Development Foundation (NHRDF), Nasik, Maharashtra which includes Agrifound Dark Red, Agrifound Light Red, Agrifound White and Light Red. Further, Mahathma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra has contributed two genotypes like N-53 and PKV-White. In addition, three local cultivars consisting of 2 lines from Maharashtra (Sataara Garva and Poona Pursangi) and one local collection from Chitradurga, Karnataka *viz*., Molakalmur local as well as two genotypes from private seed company *viz*., East West seeds. Pvt. Ltd (Prema-178 and Prerana) were used in the present investigation for assessing the genetic variability for various growth, yield and quality parameters as well as tolerance to purple blotch incidence.

4.2 Analysis of variance

The analysis of variance was done to test the significance of differences among the genotypes studied. The mean sum of squares due to various sources for different growth and yield parameters are presented in Table 2. Analysis of variance revealed highly significant (p=0.01) differences among treatments (genotypes) for all the growth

Table 2. Analysis of variance for growth and yield parameters in onion genotypes

Source	d. f.	Plant height at 90 Days (cm)	Number of leaves at 90 Days	Days to maturity (days)	Collar thickness (cm)	Neck thickness (cm)	Total yield (t/ha)	Marketable yield (t/ha)	Average bulb weight (g)
Treatment	22	24.05**	1.18**	75.42**	0.10**	0.09**	40.51**	30.66**	305.82**
Error	44	13.49	0.51	5.80	0.04	0.03	5.22	3.09	14.54
S.Em ±		2.12	0.41	1.39	0.12	0.10	1.31	1.01	2.20
C.D (5 %)		6.04	1.17	3.96	0.36	0.31	3.76	2.89	6.27
C.D (1 %)		8.07	1.57	5.29	0.48	0.41	5.02	3.86	8.38

**Significance at 1 %

Table 3. Analysis of variance for yield and quality traits in onion genotypes

Source	d.f.	Polar diameter (cm)	Equatorial diameter (cm)	Shape index	A grade bulbs (%)	B grade bulbs (%)	C grade bulbs (%)	Less than C grade bulbs (%)	Bolter bulbs (%)	TSS (%)	Double bulbs (%)
Treatment	22	0.32**	0.25**	0.07**	3.29**	38.49**	44.83**	61.09**	1.88**	5.17**	0.98**
Error	44	0.15	0.07	0.03	1.37	5.77	8.79	7.20	0.68	2.17	0.31
S.Em ±		0.22	0.16	0.10	0.67	1.38	1.71	1.55	0.47	0.85	0.32
C.D (5 %)		0.64	0.45	0.30	1.92	3.95	4.88	4.41	1.36	2.42	0.91
C.D (1 %)		0.86	0.61	0.40	2.57	5.28	6.52	5.90	1.82	3.24	1.22

** - Significance at 1 %

and yield parameters. Further, highly significant differences were also recorded for yield, quality parameters and also for purple blotch incidence among the genotypes studied (Table 3).

4.3 Genetic variability, heritability and genetic advance

With a view to understand the extent of variation observed due to genetic factors, the mean, range, genotypic variance (GV), phenotypic variance (PV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance as per cent over mean (GAM) were worked out for growth and yield parameters are presented in Table 4 and the same were presented in Table 6 for yield, quality and purple blotch incidence.

4.3.1 Growth parameters

4.3.1.1 Plant height

Plant height at 90 DAT ranged from 52.86 cm (Agrifound Light Red) to 68.56 cm (PKV-White) with a mean of 59.01cm. The genotypic (3.52) and phenotypic (17.01) variances were recorded. The estimates of PCV and GCV were low (6.99 % and 3.17%, respectively). A low heritability of 20.7 per cent was observed for this trait along with a low genetic advance as per cent over mean 2.97 per cent (Tables 4 and 5).

4.3.1.2 Number of leaves per plant

The number of leaves per plant 90 DAT ranged from 8.80 (Arka Bindu) to 11.03 (Arka Kalyan) with a grand mean of 9.89. The phenotypic (0.73) and genotypic variance (0.22) were recorded. There was a low GCV (4.79 %) and PCV (8.68 %) observed for this trait. The heritability was moderate (30.4 %) with a low (5.44 %) genetic advance as per cent over mean (Tables 4 and 5).

4.3.1.3 Foliage colour

Among the cultivars with respect to foliage colour Bhima Super, Bhima Red, Bhima Kiran, Arka Kalyan, Arka Niketan, Arka Pragati, Agrifound White, Mahalakshmi and Sataara Garva have green coloured leaves. Bhima Shweta, Bhima Raj, Bhima

Table 4. Estimates of genetic parameters for growth and yield traits in onion genotypes

Sl. No	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
A	**Growth parameters**									
1	Plant height at 90 DAT (cm)	59.01±2.12	52.86-68.56	3.52	17.01	3.17	6.99	20.7	1.75	2.97
2	Number of leaves at 90 DAT	9.89±0.41	8.80-11.03	0.22	0.73	4.79	8.68	30.4	0.53	5.44
2	Days to maturity (Days)	114.50±1.39	103.0-121.66	23.20	29.01	4.20	4.70	80.0	8.87	7.75
4	Collar thickness (cm)	1.51±0.12	1.16-2.03	0.02	0.06	9.38	17.24	29.6	0.15	10.52
5	Neck thickness (cm)	0.86±0.10	0.61-1.39	0.02	0.05	16.46	27.27	36.4	0.17	20.46
B	**Yield parameters**									
6	Total yield (t/ha)	24.05±1.31	16.36-36.86	11.76	16.98	14.26	17.13	69.2	5.88	24.44
7	Marketable yield(t/ha)	20.85±1.01	14.06-32.56	9.19	12.28	14.53	16.80	74.8	5.40	25.90
8	Average bulb weight(g)	82.42±2.20	53.66-97.00	97.09	111.63	11.95	12.81	87.0	18.93	22.96

DAT- Days After Transplanting
h^2- Broad sense heritability
PCV- Phenotypic Co-efficient of Variation
GCV- Genotypic Co-efficient of Variation
PV- Phenotypic Variance
GAM- Genetic Advance as Per cent of Mean
GV- Genotypic Variance
GA- Genetic Advance

Table 5. *Per se* performance of onion genotypes for growth parameters

Sl. No.	Genotypes	Plant height 90 DAT	No. of leaves 90 DAT	Days to maturity (Days)	Collar thickness (cm)	Neck thickness (cm)
1	Agrifound Dark Red	59.00	9.73	103.00	1.41	0.66
2	Agrifound Light Red	52.86	10.50	115.33	1.38	0.69
3	Agrifound White	55.63	10.46	114.00	1.46	1.23
4	Staara Garva	57.16	9.40	114.33	1.60	0.73
5	Arka Bindu	58.56	8.80	104.33	1.16	0.61
6	Arka Kalyan	61.53	11.03	114.00	1.66	0.69
7	Arka Pragathi	59.56	9.13	117.00	1.44	0.87
8	Arka Niketan	59.93	9.86	121.66	1.31	0.92
9	Arka Kerthiman	59.06	9.93	114.66	1.42	0.70
10	N-53	58.86	9.53	118.66	1.35	1.00
11	Bhima Super	57.00	11.00	112.33	2.03	1.39
12	Light Red	58.63	9.46	114.66	1.42	1.06
13	Bhima Shubra	58.86	8.86	120.66	1.40	0.81
14	Bhima Shakthi	60.60	9.40	120.00	1.39	0.83
15	Bhima Kiran	59.26	10.43	119.33	1.86	0.82
16	Bhima Red	56.66	9.93	116.33	1.69	0.93
17	Bhima Shewtha	58.86	9.46	114.00	1.54	0.81
18	Bhima Raj	57.90	9.66	119.33	1.57	0.91
19	Prema-178	60.73	9.93	105.33	1.46	0.84
20	Mahalaxmi	57.10	9.60	112.33	1.45	0.78
21	Prerana	60.73	10.20	113.00	1.46	0.84
22	Poona Pursangi	60.30	10.76	111.00	1.76	0.84
23	PKV-White	68.56	10.50	118.33	1.49	0.95
Mean		59.01	9.89	114.50	1.51	0.86
S.Em ±		2.12	0.41	1.39	0.12	0.10
C.D (5%)		6.04	1.17	3.96	0.36	0.31
C.D (1 %)		8.07	1.57	5.29	0.48	0.41

Shubra, Arka Bindu, Prema-178, Agrifound light red, Prerana, Poona pursangi, PKV-White and Light Red are having light green coloured leaves. Bhima Shakti and N-53 have yellowish green leaves. Arka Keerthiman and Agrifound dark red have dark green coloured leaves (Table 9).

4.3.1.4 Days to maturity

Days to maturity ranged from 103.00 days (Agrifound Dark Red) to 121.66 days (Arka Niketan) with a grand mean of 114.50 days. The estimates of phenotypic variance (29.01) and genotypic variance (23.20) were recorded. The estimates of GCV and PCV were low (4.20 % and 4.70 %, respectively). A high heritability (80%) coupled with low genetic advance as per cent over mean was observed for the character 7.75 per cent (Tables 4 and 5).

4.3.1.5 Collar thickness

The minimum collar thickness (1.16 cm) was recorded in Arka Bindu and it was maximum in Bhima Super (2.03 cm) with a grand mean of 1.51 cm. The estimates of GV (0.02) and PV (0.06) were recorded. The estimates of GCV and PCV were low to moderate (9.38 % and 17.24%, respectively). The heritability was low (29.6%) with a moderate genetic advance over per cent mean of 10.52 per cent (Tables 4 and 5).

4.3.1.6 Neck thickness

The minimum neck thickness (0.61cm) was recorded in Arka Bindu whereas Bhima Super showed the maximum neck thickness of 1.39 cm with a grand mean of 0.86 cm. The estimates of GV (0.02) and PV (0.05) were recorded. The estimates of GCV and PCV were moderate to high (16.46 % and 27.27%, respectively). The heritability was moderate (36.4%) with high genetic advance over per cent mean of 20.46 per cent (Tables 4 and 5).

4.3.2 Bulb parameters

4.3.2.1 Equatorial bulb diameter

Equatorial bulb diameter ranged from 4.60 cm (Arka Bindu) to 5.66 cm (Bhima Super). The grand mean observed was 5.13 cm. The estimates of phenotypic variance (0.13) and genotypic variance (0.05) were recorded. The estimates of GCV and PCV were low (4.74 % and 7.19 %, respectively). A moderate heritability (43.5%) coupled with a low genetic advance as per cent over mean was observed for the character 6.44 per cent (Tables 6 and 7).

4.3.2.2 Polar bulb diameter

Polar bulb diameter ranged from 3.85 cm (Arka Bindu) to 5.20 cm (Bhima Super) with a mean of 4.55 cm. The estimates of phenotypic variance and genotypic variance were (0.21 and 0.05, respectively). The estimates of GCV and PCV were low (5.17 % and 10.07 % respectively). A low heritability (26.4%) coupled with a low genetic advance as per cent over mean (5.46%) was observed for this trait (Tables 6 and 7).

4.3.2.3 Shape index

Shape index ranged from 0.65 (Arka Bindu) to 1.33 (Bhima Super) with a mean of 0.85. The estimates of phenotypic variance and genotypic variance were (0.04 and 0.01, respectively). The estimates of GCV and PCV were moderate to high (13.66 % and 25.61 % respectively). A low heritability was observed (28.4%) for this trait coupled with a moderate genetic advance as per cent over mean of 15.01 per cent (Tables 6 and 7).

4.3.2.4 Bolter bulbs

Bolting per cent ranged from 3.42 per cent (Bhima Super) to 5.96 per cent (Arka Kalyan) with a mean of 4.65 per cent. Phenotypic (1.08) and genotypic variance (0.40) were recorded for this trait. The estimates of GCV and PCV were moderate to high (13.59 % and 22.40 % respectively). Heritability was moderate (36.8%) coupled with a moderate GAM of 16.98 per cent (Tables 6 and 7).

4.3.2.5 A grade bulbs

A grade bulb per cent ranged from 5.81 per cent in Arka Bindu to 9.99 per cent in Bhima super with an overall mean of 7.50 per cent. Phenotypic and genotypic variances were 2.01 and 0.64, respectively. The estimates of GCV and PCV were moderate (10.68 % and 18.92 % respectively). Heritability was moderate (31.9 %) coupled with a moderate GAM of 12.41 per cent (Tables 6 and 7).

4.3.2.6 B grade bulbs

The per cent of B grade bulb ranged from 17.67 per cent (Arka Bindu) to 36.62 per cent (Bhima Super) with an overall mean of 27.75 per cent. Phenotypic (16.68) and genotypic variances (10.90) were recorded for this trait. The estimates of GCV and PCV were moderate (11.90 % and 14.71% respectively). Heritability was high (65.4%) coupled with a moderate GAM of 19.82 per cent (Tables 6 and 7).

4.3.2.7 C grade bulbs

C grade bulb per cent ranged from 34.14 per cent (Bhima Super) to 51.07 per cent (Arka Bindu). The grand mean for the trait was 41.95 per cent. The estimates of phenotypic variance (20.81) and genotypic variance (12.01) were recorded. The estimates of GCV and PCV were low to moderate (8.26 % and 10.87 % respectively). Heritability was moderate (57.7%) coupled with a moderate GAM of 12.93 per cent (Tables 6 and 7).

4.3.2.8 Less than C grade bulb

Less than C grade bulb per cent ranged from 8.77 per cent (Bhima Super) to 23.68 per cent (Arka Bindu). The grand mean observed was 15.95 per cent. The estimates of phenotypic variance (25.17) and genotypic variance (17.96) were recorded for this trait. The estimates of GCV and PCV were high (26.55 % and 31.44% respectively). The heritability was high (71.4%) coupled with a high GAM of 46.21 per cent (Tables 6 and 7).

Table 6. Estimates of genetic parameters for yield and quality traits in onion genotypes

Sl. No.	Character	Mean ± S. Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM (%)
A	**Bulb parameters**									
1	Polar bulb diameter (cm)	4.55 ±0.22	3.85-5.20	0.05	0.21	5.17	10.07	26.4	0.24	5.46
2	Equatorial bulb diameter (cm)	5.13 ±0.16	4.60-5.66	0.05	0.13	4.74	7.19	43.5	0.33	6.44
3	Shape index	0.85 ±0.10	0.65-1.33	0.01	0.04	13.66	25.61	28.4	0.12	15.01
4	A Grade bulbs (%)	7.50 ±0.67	5.81-9.99	0.64	2.01	10.68	18.92	31.9	0.93	12.41
5	B Grade bulbs (%)	27.75 ±1.38	17.67-36.62	10.90	16.68	11.90	14.71	65.4	5.50	19.82
6	C Grade bulbs (%)	41.95 ±1.71	34.14-51.07	12.01	20.81	8.26	10.87	57.7	5.42	12.93
7	Less than C grade bulb (%)	15.95 ±1.55	8.77-23.68	17.96	25.17	26.55	31.44	71.4	7.37	46.21
9	Bolter bulbs (%)	4.65±0.47	3.42-5.96	0.40	1.08	13.59	22.40	36.8	0.79	16.98
B	**Quality parameters**									
1	Double bulbs (%)	3.74±0.32	2.58-4.89	0.22	0.53	12.63	19.51	41.9	0.63	16.83
2	TSS (%)	11.17±0.85	8.35-13.55	0.99	3.17	8.94	15.94	31.5	1.15	10.34

DAT- Days After Transplanting
h^2- Broad sense heritability
PCV- Phenotypic Co-efficient of Variation
GCV- Genotypic Co-efficient of Variation
PV- Phenotypic Variance
GAM- Genetic Advance as Per cent of Mean
GV- Genotypic Variance
GA- Genetic Advance

Table 7. ***Per se*** **performance of onion genotypes for bulb parameters**

Cultivars	Pollar diameter (cm)	Equatorial diameter (cm)	Shape index	A grade bulb (%)	B grade bulbs (%)	C grade bulbs (%)	Bolter bulbs (%)	Less than C grade bulbs (%)
Agrifound Dark Red	4.53	5.66	0.86	6.34	25.58	46.77	3.91	17.95
Agrifound Light Red	4.63	5.54	0.67	6.02	28.67	37.27	5.51	18.37
Agrifound White	4.88	4.70	0.76	7.71	30.21	43.07	4.56	9.47
Staara Garva	4.83	5.33	1.21	7.99	29.43	39.90	3.90	15.00
Arka Bindu	3.85	4.60	0.65	5.81	17.67	51.07	5.38	23.68
Arka Kalyan	4.13	5.10	0.85	7.94	26.33	49.00	5.96	18.30
Arka Pragathi	4.76	4.96	0.83	7.20	26.79	40.29	3.66	14.46
Arka Niketan	4.35	5.22	0.90	6.27	28.76	46.66	5.60	19.55
Arka Kerthiman	4.63	4.96	0.88	7.53	28.62	37.52	4.46	16.93
N-53	4.90	4.83	0.86	8.20	28.45	42.49	4.83	21.52
Bhima Super	5.20	5.66	1.33	9.99	36.62	34.14	3.42	8.77
Light Red	4.66	5.27	0.79	7.83	26.54	39.48	3.51	21.63
Bhima Shubra	4.58	4.84	0.91	6.57	25.65	42.88	3.85	21.24
Bhima Shakthi	4.37	5.26	0.86	8.69	23.03	42.10	5.88	11.10
Bhima Kiran	4.63	5.48	0.78	9.13	26.76	45.05	5.87	17.46
Bhima Red	4.50	5.11	0.80	7.97	25.37	39.63	4.57	11.60
Bhima Shewtha	4.20	5.00	0.83	7.04	32.10	42.88	5.12	9.11
Bhima Raj	4.93	5.35	0.74	7.69	25.91	40.44	4.60	19.96
Prema-178	4.24	5.09	0.85	8.27	30.63	43.36	4.88	10.16
Mahalaxmi	4.80	5.13	0.71	5.83	30.19	39.67	4.31	11.88
Prerana	4.28	4.81	0.65	7.23	29.08	40.37	3.72	14.99
Poona Pursangi	4.05	4.90	0.98	7.49	30.04	40.57	4.55	19.23
PKV-White	4.80	5.10	0.85	7.73	25.75	40.28	4.92	14.60
Mean	4.55	5.13	0.85	7.50	27.75	41.95	4.65	15.95
S.Em ±	0.22	0.16	0.10	0.67	1.38	1.71	0.47	1.55
C.D (5%)	0.64	0.45	0.30	1.92	3.95	4.88	1.36	4.41
C.D (1 %)	0.86	0.61	0.40	2.57	5.28	6.52	1.82	5.90

4.3.3 Quality parameters

4.3.3.1 Total soluble solids

The TSS range observed was 8.35^{o} Brix (Mahalaxmi) to 13.55^{o} Brix (Arka Bindu) whereas, the grand mean observed was 11.17^{o} Brix. The phenotypic and genotypic variance (3.17 and 0.99, respectively), the estimates of GCV and PCV (8.94 % and 15.94 % respectively) low to moderate were recorded. The heritability was moderate (31.5%) with a moderate GAM of 10.34 per cent (Tables 6 and 8).

4.3.3.2 Double bulbs

Double bulbs per cent ranged from 2.58 per cent (Bhima Super) to 4.89 per cent (Agrifound light red). The grand mean observed was 3.74 per cent. Phenotypic variance (0.53) and genotypic variance (0.22) were recorded. The estimates of GCV and PCV were moderate (12.63 % and 19.51% respectively). Heritability was moderate (41.9%) coupled with moderate GAM 16.83 per cent (Tables 6 and 8).

4.3.3.3 Uniformity in bulb colour

The cultivars Agrifound Dark Red, Bhima Raj, Arka Kalyan and Arka Bindu have recorded the dark red bulb colour, while N-53, Bhima Red, Prema -178, Arka Pragati, Arka Keerthiman, Bhima Shakti, Bhima Super and Mahalakshmi have red coloured bulbs. However, the varieties like Arka Niketan, Agrifound Light Red, Poona Pursangi, Sataara Garva, Light Red, Prerana and Bhima Kiran have light red coloured bulbs. White bulb colour was observed in case of Agrifound White, Bhima Shubra, Bhima Shweta and PKV-White (Table 9).

4.3.3.4 Uniformity in bulb shape

Among the cultivars with respect to bulb shape, Bhima Super, Bhima Shakti, Bhima Red, Bhima Shweta, PKV-White, Mahalakshmi, Poona Pursangi, Prema-178, Sataara Garva and Light Red have recorded round shape, while cultivars Bhima Raj, Bhima Kiran, Bhima Shubra were oval to round in shape. The varieties like Arka Kalyan, Arka Niketan, Arka Pragati, Arka Keerthiman, Agrifound Dark Red, Agrifound

Table 8. ***Per se*** **performance of onion genotypes for yield and quality traits**

Cultivars	Total Yield (t/ha)	Marketable Yield (t/ha)	Average bulb weight (g)	Double bulbs (%)	TSS (%)
Agrifound Dark Red	25.41	23.46	75.66	4.02	11.00
Agrifound Light Red	23.71	19.53	87.33	4.89	11.45
Agrifound White	21.00	18.26	90.00	3.74	8.96
Staara Garva	25.21	22.01	86.66	2.92	9.75
Arka Bindu	16.36	14.06	53.66	4.24	13.55
Arka Kalyan	26.05	20.27	77.00	3.40	12.21
Arka Pragathi	21.15	20.52	81.00	3.75	10.71
Arka Niketan	23.93	21.40	70.66	3.58	11.56
Arka Kerthiman	22.57	19.73	85.66	3.00	12.66
N-53	23.71	18.47	89.00	3.81	11.60
Bhima Super	36.86	32.56	97.00	2.58	10.43
Light Red	23.03	19.75	94.66	3.16	12.31
Bhima Shubra	26.48	21.50	92.66	4.31	9.43
Bhima Shakthi	22.54	19.87	78.00	4.68	12.46
Bhima Kiran	26.00	23.33	76.00	3.26	12.28
Bhima Red	20.96	19.46	66.66	4.39	10.80
Bhima Shewtha	23.76	20.66	77.66	3.19	10.63
Bhima Raj	21.47	19.23	85.00	3.84	9.43
Prema-178	25.20	21.70	88.66	3.85	12.40
Mahalaxmi	26.66	20.38	85.33	3.66	8.35
Prerana	24.28	21.30	79.33	4.19	11.46
Poona Pursangi	25.40	22.23	96.00	3.55	11.66
PKV-White	21.33	19.86	82.00	4.01	11.76
Mean	24.05	20.85	82.42	3.74	11.17
S.Em ±	1.31	1.01	2.20	0.32	0.85
C.D (5%)	3.76	2.89	6.27	0.91	2.42
C.D (1 %)	5.02	3.86	8.38	1.22	3.24

Light Red, Agrifound White and N-53 were globular in shape. Further, varieties like Arka Bindu and Prerana are flatish globe in their shape (Table 9).

4.3.4 Yield parameters

4.3.4.1 Average bulb weight

Wide range was observed for bulb weight and it ranged from 53.66 g (Arka Bindu) to 97.00 g (Bhima Super) with a mean of 82.42 g. The phenotypic variance (111.63) and genotypic variance (97.09), as well as GCV and PCV were moderate (11.95 % and 12.81%, respectively). Heritability was high (87%) with high a GAM of 22.96 per cent (Tables 4 & 8).

4.3.4.2 Total yield

A relatively wide range of variation was observed for this character wherein maximum yield of 36.86 tons per hectare was recorded in Bhima Super and the yield was minimum in Arka Bindu (16.36 tons per hectare) with an overall mean of 24.05 tons per hectare. Phenotypic variance (16.98) and genotypic variances (11.76) were recorded. The estimates of GCV and PCV were moderate (14.26 % and 17.13%, respectively). The high estimates of heritability (69.2%) associated with a high GAM (24.44%) was observed (Tables 4 and 8) (Plate 2)

4.3.4.3 Marketable yield

This trait has exhibited a wide variation and the minimum yield was recorded in Arka Bindhu (14.06 tons per hectare) whereas maximum yield of 32.56 tons per hectare was noticed in Bhima Super with an overall mean of 20.85 tons per hectare. Phenotypic variance (12.28) and genotypic variances (9.19) were recorded. The estimates of GCV and PCV were moderate (14.53 % and 16.80 %, respectively). The high estimates of heritability (74.8%) associated with a high GAM (25.90%) was observed for this trait (Tables 4 and 8).

Table 9. Qualitative parameters in onion genotypes

Cultivars	Bulb Shape	Bulb Colour	Foliage Colour
Agrifound Dark Red	Globular	Dark Red	Dark Green
Agrifound Light Red	Globular	Light Red	Light Green
Agrifound White	Globular	White	Green
Staara Garva	Round	Light Red	Green
Arka Bindu	Flatish globe	Dark Red	Dark Green
Arka Kalyan	Globular	Dark Red	Green
Arka Pragathi	Globular	Red	Green
Arka Niketan	Globular	Red	Green
Arka Kerthiman	Globular	Red	Dark Green
N-53	Globular	Red	Yellow Green
Bhima Super	Round	Red	Green
Light Red	Round	Light Red	Light Green
Bhima Shubra	Oval-round	White	Light Green
Bhima Shakthi	Round	Red	Yellow Green
Bhima Kiran	Oval-round	Light Red	Green
Bhima Red	Round	Red	Green
Bhima Shewtha	Round	White	Light Green
Bhima Raj	Oval-round	Dark Red	Light Green
Prema-178	Round	Red	Light Green
Mahalaxmi	Round	Red	Green
Prerana	Flatish globe	Light Red	Light Green
Poona Pursangi	Round	Light Red	Light Green
PKV-White	Round	White	Light Green

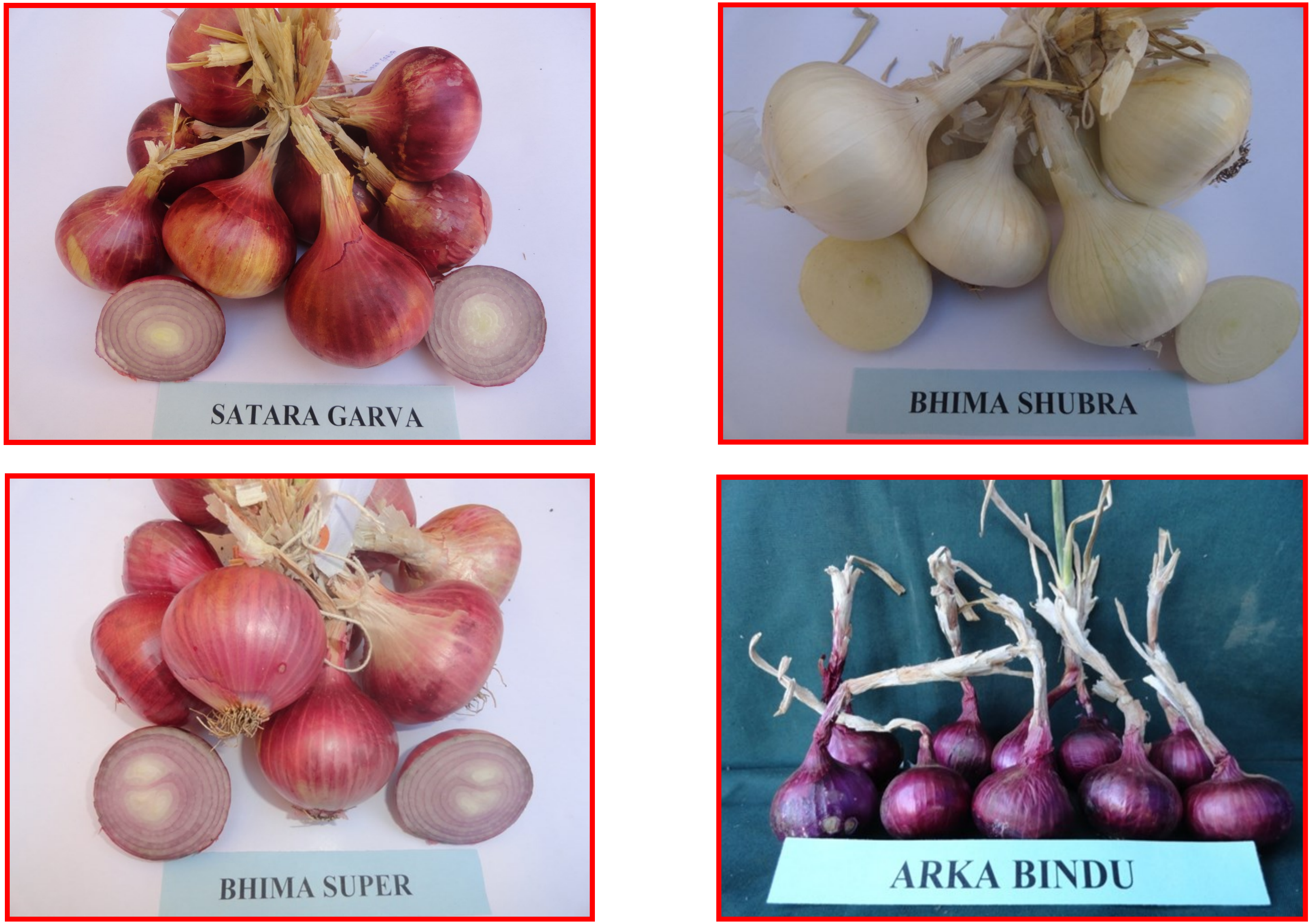
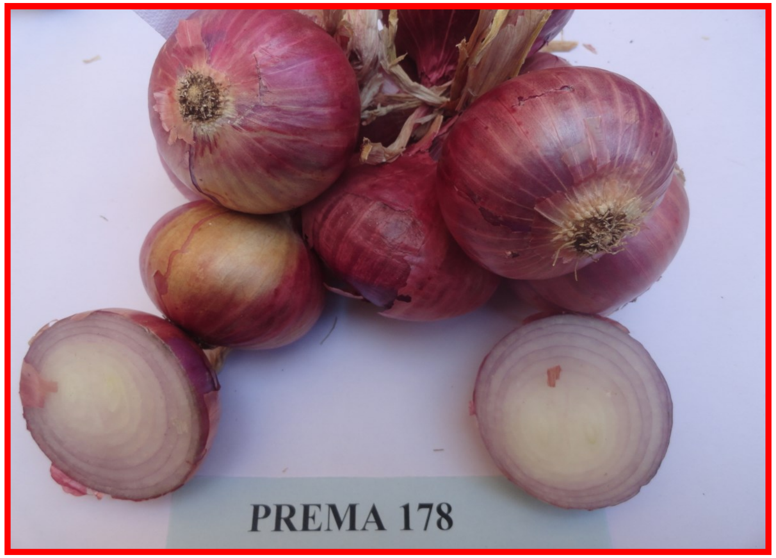


Plate 2. Promising onion varieties


POONA PURSANGI


MAHALAKSHMI


PREMA 178


AGRIFOUND DARK RED

4.3.5 Correlation studies

The phenotypic and genotypic correlation coefficients were determined to know the nature of relationship existing between yield and its component characters as well as the association among component characters themselves.

The degree of association of morphological, bulb character and quality characters with bulb yield and also among themselves at genotypic and phenotypic level are depicted in Tables 10 and 11.

4.3.5.1 Character association

The correlation co-efficient was determined to know the nature of relationship between yield and its component characters as well as the association between component characters themselves. The degree of association between morphological characters with bulb yield and bulb characters was studied.

4.3.5.2 Genotypic correlation coefficient

4.3.5.2.1 Correlation of bulb yield with other traits

Bulb yield was found to have highly significant and positive correlation with number of leaves at 90 days (0.847), collar thickness (0.408), polar diameter (0.658), equatorial diameter (0.705), neck thickness (0.648), shape index (0.885), per cent A grade bulbs (0.601), per cent B grade bulbs (0.776), per cent bolter bulbs (0.473), marketable yield (0.684) and average bulb weight (0.600) whereas it had highly significant and negative correlation with per cent C grade bulbs (-0.494), per cent less than C grade bulbs (-0.376) and also shown significant and negative correlation with TSS (-0.307).

4.3.5.2.2 Association among component traits

The genotypic correlation among the various component traits in 23 onion genotypes was worked out and presented in Table 10. Among different characters studied, Plant height at 90 DAT has exhibited highly significant and positive correlation with, per cent C grade bulbs (0.443), TSS (0.736) and also had positive significant association with per cent A grade bulbs (0.270), per cent bolter bulbs (0.242) and

Table 10. Estimates of genotypic correlation coefficients among growth, yield and quality parameters of onion

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	16	17
1	**1.000**	0.166	-0.382**	-0.564**	-0.368**	-0.012	0.007	0.270*	-0.464**	0.443**	0.242*	-0.420**	0.023	0.254*	-0.197	0.736**	0.196
2		**1.000**	0.448**	0.154	0.529**	0.031	0.478**	0.667**	0.730**	-0.512**	0.503**	0.184	-0.368**	0.754**	0.374**	0.226	0.847**
3			**1.000**	0.367**	0.352**	0.925**	0.774**	0.935**	0.392**	-0.380**	0.164	0.483**	-0.394**	0.709**	0.043	-0.229	0.408**
4				**1.000**	0.613**	0.665**	0.906**	0.586**	0.693**	-0.905**	0.114	0.134	-0.373**	0.583**	0.780**	-0.560**	0.658**
5					**1.000**	0.680**	0.103	0.471**	0.417**	-0.375**	0.466**	0.097	-0.168	0.785**	0.216	-0.167	0.705**
6						**1.000**	0.614**	0.647**	0.793**	-0.731**	0.106	-0.132	-0.321**	0.981**	0.581**	-0.168	0.885**
7							**1.000**	0.606**	0.764**	-0.586**	0.206	0.300*	-0.521**	0.659**	0.630**	-0.514**	0.648**
8								**1.000**	0.476**	-0.503**	0.639**	0.166	-0.526**	0.739**	0.451**	-0.019	0.601**
9									**1.000**	-0.692**	0.451**	-0.129	-0.625**	0.769**	0.743**	-0.493**	0.776**
10										**1.000**	0.001	-0.439**	0.477**	-0.523**	-0.738**	0.568**	-0.494**
11											**1.000**	0.229	-0.332**	0.398**	0.023	0.271*	0.473**
12												**1.000**	-0.328**	-0.078	-0.199	0.226	-0.124
13													**1.000**	-0.417**	-0.135	0.509**	-0.376**
14														**1.000**	0.485**	-0.289*	0.684**
15															**1.000**	-0.528**	0.600**
16																**1.000**	- 0.307*

Critical r_g value at 5% = 0.236 * Significant at p=0.05 Critical r_g value at 1% =0.308 **Significant at p=0.01

1. Plant height at 90 DAT (cm)
2.Number of leaves at 90DAT
3. Collar thickness (cm)
4. Polar diameter (cm)
5.Equatorial diameter (cm)
6. Shape index
7. Neck thickness (cm)
8. A grade bulbs (%)
9. B grade bulbs (%)
10. C grade bulbs (%)
11.Bolter bulbs (%)
12.Double bulbs (%)
13.Less than C grade bulbs (%)
14. Marketable yield (ton/ha)
15.Average bulb weight (g)
16. TSS (%)
17.Total yield (ton/ha)

Table 11. Estimates of phenotypic correlation coefficients among growth, yield and quality parameters of onion

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	16	17
1	**1.000**	0.068	-0.040	-0.070	-0.088	0.039	-0.099	0.100	-0.040	0.102	-0.008	-0.037	0.092	-0.033	-0.060	0.198	0.013
2		**1.000**	0.082	0.076	0.141	0.328 * *	0.232	0.268*	0.308**	0.006	0.270 *	0.182	-0.189	0.311**	0.225	-0.026	0.293*
3			**1.000**	0.089	0.153	0.114	0.114	0.170	0.137	-0.280*	-0.113	-0.013	-0.115	0.308**	0.080	0.045	0.270*
4				**1.000**	0.259*	0.190	0.220	0.236	0.214	-0.443**	-0.062	0.002	-0.106	0.249*	0.342**	-0.252*	0.136
5					**1.000**	0.151	0.057	0.144	0.095	-0.210	0.325 **	0.124	-0.083	0.388* *	0.112	-0.001	0.276*
6						**1.000**	0.240 *	0.233	0.310**	-0.047	0.179	0.008	-0.208	0.419* *	0.323 **	-0.167	0.329**
7							**1.000**	0.244*	0.297*	-0.332**	0.059	0.011	-0.253*	0.349* *	0.336**	-0.160	0.274*
8								**1.000**	0.242*	-0.190	0.258 *	0.140	-0.263*	0.336**	0.260*	0.229	0.300*
9									**1.000**	-0.447**	0.069	0.037	-0.448 * *	0.512* *	0.535**	-0.357 **	0.551**
10										**1.000**	0.062	-0.011	0.262*	-0.325* *	-0.531**	0.145	-0.261*
11											**1.000**	0.230	-0.227	0.234	-0.022	0.118	0.307*
12												**1.000**	-0.245*	-0.052	-0.166	0.023	-0.093
13													**1.000**	-0.352 **	-0.166	0.188	-0.224
14														**1.000**	0.382 **	-0.047	0.816**
15															**1.000**	-0.237 *	0.420**
16																1.000	-0.091

Critical r_p value at 5% =0.236 *Significant at p=0.05 Critical r_p value at 1% =0.308 **Significant at p=0.01

1. Plant height at 90 DAT (cm)
2.Number of leaves at 90DAT
3. Collar thickness (cm)
4. Polar diameter (cm)
5.Equatorial diameter (cm)
6. Shape index
7. Neck thickness (cm)
8. A grade bulbs (%)
9. B grade bulbs (%)
10. C grade bulbs (%)
11.Bolter bulbs (%)
12.Double bulbs (%)
13.Less than C grade bulbs (%)
14. Marketable yield (ton/ha)
15.Average bulb weight (g)
16. TSS (%)
17.Total yield (ton/ha)

marketable yield (0.254). Highly significant and negative correlation of this trait was found with collar thickness (-0.382), polar diameter (-0.564), equatorial diameter (-0.368), per cent B grade bulbs (-0.464), per cent double bulbs (-0.420).

Number of leaves at 90 days showed highly positive significant correlation with collar thickness (0.448), equatorial bulb diameter (0.529), neck thickness (0.478), per cent A grade bulbs (0.667), per cent B grade bulbs (0.730), per cent bolter bulbs (0.503), marketable yield (0.754) and average bulb weight (0.374) while there was a highly negative significant association of this trait with the per cent C grade bulbs (-0.512) and per cent less than C grade bulbs (-0.368).

Collar thickness showed highly significant and positive correlation with polar diameter (0.367), equatorial diameter (0.352), shape index (0.925), neck thickness (0.774), per cent A grade bulbs (0.935), per cent B grade bulbs (0.392), per cent double bulbs (0.483) and marketable yield (0.709) but it had a highly significant and negative correlation with per cent C grade bulbs (-0.380) and per cent less than C grade bulbs (-0.394).

Equatorial bulb diameter showed highly significant and positive association with Shape index (0.680), per cent A grade bulbs (0.471), per cent B grade bulbs (0.417), per cent bolter bulbs (0.466) and marketable yield (0.785) and but it showed a highly significant and negative correlation with per cent C grade bulbs (-0.375).

Polar bulb diameter showed highly significant and positive association with equatorial diameter (0.613), shape index (0.665), neck thickness (0.906), per cent A grade bulbs (0.586), per cent B grade bulbs (0.693), marketable yield (0.583) and average bulb weight (0.780) but it had a highly significant and negative correlation with per cent C grade bulbs (-0.905), per cent less than C grade bulbs (-0.373) and TSS (-0.980).

Shape index showed highly significant and positive association with neck thickness (0.614), per cent A grade bulbs (0.647), per cent B grade bulbs (0.793), marketable yield (0.981) and average bulb weight (0.581) but had a highly significant and negative correlation with per cent C grade bulbs (-0.731) and per cent less than C grade bulbs (-0.321).

Neck thickness showed highly significant and positive association with per cent A grade bulbs (0.606), per cent B grade bulbs (0.764), marketable yield (0.659) and average bulb weight (0.630) and also a significant and positive association with per cent double bulbs (0.300). However, this trait had a highly significant and negative correlation with per cent C grade bulb, (-0.586), per cent less than C grade bulbs (-0.521) and TSS (-0.514).

Per cent A grade bulbs showed highly significant and positive association with per cent B grade bulbs (0.476), per cent bolter bulbs (0.639), marketable yield (0.739) and average bulb weight (0.451) but there exists a highly significant and negative correlation of this trait with per cent C grade bulbs (-0.503) and per cent less than C grade bulbs (-0.526).

Per cent B grade bulbs showed highly significant and positive association with per cent bolter bulbs (0.451), marketable yield (0.769) and average bulb weight (0.743) while there exists a highly significant and negative correlation with per cent C grade bulbs (-0.692), per cent less than C grade bulbs (-0.625) and TSS (-0.493).

Per cent C grade bulbs showed highly significant and positive association with per cent less than C grade bulbs (0.477), TSS (0.568) and highly significant and negative correlation with per cent double bulbs (-0.439), marketable yield (-0.522) and average bulb weight (-0.738).

Per cent bolter bulbs showed highly significant and positive association with marketable yield (0.398) and significant and positive association with TSS (0.271) whereas highly significant and negative association with per cent less than C grade bulbs (-0.332).

Per cent double bulb showed highly significant and negative association with per cent less than C grade bulbs (-0.328). Per cent less than C grade bulbs showed highly significant and negative association with marketable yield (-0.417) and highly significant and positive association with TSS (0.509). Marketable yield showed highly significant and positive association with average bulb weight (0.485) but a significant and negative association with TSS (-0.289). Average bulb weight showed highly significant and negative association with TSS (-0.528) and the TSS showed significant and negative association with total yield (-0.307).

4.3.5.3 Phenotypic correlation

4.3.5.3.1 Correlation of bulb yield with other traits

Bulb yield was found to have a highly significant and positive correlation with shape index (0.329), per cent B grade bulbs (0.551), marketable yield (0.816) and average bulb weight (0.420) also a significant and positive correlation with number of leaves at 90 days (0.293), collar thickness (0.270), equatorial diameter (0.276), neck thickness (0.274), per cent A grade bulbs (0.300) and per cent bolter bulbs (0.307). However, there exists a significant and negative correlation with per cent C grade bulbs (-0.261).

4.3.5.3.2 Association among component traits

Phenotypic correlation coefficient for 17 component traits in onion genotypes was worked out and presented in the Table 11.

Among different growth parameters studied, Number of leaves at 90 days showed highly positive significant association with shape index (0.328), per cent B grade bulbs (0.308) and marketable yield (0.311) and also a positive significant relationship with per cent A grade bulbs (0.268) and per cent bolter bulbs (0.270). Collar thickness showed highly significant and positive correlation with marketable yield (0.308) but a significant and negative correlation with per cent C grade bulbs (-0.280).

Neck thickness showed highly significant and positive correlation with marketable yield (0.349) and average bulb weight (0.336) and also a significant and positive correlation with per cent B grade bulbs (0.297), per cent A grade bulbs (0.244) but a highly significant and negative correlation with per cent C grade bulbs (-0.332) and also a significant and negative correlation with per cent less than C grade bulbs (-0.253).

Among the various bulb and quality parameters studied, polar diameter showed highly significant and positive correlation with average bulb weight (0.342) and also a significant and positive correlation with equatorial diameter (0.259) and marketable yield (0.249) while it had a highly significant and negative correlation with per cent C grade bulbs (-0.443) and also a significant and negative correlation with TSS (-0.252). The equatorial diameter showed highly significant and positive correlation with per cent bolter bulbs (0.325) and marketable yield (0.388). Shape index showed highly significant and positive correlation with per cent B grade bulbs (0.310), marketable yield (0.419) and average bulb weight (0.323) whereas there was a significant and positive correlation of shape index with neck thickness (0.240).

Per cent A grade bulbs showed highly significant and positive correlation with marketable yield (0.336) and also a significant and positive correlation with per cent B grade bulbs (0.242), per cent bolter bulbs (0.258) and average bulb weight (0.260) but had a significant and negative correlation with per cent less than C grade bulbs (-0.263). The per cent B grade bulbs showed highly significant and positive correlation with marketable yield (0.512) and average bulb weight (0.535) but had a highly significant and negative correlation with per cent C grade bulbs (-0.447), per cent less than C grade bulbs (-0.448) and TSS (-0.357). However, the per cent C grade bulbs showed highly significant and negative correlation with marketable yield (-0.325) and average bulb weight (-0.531) but exhibited a significant and positive correlation with per cent less than C grade bulbs (0.262). Per cent double bulbs showed significant and negative correlation with per cent less than C grade bulbs (-0.245) and the trait *viz*., per cent less than C grade bulbs showed highly significant and negative correlation with marketable yield (-0.352). The marketable yield showed highly significant and positive correlation with average bulb weight (0.383) the average bulb weight which had a significant and negative correlation with TSS (-0.237).

4.3.6 Screening of onion genotypes for tolerance to purple blotch disease

A total of 23 onion cultivars were screened for tolerance to purple blotch disease in field under natural conditions in the Central Dry Zone of Karnataka during *Kharif* 2014-15. The genotypes were grouped as per the scale of Bhangale and Joi (1985) and data on per cent disease index (PDI) is presented in Table 12.

Among the genotypes tested, none of them were found to be resistant as there was no genotype to be categorised under moderately resistant, resistant or immune. However, three genotypes *viz*., Arka Kalyan, Bhima Shakti and Bhima Kiran were found moderately susceptible with a grade scale of 3. The per cent leaf area infection ranged from 21-40 per cent in these genotypes. Out of 23 genotypes, 16 (Agrifound Dark Red, Agrifound Light Red, Sataara Garva, Arka Bindu, Arka Pragati, Arka Niketan, Arka Keertiman, Bhima Super, Bhima Shubra, Bhima Red, Bhima Shweta, Bhima Raj, PKV-White, Prerana, Poona Pursangi and Mahalakshmi) were grouped under susceptible category having a grade scale of 4 with 41-60 per cent leaf area infection. Four cultivars *viz*., Agrifound white, N-53, Light Red and Prema -178 cultivars were categorized under a grade scale of 5 with a leaf area infection more than 61 per cent and hence were considered as highly susceptible.

Table 12. Screening of different cultivars of onion against purple blotch disease

Sl. No.	Cultivars	Plant Disease Index	Category of resistance
1	Agrifound Dark Red	51.33	S
2	Agrifound Light Red	50.00	S
3	Agrifound White	63.00	HS
4	Staara Garva	43.00	S
5	Arka Bindu	44.66	S
6	Arka Kalyan	30.00	MS
7	Arka Pragathi	42.33	S
8	Arka Niketan	52.33	S
9	Arka Kerthiman	42.66	S
10	N-53	66.33	HS
11	Bhima Super	43.00	S
12	Light Red	63.33	HS
13	Bhima Shubra	51.0	S
14	Bhima Shakthi	37.66	MS
15	Bhima Kiran	35.00	MS
16	Bhima Red	43.00	S
17	Bhima Shewtha	54.66	S
18	Bhima Raj	52.00	S
19	Prema-178	62.33	HS
20	Mahalaxmi	47.33	S
21	Prerana	47.00	S
22	Poona Pursangi	50.00	S
23	PKV-White	55.33	S

Scale: 0 = (I) Immune
1 = (R) Resistant (1-10%)
2 = (MR) Moderately resistant (11-20%)
3 = (MS) Moderately susceptible (21-40%)
4 = (S) Susceptible (41-60%)
5 = (HS) Highly susceptible (61% and Above).

DISCUSSION

V. DISCUSSION

Onion (*Allium cepa* L.) is the most important species of the *Allium* group and belongs to the family Alliaceae and it can be regarded as the single most important vegetable species in the World after tomatoes. India has the largest area in the World, but productivity is very low when compared to major onion growing countries. Systematic breeding work is very much lacking in onion, even though, some of the institutes like, Directorate of Onion and Garlic Research (DOGR) Rajguru Nagar, Pune, Indian Institute of Horticultural Research, Bengaluru and National Horticultural Research and Development Foundation, Nasik and some State Agricultural and Horticultural Universities have released some varieties. However, the systematic crop improvement work is still inadequate in onion when compared to other commercial vegetables. This important vegetable received less attention in earlier days because of its biennial nature and minute flower with high inbreeding depression.

For systematic improvement of any crop, information on genetic variability is very much essential and forms the basis for breeding programme. In onion, some important reports are available on this aspect (Patil, 1997; Mohanty, 2001; Dhotre, 2009; Ananthan and Moorthy, 2007; Hosamani *et al.*, 2010; Singh and Dubey, 2011; Ram *et al.*, 2011). In Karnataka, onion is grown in an area of 159.60 (Thousand hectares) and majority of the area is covered with local cultivars or varieties which are maintained by farmers themselves since many decades. Due to the continuous cultivation of the same varieties or cultivars and poor attention towards the genetic purity, they are losing their potentiality and becoming susceptible to many pests and diseases. Hence, to initiate an improvement work, present investigation was carried out at ZAHRS, Hiriyur by using twenty three genotypes of onion collected from different sources and were screened to assess the nature and magnitude of genetic variability for morphological, yield and quality parameters as well as tolerance to purple blotch incidence in onion.

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

5.1 Exploration and collection of onion germplasm

In an attempt to study the genetic variability for various growth and yield parameters as well as for purple blotch incidence, onion germplasm including improved cultivated varieties, local cultivars and other germplasm lines were collected from various sources across India. In order to collect the onion germplasm for the present investigation, an exploration was under taken to visit various research stations in Karnataka and Maharashtra as well as onion growing areas in Chitradurga district. Seven genotypes *viz*., Bhima Super, Bhima Shubra, Bhima Shakti, Bhima Kiran, Bhima Red, Bhima Shweta and Bhima Raj were collected from Directorate of Onion and Garlic Research (DOGR), Pune. Five genotypes *viz*., Arka Bindu, Arka Kalyan, Arka Pragati, Arka Niketan and Arka Keerthiman were collected from Indian Institute of Horticulture Research (IIHR), Hesaraghatta, Bengaluru. The National Horticultural Research and Development Foundation (NHRDF), Nasik, Maharashtra has contributed 4 genotypes *viz*., Agrifound Dark Red, Agrifound Light Red, Agrifound White and Light Red. Further, Mahathma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra has contributed two genotypes like N-53 and PKV-White. In addition, three local cultivars consisting of 2 genotypes from Maharashtra (Sataara Garva and Poona Pursangi) and one local collection from Chitradurga, Karnataka *viz*., Molakalmur local were collected and included in the present study. Two genotype from private seed company *viz*., East West seeds Pvt. Ltd (Prema-178 and Prerana) was also used in the present investigation for assessing the genetic variability for various growth, yield and quality parameters as well as tolerance to purple blotch incidence. In total, we used 23 genotypes which include both improved varieties and local cultivars.

5.2 Genetic variability for growth and yield parameters

Totally 23 genotypes were evaluated to know the amount of variability for growth and yield parameters. The analysis of variance indicated highly significant differences among genotypes for all the studied characters *viz.,* plant height, number of leaves per plant, days to maturity, polar diameter (cm), equatorial diameter (cm), shape index, collar thickness (cm), neck thickness (cm), per cent bolter bulbs, per cent A grade bulbs, per cent B grade bulbs, per cent C grade bulbs, per cent less than C grade bulbs, total yield (t/ha), marketable yield (t/ha), average bulb weight (g/plant), TSS of bulb (%), per cent double bulbs and also purple blotch intensity (%)**.** This indicates that, high variability existed for the characters studied and considerable improvement could be achieved in most of the characters by selection. However, the analysis of variance by itself is not enough and conclusive to explain all the inherent genotypic variance in the genotypes.

One of the way by which the variability present in these characters were assessed through a simple approach of examining the range of variation. Range of variation observed for all the traits in the present study indicated the presence of sufficient amount of variation among the genotypes for all the characters studied. The range in the values reflects the amount of phenotypic variability, which is not reliable, since it includes genotypic, environmental and genotype × environment interaction components and does not reveal as to which character is showing higher degree of variability. Further, the phenotype of crop is influenced by additive gene effect (heritable fixable), dominance (heritable non-fixable) and epistasis (non-allelic interaction). Hence, it becomes necessary to split the observed variability into phenotypic coefficient of variation and genotypic coefficient of variation, which ultimately indicate the extent of variability existing for various traits. However, even this does not give a true picture about the extent of inheritance of the character. Therefore, the heritability of a character can be relied upon, as it enables the plant breeder to decide the extent of selection pressure to be applied under a particular environment, which separates the environmental influence from the total variability. Nevertheless, its use would be limited as this is prone to change with the environment, material, *etc.*

The estimation of heritability has a greater role to play in determining the effectiveness of selection of a character provided it is considered in conjunction with the predicted genetic advance as suggested by Johnson and Robinson (1955). Heritability is influenced by biometrical method, generation of hybrid, sample size of experimental material and environment. With these, the results of the present investigation on various parameters are discussed in this chapter.

In the present investigation high GCV and PCV were observed for per cent less than C grade bulbs (Fig. 3). This characters recorded higher range of variation and have better scope of improvement through selection. High estimates of GCV and PCV for per cent less than C grade bulbs are in agreement with earlier reports of Trivedi and Dhumal (2010).

Moderate GCV and PCV were observed for, per cent A grade bulbs, per cent B grade bulbs, per cent double bulbs, total yield, marketable yield and average bulb weight (Fig. 2 & 3) indicating moderate amount of variability. Moderate estimates of GCV and PCV for per cent double bulbs are in agreement with earlier reports of Yadav *et al.* (2009) and Khar *et al.* (2007)**.** Moderate estimates of GCV and PCV for total yield were also earlier reported by Singh *et al*. (2010), Mushtaq *et al*. (2013) and Tripathy *et al*. (2013). Chattopadhyay *et al*. (2013), Singh *et al*. (2012), Singh and Dubey (2011) and Singh *et al*. (2010) reported moderate estimates of GCV and PCV for marketable yield**.** Moderate estimates of GCV and PCV observed for average bulb weight in the present study has similarity with the reports of Bharti *et al*. (2011). The moderate estimates of GCV and PCV of these traits indicates more possibility of improving these characters by selection.

Lower estimate of GCV and PCV were observed for, number of leaves at 90 DAT, plant height at 90 DAT, equatorial diameter, polar diameter and days to maturity. Lower estimates of GCV and PCV for number of leaves is in agreement with earlier reports of Rashid *et al*. (2012), Singh *et al*. (2010), Singh and Dubey (2011), Ram *et al.* (2011). Golani *et al*. (2006), Dhotre (2009), Singh and Dubey (2011) reported lower estimates of GCV and PCV for plant height**.** lower estimates of GCV and PCV observed equatorial diameter is in agreement with earlier reports of Dhotre (2009), Singh and Dubey (2011), Ram *et al*. (2011). Dhotre (2009), Singh and Dubey (2011), Ram *et al*. (2011) reported lower estimates of GCV and PCV for polar diameter. Lower estimates of GCV and PCV for days to maturity is in agreement with earlier reports of Patil (1997),

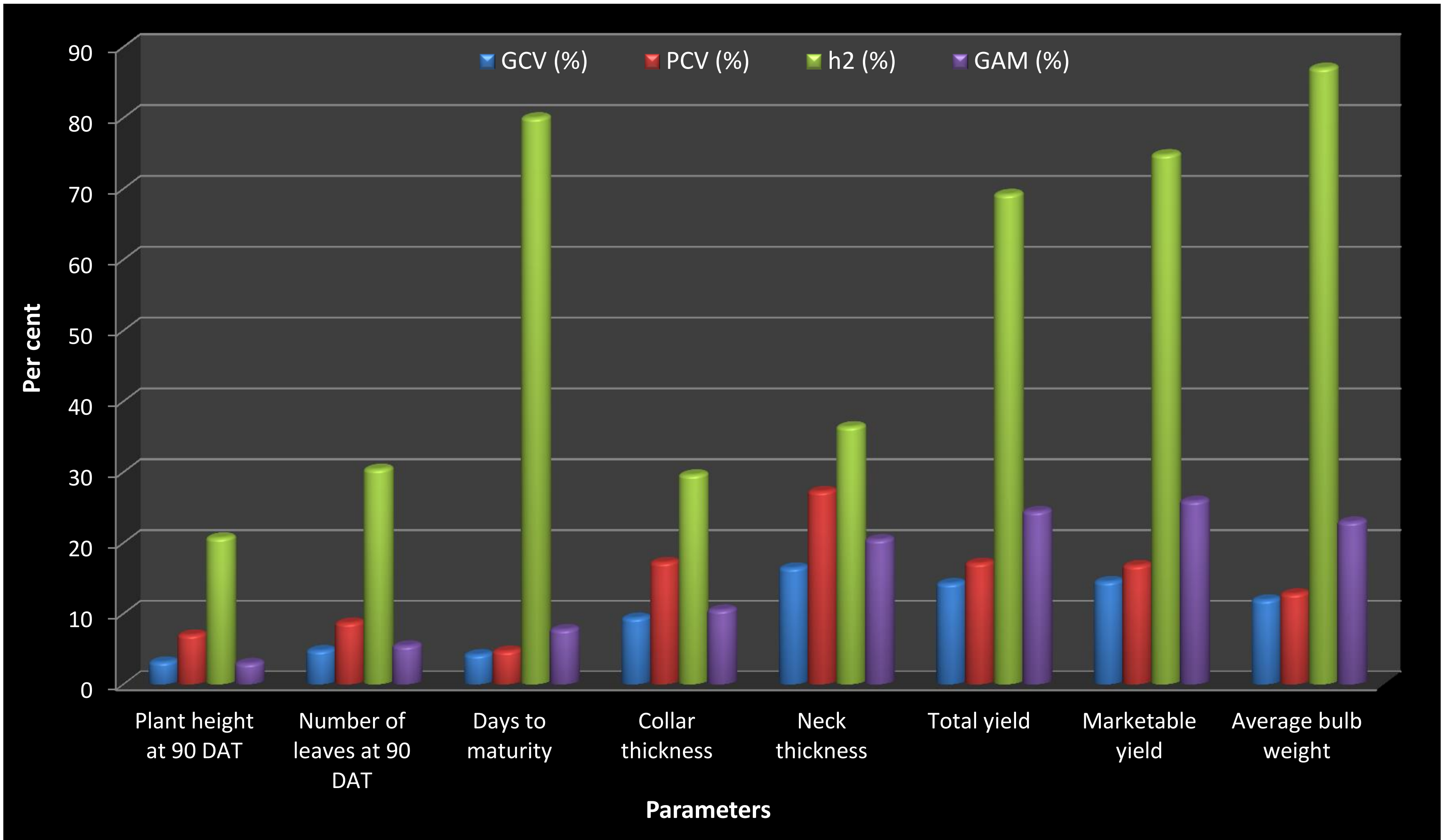


Fig. 2. GCV, PCV, Heritability and Genetic advance over per cent mean for growth and yield parameters in onion genotypes

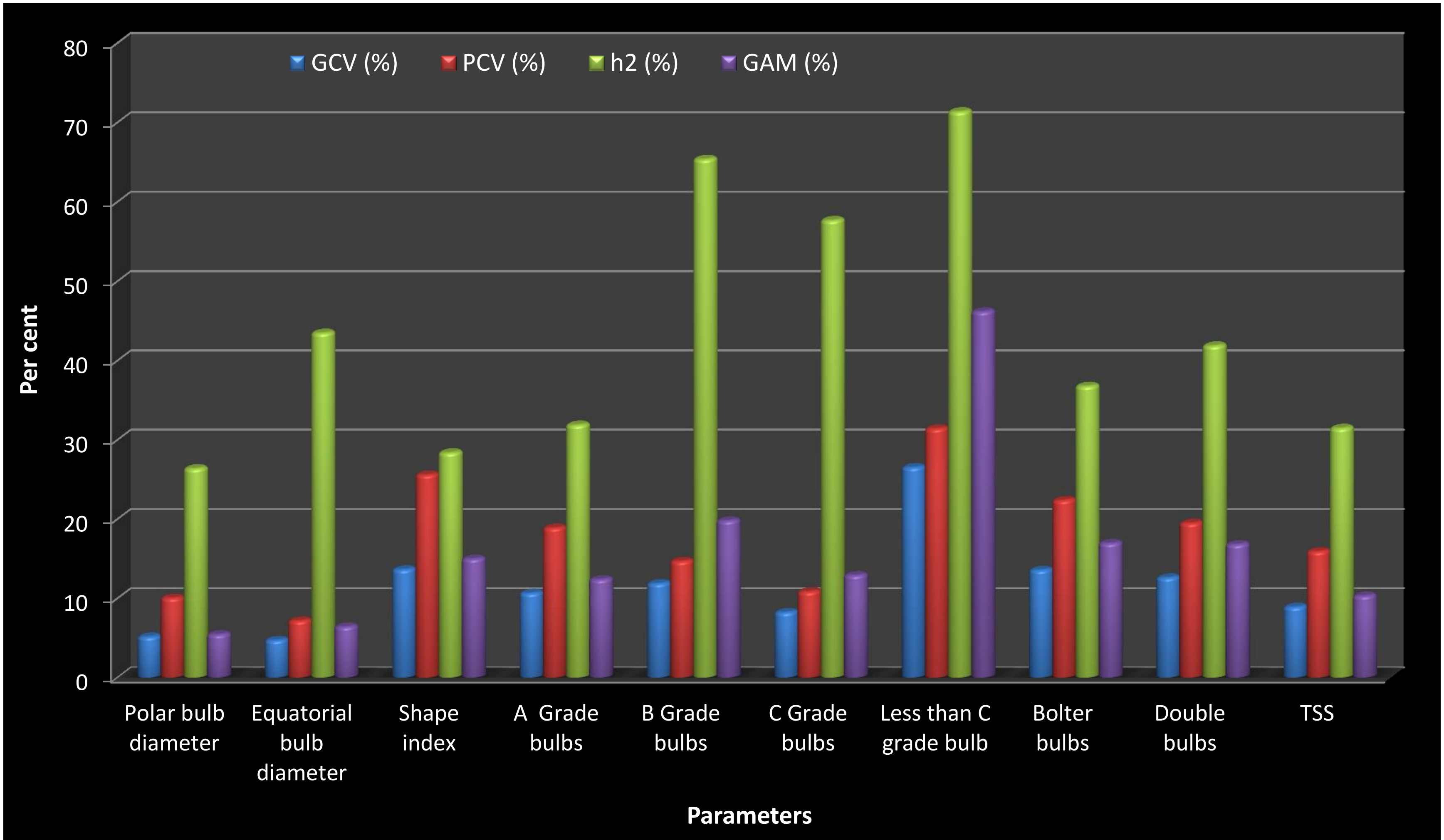


Fig. 3. GCV, PCV, Heritability and Genetic advance over per cent mean for yield and quality traits in onion genotypes

Sendek *et al*. (2008) and Dhotre (2009). Lower GCV and PCV for these traits provide evidence of low variability. Hence, the variability has to be generated through introduction and hybridizing diversified genotypes to generate transgressive segregants.

Moderate GCV and higher PCV were observed for shape index, neck thickness and per cent bolter bulbs. Moderate estimates of GCV and higher PCV for neck thickness is in agreement with earlier reports of Patil (1997), Hosamani *et al*. (2010), Ananthan and Moorthy (2007). Ibrahim *et al.* (2013) reported Moderate GCV and higher PCV were observed for per cent bolter bulbs.

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

In the present study, high heritability coupled with high genetic advance as per cent over mean was recorded for the characters *viz.*, per cent less than C grade bulbs, total yield, marketable yield and average bulb weight (Fig. 2 & 3). Therefore, additive component is predominant here. Thus, there is ample scope for improving these characters through direct selection. Trivedi and Dhumal (2010) reported high heritability and high GAM for per cent less than C grade bulb. Singh *et al*. (2010), Singh *et al*. (2012) reported high heritability and high GAM for total yield as observed in the present study. Sendek *et al.* (2008), Singh *et al*. (2010), Singh and Dubey (2011), Singh *et al*. (2012) and Chattopadhyay *et al*. (2013), reported high heritability and high GAM for marketable yield. High heritability with high GAM for average bulb weight is in accordance with the findings of Dhotre (2009), Hosamani *et al*. (2010), Mohanty (2001).

Moderate heritability with moderate GAM was observed for per cent A grade bulbs, per cent C grade bulbs, per cent bolter bulbs and per cent double bulbs as depicted in (Fig. 3). This indicates the importance of additive effects for this trait and there can be better response to selection. Patil (1997), Ibrahim *et al.* (2013) reported moderate heritability with moderate GAM for per cent bolter bulbs. Yadav *et al.* (2009) reported moderate heritability with moderate GAM for per cent double bulbs as observed in the present study. Ahmed and Sharma (2014) reported moderate heritability with moderate GAM for per cent A grade bulbs.

Moderate heritability with low GAM was observed for, number of leaves 90 DAT and equatorial diameter. Singh *et al*. (2010), Singh and Dubey (2011) reported Moderate heritability with low GAM was observed for number of leaves. Ram *et al*. (2011) and Mohanty (2001) reported Moderate heritability with low GAM was observed for equatorial diameter.

5.3 Genetic variability for qualitative traits

5.3.1 Foliage colour

Among the cultivars *viz*., Bhima Super, Bhima Red, Bhima Kiran, Arka Kalyan, Arka Niketan, Arka Pragati, Agrifound White, Mahalakshmi and Sataara Garva had green coloured leaves. Bhima Shweta, Bhima Raj, Bhima Shubra, Arka Bindu, Prema-178, Agrifound light red, Prerana, Poona pursangi, PKV-White and Light Red are having light green coloured leaves. However, Bhima Shakti and N-53 are having yellowish green leaves. The genotypes – Arka keerthiman and Agrifound dark red are having dark green colored leaves. These findings are in agreement with that of Brown (2013) and Jelica *et al*. (2013).

5.3.2 Uniformity in Bulb colour

Among the cultivars *viz*., Agrifound Dark Red, Bhima Raj, Arka Kalyan and Arka Bindu are having dark red coloured bulbs whereas N-53, Bhima Red, Prema -178, Arka Pragati, Arka Keerthiman, Bhima Shakti, Bhima Super and Mahalakshmi were red in colour. The cultivars *viz*., Arka Niketan, Agrifound Light Red, Poona Pursangi, Sataara Garva, Light Red, Prerana and Bhima Kiran possess light red coloured bulbs. Agrifound White, Bhima Shubra, Bhima Shweta and PKV-White registered white bulb skin colour. These findings are in agreement with that of Mallor *et al.,* (2011) and Yadav *et al.* (2009)

5.3.3 Uniformity in Bulb shape

Among the cultivars *viz*., Bhima Super, Bhima Shakti, Bhima Red, Bhima Shweta, PKV-White, Mahalakshmi, Poona Pursangi, Prema-178, Sataara Garva and Light Red have round shaped bulbs while, Bhima Raj, Bhima Kiran and Bhima Shubra have oval to round shaped bulbs. The bulbs of Arka Kalyan, Arka Niketan, Arka Pragati, Arka Keerthiman, Agrifound Dark Red, Agrifound Light Red, Agrifound White and N-53 were globular in shape. Arka Bindu and Prerana have flatish globe shaped bulbs. These findings are in agreement with that of (Mallor *et al.,* 2011).

5.4 Correlation studies

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

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

In the present study it was observed that the genotypic correlation coefficient was more than the phenotypic correlation indicating the presence of inherent association between various traits.

5.4.1 Genotypic correlation coefficient

The genotypic correlation among the various component traits in 23 onion genotypes was worked out and discussed here.

Bulb yield was found to have highly significant and positive correlation with, number of leaves at 90 DAT, collar thickness, polar diameter, equatorial diameter, neck thickness, shape index, per cent A grade bulbs, per cent B grade bulbs, per cent bolter bulbs, marketable yield and average bulb weight whereas it had highly significant and negative correlation with per cent C grade bulbs, per cent less than C grade bulbs and also shown significant and negative correlation with TSS. Similar results were reported by Vidyasagar and Monika (1993) and Mohanty (2004).

Plant height at 90 DAT has exhibited highly significant and positive correlation with, per cent C grade bulbs, TSS and also had positive significant association with per cent A grade bulbs, per cent bolter bulbs and marketable yield. Highly significant and negative correlation of this trait was found with collar thickness, polar diameter, equatorial diameter, per cent B grade bulbs, per cent double bulbs is in line with the findings of Ananthan and Moorthy (2007).

Number of leaves at 90 days showed highly positive significant correlation with collar thickness, equatorial bulb diameter, neck thickness, per cent A grade bulbs, per cent B grade bulbs, per cent bolter bulbs, marketable yield and average bulb weight while there was a highly negative significant association of this trait with the per cent C grade bulbs and per cent less than C grade bulbs was in accordance with the findings of Mohanty (2004).

Collar thickness showed highly significant and positive correlation with polar diameter, equatorial diameter, shape index, neck thickness, per cent A grade bulbs, per cent B grade bulbs, per cent double bulbs and marketable yield but it had a highly significant and negative correlation with per cent C grade bulbs and per cent less than C grade bulbs has a similarity with the results earlier published by Bharti *et al*. (2011).

Equatorial bulb diameter showed highly significant and positive association with shape index, per cent A grade bulbs, per cent B grade bulbs, per cent bolter bulbs and marketable yield and but it showed a highly significant and negative correlation with per cent C grade bulbs which are in line with the findings of Netrapal *et al*. (1988).

Polar bulb diameter showed highly significant and positive association with equatorial diameter, shape index, neck thickness, per cent A grade bulb, per cent B grade bulb, marketable yield, average bulb weight and highly significant and negative correlation with per cent C grade bulb, per cent less than C grade bulb, TSS which are in line with the findings of (Mohanty, 2002).

Shape index showed highly significant and positive association with neck thickness, per cent A grade bulbs, per cent B grade bulbs, marketable yield and average bulb weight but had a highly significant and negative correlation with per cent C grade bulbs and per cent less than C grade bulbs.

Neck thickness showed highly significant and positive association with per cent A grade bulbs, per cent B grade bulbs, marketable yield and average bulb weight and also a significant and positive association with per cent double bulbs. However, this trait had a highly significant and negative correlation with per cent C grade bulb, per cent less than C grade bulbs and TSS. Similar result was recorded by Bharti *et al*. (2011).

Per cent A grade bulbs showed highly significant and positive association with per cent B grade bulbs, per cent bolter bulbs, marketable yield and average bulb weight but there exists a highly significant and negative correlation of this trait with per cent C grade bulbs and per cent less than C grade bulbs which are in line with the findings of Trivedi and Dhumal (2010).

Per cent B grade bulbs showed highly significant and positive association with per cent bolter bulbs, marketable yield and average bulb weight while there exists a highly significant and negative correlation with per cent C grade bulbs, per cent less than C grade bulbs and TSS which are in line with the findings of Trivedi and Dhumal (2010).

Per cent C grade bulbs showed highly significant and positive association with per cent less than C grade bulbs, TSS and highly significant and negative correlation with per cent double bulbs, marketable yield and average bulb weight. Per cent bolter bulbs showed highly significant and positive association with marketable yield and significant and positive association with TSS whereas highly significant and negative association with per cent less than C grade bulbs.

Per cent double bulb showed highly significant and negative association with per cent less than C grade bulbs. Per cent less than C grade bulbs showed highly significant and negative association with marketable yield and highly significant and positive association with TSS which are in line with the findings of Dhotre (2009). Marketable yield showed highly significant and positive association with average bulb weight but a significant and negative association with TSS. Similar result was recorded by Hosamani *et al*. (2010). Average bulb weight showed highly significant and negative association with TSS Similar result was recorded by Hosamani *et al*. (2010) and the TSS showed significant and negative association with total yield.

5.4.2 Phenotypic correlation

Phenotypic correlation coefficient for 17 characters was worked out among 23 onion genotypes was worked out discussed here.

Bulb yield was found to have a highly significant and positive correlation with shape index, per cent B grade bulbs, marketable yield and average bulb weight whereas significant and positive correlation with, number of leaves at 90 days, collar thickness, equatorial diameter, neck thickness, per cent bolter bulbs, per cent A grade bulbs. However, there exists a significant and negative correlation with per cent C grade bulbs.

These results are in conformity with that of Vidyasagar and Monika (1993) and Mohanty (2004).

Among different growth parameters studied, number of leaves at 90 days showed highly positive significant association with shape index, per cent B grade bulbs and marketable yield and also a positive significant relationship with per cent A grade bulbs and per cent bolter bulbs, Such results were earlier reported in the findings of Aliyu *et al*. (2007) and Netrapal *et al*. (1988).

Collar thickness showed highly significant and positive correlation with marketable yield but a significant and negative correlation with per cent C grade bulbs as noticed by Bharti *et al*. (2011).

Neck thickness showed highly significant and positive correlation with marketable yield and average bulb weight and also a significant and positive correlation with per cent B grade bulbs, per cent A grade bulbs but a highly significant and negative correlation with per cent C grade bulbs and also a significant and negative correlation with per cent less than C grade bulbs, Similar trend was observed by Bharti *et al*. (2011).

Among the various bulb and quality parameters studied, polar diameter showed highly significant and positive correlation with average bulb weight and also a significant and positive correlation with equatorial diameter and marketable yield while it had a highly significant and negative correlation with per cent C grade bulbs and also a significant and negative correlation with TSS. Mohanty (2002) and Bharti *et al*. (2011) also observed similar findings in their study.

The equatorial diameter showed highly significant and positive correlation with per cent bolter bulbs and marketable yield. Shape index showed highly significant and positive correlation with per cent B grade bulbs, marketable yield and average bulb weight whereas there was a significant and positive correlation of shape index with neck thickness. These findings are in agreement with the results of Bharti *et al*. (2011) and Netrapal *et al*. (1988).

Per cent A grade bulbs showed highly significant and positive correlation with marketable yield and also a significant and positive correlation with per cent B grade bulbs, per cent bolter bulbs and average bulb weight. These results are similar to that of Trivedi and Dhamul (2010).

The per cent B grade bulbs showed highly significant and positive correlation with marketable yield and average bulb weight but had a highly significant and negative correlation with per cent C grade bulbs, per cent less than C grade bulbs and TSS. Similar results were observed in the studies of Trivedi and Dhumal (2010).

However, the per cent C grade bulbs showed highly significant and negative correlation with marketable yield and average bulb weight but exhibited a significant and positive correlation with per cent less than C grade bulbs. Per cent double bulbs showed significant and negative correlation with per cent less than C grade bulbs and the trait *viz*., per cent less than C grade bulbs showed highly significant and negative correlation with marketable yield. The marketable yield showed highly significant and positive correlation with average bulb weight which had a significant and negative correlation with TSS. Hosamani *et al*. (2010) also reported such findings in their study.

5.5 Field screening of onion cultivars for purple blotch disease

A total of twenty three cultivars of onion were screened in field for purple blotch disease (*Alternaria porri*) incidence under natural condition in Central Dry Zone of Karnataka during *Kharif* 2014-15. The genotypes were grouped as per the scale of Bhangale and Joi (1985) and data is presented in (Fig. 4).

Among the treatments none of them were found moderately resistant, resistant or immune. However, three genotypes *viz*., Arka Kalyan, Bhima Shakti and Bhima Kiran were found to be moderately susceptible with grade scale of 3. The per cent leaf area infection ranged from 21-40 per cent in these cultivars. Sixteen cultivars were found to be susceptible with a grade scale of 4 recording 41-60 per cent leaf area infection. The susceptible cultivars include Agrifound Dark Red, Agrifound Light Red, Satara Garva, Arka Bindu, Arka Pragati, Arka Niketan, Arka Keertiman, Bhima Super, Bhima Shubra,

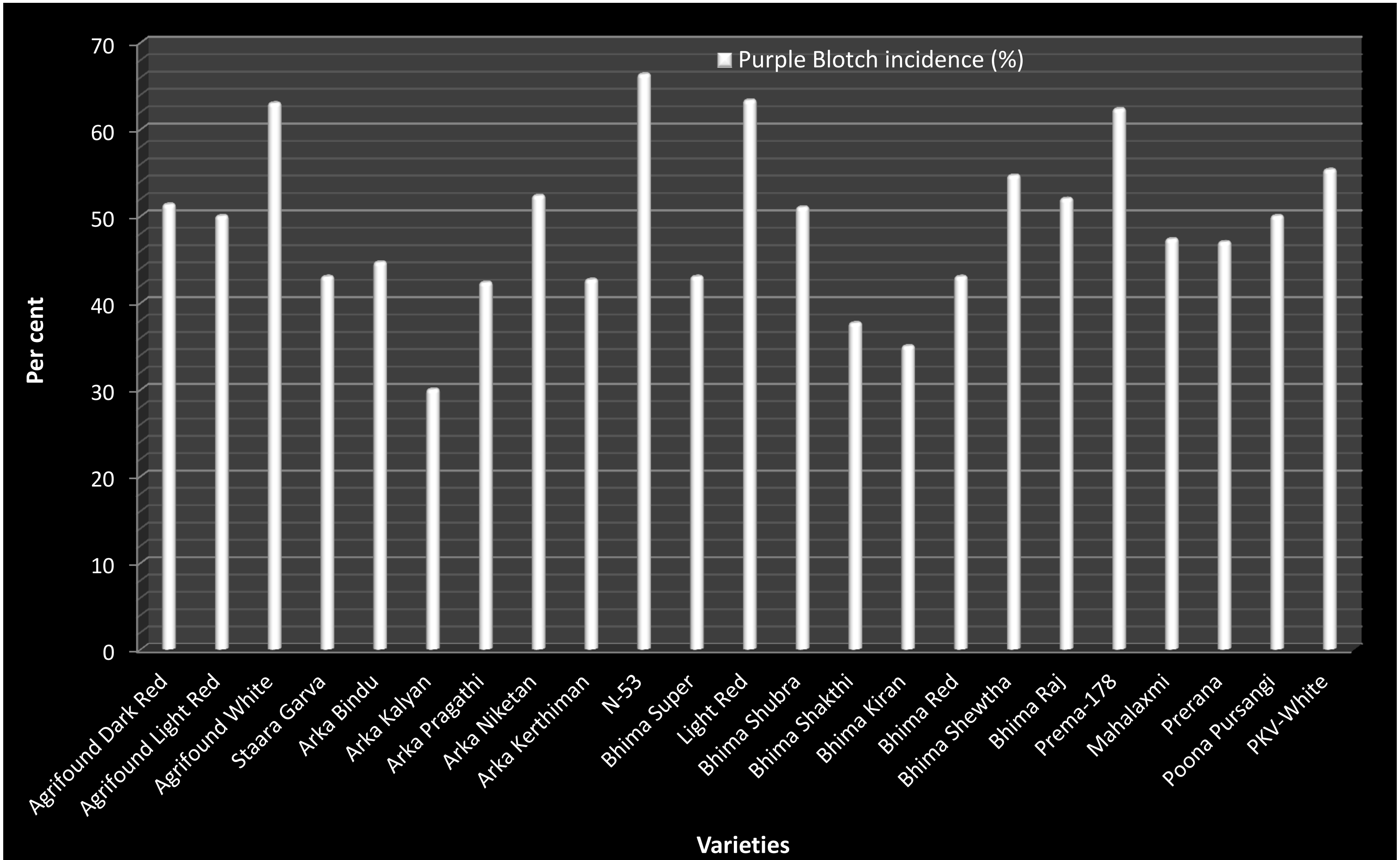


Fig. 4. Purple blotch incidence in onion genotypes (%)

Plate 3. Moderately susceptible onion varieties against purple blotch incidence

Plate. 4 Variability in bulb shape, size and colour of the onion genotypes

Bhima Red, Bhima Shweta, Bhima Raj, PKV-White, Prerana, Poona Pusangi and Mahalakshmi which have recorded 41-60 per cent leaf area infection. Four cultivars with highly susceptible reaction are N-53, Light Red, Prema -178 and Agrifound White which have recorded more than 61 per cent leaf area infection. Similar findings were reported by Sandhu *et al.* (1981), Dhiman *et al.* (1986), Pathak *et al.* (1986) as well as Upmanyu and Sharma (2007).

Salient features of investigation

- ❖ Based on the results of the study it is concluded that among all the cultivars Bhima Super, Bhima Shubra, Bhima Kiran, Arka Kalyan and Sataara Garva proved to be superior considering the yield characteristics for cultivation under Central Dry Zone of Karnataka.
- ❖ For quality aspects like total soluble solids cultivar Arka Bindu found to be the best among all the cultivars, hence can be better utilized for dehydration and processing purpose.
- ❖ The cultivars Arka Kalyan, Bhima Shakti and Bhima Kiran were found to be moderately susceptible to purple blotch hence these cultivars can recommended for commercial cultivation in purple blotch disease prone areas.

Future line of work

1 The cultivars with best quality parameters are needed to be utilized for processing and dehydration studies.

2 While breeding for high bulb yield, thrust could be given to the characters like, average bulb weight, bulb dimensions (equatorial and polar bulb diameter), TSS and neck thickness should be given more attention.

3 There is absolute need to screen a large germplasm collection to identify the stable resistant source for purple blotch diseases and to utilize them in the purple blotch resistance breeding programme.

SUMMARY

VI. SUMMARY

An investigation was undertaken during 2014-15 at Zonal Agricultural and Horticultural Research Station Hiriyur, coming under the jurisdiction of the University of Agricultural and Horticultural Sciences, Shivamogga to study the genetic variability in twenty three onion genotypes. The experimental data was subjected to statistical analysis for elucidating the information on genetic variation existing for different components of growth and yield. The genetic variability was assessed using the parameters like genotypic variance (GV) and phenotypic variance (PV), genotypic co-efficient of variation (GCV) and phenotypic coefficient of variation (PCV), heritability and genetic advance over mean (GAM). Correlation analysis was also carried out to know the relationship among various growth and yield components. The experimental results of the present study are summarized below.

The analysis of variance revealed significant difference among the genotypes for all the traits under study. High genotypic and phenotypic co-efficient of variation was recorded for per cent less than C grade bulb indicating the existence of high variability among the germplasm, which would be amenable for further selection.

Moderate GCV and PCV were observed for, per cent A grade bulbs, per cent B grade bulbs, per cent double bulbs, total yield, marketable yield and average bulb weight, indicating moderate amount of variability. Moderate GCV and high PCV were observed for shape index, neck thickness and per cent bolter bulbs.

Low GCV and PCV were observed for number of leaves at 90 days after transplanting, plant height at 90 days after transplanting, equatorial and polar diameter, days to maturity indicating lower amount of variability. Lower GCV and PCV for these traits provide evidence of low variability, hence, the variability has to be generated through introduction and hybridizing diversified genotypes to generate transgressive segregants.

Among all the characters studied, very high heritability and GAM noticed for per cent less than C grade bulbs, total yield, marketable yield and average bulb weight. These characters are likely to be governed by additive gene effects. It may also be concluded that selection on the basis of these characters will be more useful for the improvement of yield in this crop.

Moderate heritability with moderate GAM were observed for per cent A grade bulbs, per cent C grade bulbs, per cent bolter bulbs and per cent double bulbs. This indicates the importance of additive effects for these traits and there can be better response to selection. Moderate heritability with low GAM was observed for, number of leaves at 90 days and equatorial diameter.

Correlation studies indicated that highly positive significant association between total bulb yield with shape index, per cent B grade bulbs, marketable yield and average bulb weight at both genotypic and phenotypic levels. Whereas it had highly significant and negative correlation with per cent C grade bulbs, per cent less than C grade bulbs and also shown significant and negative correlation with TSS.

In the present study it was observed that the genotypic correlation coefficient was more than the phenotypic correlation indicating the presence of inherent association between various traits.

Based on the results of the study, it can be concluded that among all the cultivars Bhima Super, Bhima Shubra, Bhima Kiran, Arka Kalyan, Mahalakshmi and Sataara Garva proved to be superior considering the yield characteristics for cultivation under Central Dry Zone of Karnataka. For quality aspects like total soluble solids, cultivars like Arka Bindu, are found to be the best among all the cultivars, hence these can be better utilized for dehydration and processing purpose.

The cultivars Arka Kalyan, Bhima Shakti and Bhima Kiran were found to be moderately susceptible to purple blotch hence these cultivars can recommended for commercial cultivation in purple blotch disease prone areas.

Considering the growth, yield and quality performances the cultivars Arka Kalyan, PKV-White, Bhima Super, Bhima Shubra, Bhima Kiran and Arka Bindu are suitable for late *Kharif* season cultivation.

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*Originals not seen

APPENDICES

APPENDIX –I

Mean monthly meteorological data for the year 2014-2015 recorded at meteorological observatory of Zonal Agricultural and Horticultural Research Station, Hiriyur, Chitradurga District.

Months	**Rainfall (mm)**	**Temperature (^{0}C)**		**Relative humidity (%)**	
		Maximum	**Minimum**	**Morning**	**Evening**
April, 2014	158.00	36.06	21.60	86.57	63.13
May, 2014	43.40	35.34	21.79	84.52	63.39
June, 2014	2.40	33.69	22.34	92.00	70.30
July, 2014	11.80	30.87	20.70	89.19	62.45
August, 2014	116.30	30.93	20.34	76.84	62.23
September, 2014	71.40	31.71	27.38	82.97	68.10
October, 2014	24.40	32.01	21.59	78.32	60.48
November, 2014	84.00	30.65	19.04	71.10	44.33
December, 2015	1.40	30.22	17.45	71.74	52.71
January, 2015	0.00	31.57	17.26	91.10	73.13
February, 2015	5.00	33.02	19.64	45.36	60.18
March, 2015	9.00	35.40	21.85	63.42	60.52
Mean/ Total	527.10	31.49	20.91	77.76	61.74

APPENDIX –II

Chemical properties of experimental soil before planting

Particulars	Values	Method adopted
pH	8.03	PH meter (Jackson,1967)
EC (dsm^{-1})	0.14	Conductivity bridge (Jackson,1967)
Organic carbon (%)	0.19	Walkey and Block method, 1965
Available nitrogen (kg ha^{-1})	186	Alkaline permanganate method (subbaiah and Asija,1956)
Available phosphorous (kg ha^{-1})	17	Brays Extractant No-1 method (Jackson,1967)
Available potassium (kg ha^{-1})	186	Neutral Normal Ammonium Acetate method by (Jackson,1967)

APPENDIX - III

Lists of abbreviations and symbols

%	Per cent
@	At
^{o}C	Degree centigrade
CD	Critical difference
Viz.	As follows
DAT	Days After Transplanting
et al.	Et allii (and others)
G	Gram
^{o} Brix	Degree brix
i.e.	That is
Mg	milligram
Mm	Millimeter
S. Em ±	Standard error of mean