Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm

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CERTIFICATE-I

This is to certify that the thesis entitled **"Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **CHETHAN KUMAR S.** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled **"Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm"** submitted by **CHETHAN KUMAR S.** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLESCIENCE)** has been approved by the student's advisory committee and external examiner.

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ABSTRACT

The present investigation entitled, **"Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm"** was conducted at AICRP on Vegetable Crops, Orissa University of Agriculture & Technology, Bhubaneswar, Odisha, India during *Rabi* season of 2017-18 with an objective to study the nature and extent of genetic variability in chilli genotypes for improvement in fruit yield and yield attributing traits. Thirty four genotypes were evaluated in a RBD with three replication. The genotypes were evaluated on the basis of 17 parameters that included growth, yield and quality parameters.

The analysis of variance revealed significant difference among 34 genotypes for all the character studied indicating the presence of variability in the studied material. The GCV and PCV were more in fruit yield per plant (37.02 % and 40.75 %), average dry fruit weight (19.25 and 20.42 %) and average fresh fruit weight (33.10 and 34.38 %). High heritability was found with TSS (96.18 %), average dry fruit weigh (92.69 %), and average fresh fruit weight (91.33 %); genetic advance as percentage of mean was higher in case of dry fruit yield per plant (69.28 %) and average dry fruit weight (65.64 %). Characters like average fresh fruit weight, number of fruits per plant, fruit girth, and average dry fruit weight were positively and significantly correlated to yield at genotypic and phenotypic level. However, significant negative correlations were found with days to initial flowering, days to 50% flowering and leaf area.

Character like number of fruits per plant, average fresh and dry fruit weight and fruit girth exhibited high direct positive effect with yield along with high correlations. All the genotypes were grouped into 6 clusters based on Mahalanobi's D^2 statistics. The cluster I consisted of 9 genotypes, cluster II had 12 genotypes, cluster IV had 8 genotype and cluster III & cluster V had single genotype. Maximum inter cluster distance was found between cluster III and VI (217.467) and high cluster mean value for yield was recorded in cluster II. From the present investigation it can be concluded that the genotypes BC-28(1529.20), BC-5-1-7(1493.24) and BC-78-1-2(1424.44) ranked according to dry yield per plot (g) and genotype BC-40-2(66.66),BC-40-2-1-1(56.60) and Utkal Rashmi(52.17) ranked according to their ascorbic acid content(mg/100g). However, for crop improvement in chilli number of fruits per plant and average fruit weight along with other desirable characters may be taken into consideration.

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ABBREVIATIONS USED

%	: Per cent
/	: Per
@	: At the rate
CV	Coefficient of variation
C.D.	: Critical Difference
Cm	: Centimeter
Cm^2	: square centimeter
DAS	: Days after sowing
ESS	: Error sum of square
et al.	: And others
etc.	: Etcetera
g	: Gram
ha	: Hectare
Hrs.	: Hours
i.e.	: (*Id est.*) that is
Kg	: Kilogram
P	: phosphorus
m	: Meter
Max.	: Maximum
Min.	: Minimum
mm	: Millimeter
No.	: Number
R.H.	: Relative humidity
RSS	: Replication sum of square
AICRP	All India Coordinated Research Project
Tss	: Treatment sum of square
T	: Tonnes
Viz.	: (*Videlicet*) Namely
°C	: Degree Celsius

INTRODUCTION

Chilli or hot pepper (*Capsicum annuum* L.) native to new world tropics is one of the most important vegetable and spice crop in all over the world. In India, it is an indispensable spice cum vegetable in every household. Chilli belongs to family solanaceae of the genus capsicum with eleven species and the diploid chromosome number of this genus is 2n=2x=24.

Chillies were cultivated from 3500B.C. Christopher Columbus who discovered America in 1493 brought chilli to the rest of the world. Through, it was introduced in India, late in the 17^{th} century, chillies have become an essential part of Indian cuisine and are valued for their characteristics pungency, color, aroma and taste it imparts to the food materials. Majority of the Indian chilli belonging to species *Capsicum annuum* L. is distinguished for its medium pungency and short duration .It is cultivated almost all the states of the country like Andra Pradesh, Karnataka, west Bengal, Madya Pradesh, Odisha ,Rajasthan,Maharastra,Gujarat,Bihar etc.

India is the world’s leader in production of both green and dried chilli. Green chilli occupies area of 2.87 lakh ha area with production of 34.06 lakh MT followed by china and dry chilli occupies area of 0.83 lakh ha area with production of 18.72 lakh MT and productivity 2.25t/ha. In Odisha dry chilli is cultivated in an area of 65.50 thousand hectares with production 64.50 thousand MT and productivity 0.98 t/ha. (NHB 2017).

In spite of its great important, very little effort have been made for its improvement in the past. The average dry yield is 2.25t/ha, it is low as compared to progressive chilli producing countries like Korea and Indonesia (4 to 5 t/ha). Low yield is mainly due to lack of improved variety, hybrids and susceptibility of the variety to disease and insect pests and poor adoptability of a variety in different agro climatic condition.

High variability present in this crop in India has not been fully utilized. Limited efforts have been made by some research institutes to release varieties suited for different location with resistant to insect pest and disease with high yield. There is an urgent need to evaluate and develop important varieties for different purposes based on various traits. Highly resistant and stable lines need to be evaluated for use in the future breeding programme. Chilli, being an often self-pollinated crop is often found with enormous amount of variability for yield and other economically important yield attributes character. There is a possibility to exploit the available variability to achieve substantial crop improvement in chilli.

Varietal improvement work consequently depends on the amount of genetic variability present in existing material. The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important pre-requisites for formulating effective breeding methods (Krishna *et al.*, 2007).

Greater the variability in a population, there are the greater chance for effective selection for desirable types (Vavilov, 1951). When variability is partitioned into heritable and non-heritable components, efficiency of selection is better understood. Heritability is the portion of phenotypic variation which is transmitted from parent to progeny. Higher the heritable variation, greater will be the possibility of fixing the characters by selection. Hence, heritability studies are of foremost importance to judge whether the observed variation for a particular character is due to genotype or due to environment. Heritability estimates may not provide clear predictability of the breeding value. Thus, estimation of heritability accompanied with genetic advance is generally more useful than heritability alone in prediction of the resultant effect for selecting the best individuals (Johnson *et al.*, 1955).Wide ranges of variability reportedly exist in this crop (Munshi and Behera, 2000). The improvement of genotypes is based on the amount of genetic variability present in existing material.

Correlation and path coefficient analysis provides information regarding the nature and magnitude of various characters associations and help in the measurement of direct influence of one variable on other. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield of chilli crop. Path coefficient analysis would help in assessing the direct and indirect effects of each component towards yield of crop and identifying the reliable characters contributing to total yield. Mahalanobi's D^2 technique analysis appears to be a positive approach which is based on multivariate analysis and serves to be a good index of estimating genetic diversity (Gadekar *et al.*, 1992).

However, collection, evaluation and character association of existing germplasm for yield and yield attributes character and other traits is an important step in crop improvement. Keeping this in view, the present investigation initiated was carried out at AICRP on Vegetable crops with some local germplasm along with some elite varieties with the following objective.

1. To study genetic variability with respect to growth, yield and yield attributing traits of chilli germplasm.

2. To study character association among the germplasm.

3. To study path analysis of chilli germplasm and genetic divergence through D^2 analysis.

4. To estimate the quality parameters in chilli germplasm.

REVIEW OF LITERATURE

In the present investigation, an effort has been made to study the genetic variability, heritability, genetic advance, correlation, path coefficient analysis and genetic divergence in chilli.

The literature available related to present study entitled, "Genetic variability, and character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm" have been reviewed in this chapter under the following broad outlines:

2.1 Genetic variability, heritability and genetic advance

2.2 Correlation coefficient and Path coefficient analysis, and

2.2 Genetic divergence

2.1 Genetic variability, heritability and genetic advance

A critical estimate and study of genetic variability is a pre-requisite for initiating appropriate breeding procedures in crop improvement programmes which demands wide range of variability in a population. The improvement in any crop is proportional to the magnitude of its genetic variability present in the germplasm. Greater the variability in a population, greater is the chance for effective selection for desirable types (Vavilov, 1951).

The variability observed in any population could be due to two factors, the genetic and environmental, which further decide the genetic gain possible through selection in the given population. The genetic and environmental components of variation were discussed in the early part of last century by Johannsen (1909), who attributed the variation in a segregating population to both heritable and non-heritable factors and variation within pure line to only environmental factors.

The phenotypic variability is a measure of variability due to genotype, environment and their interaction. The genetic variability is the true measure of variability present in a population. It indicates the relative magnitude of genetic diversity existing in the plant population and helps to compare the genetic variability present for different traits.

The success of breeding programme for high yield and quality depends on the nature and magnitude of variation available in the genotypes. Selection from quantitative trait is less efficient, if it is based on phenotypic expression. Hence, it is necessary to estimate the relative extent of genetic and non-genetic variability exhibited by individual characters. So, partitioning of overall variability into heritable and non-heritable components by calculating genetic parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) is necessary (Chadha and Sindhu, 1983 and Singh and Singh, 1994).

Heritability

Heritability is the portion of phenotypic variation which is inherited from parents to offspring. Higher the heritable variation greater will be the possibility of fixing the characters by selection methods. Therefore, heritability studies are of foremost importance to judge whether the observed variation for a particular character is due to genotype or due to environment. The ratio of genotypic variance to total variance in non-segregating population is known as heritability in broad sense (Hanson *et al.,* 1956). Thus, heritability denotes the proportion of phenotypic variance that is due to genotype which is heritable.

Genetic Advance

Genetic advance is the measure of improvement that can be achieved by practicing selection in a population. Genetic advance under selection is the improvement in the mean genotypic value of selected plants over parental population which further depends upon the genetic variability present in the population, heritability of the characters and the intensity of selection. Heritability estimates may not provide clear predictability of the breeding value. Therefore, estimation of heritability accompanied with genetic advance is generally more useful than heritability alone in prediction of the resultant effect for selecting the best individuals (Johnson *et al.*, 1955). This is due to the fact that, a character having high heritability may have very less phenotypic variation thus leading to low genetic advances. But, in the presence of additive gene effects high genetic advances can be expected (Panse, 1957).

Thus, study on components of variance and heritable components with suitable genetic parameters such as genotypic and phenotypic coefficients of variation, heritability and genetic advance are important tools for the breeders in selection of elite genotypes from diverse population.

In the following paragraph the works pertaining nature of genetic variability, heritability and genetic advance in chilli have been reviewed.

Gogoi and Gautam (2002) studied genetic variability for various characters in fifty-two chilli. The characters fruit drop percentage, fresh fruit yield per plant and dry fruit yield per plant showed high PCV and GCV. Heritability estimates were moderate to high for all the characters, except for number of primary branches. High heritability along with high genetic advance were observed for fruit length, number of fruits per plant, fresh and dry fruit yield per plant. Fruit drop percentage and leaf area index, indicating the importance of these traits in yield improvement programme.

Shivkumar and Hosamani (2006) evaluated sixty nine genotypes of chilies. The study indicated that the moderate to high PCV and GCV were observed for all the characters, high heritability (broad sense) with high genetic advance as percent mean was observed for most of the characters except plant height.

Ukkund *et al*. (2007) studied genetic variability, heritability, genetic advance and genetic advance as a percent over mean for twelve characters in eighty chilli accessions. High degree of variation was observed for all characters. The difference between phenotypic coefficient of variation and genotypic coefficient of variation were found to be narrow for most of the traits except primary and secondary branches, tertiary branches, fifty per cent flowering, early and late fruit yield per plant. The high estimates of heritability was found for plant height (93.40%), days to first flowering (83.50%), percent fruit set (70.70%), number of fruits per plant(81.10%), fruit length (92.40%), ten fruit weight (92.40%) and total green fruits per plant (88.40%). Most of these characters also had moderate to high estimates of genetic advances as a percent over mean except days to first flowering

Patil *et al*. (2008) conducted a field experiment with 37 chilli genotypes. The genotypic and phenotypic coefficients of variation were moderate on matured ripe chilli yield (33.95% and 34.18%). Low GCV and PCV were recorded for plant height

(14.06% and 14.22%), crown size (10.65% and14.25%), plant girth (16.18% and 16.61%), primary branches (8.63% and 11.73%), secondary branches (8.81% and 10.45%), days to 50 per cent flowering (7.34% and 9.18%), number of fruits per plant (18.62% and 19.47%) and dry chilli yield (26.56% and 26.85%), respectively. High heritability in association with low genetic advance over mean (GAM) was recorded for plant height (97.80% and 28.66%). High heritability coupled with moderate genetic advance as per cent over mean for plant girth (94.90% and 32.35%), number of fruits per plant (91.40% and 36.68%), matured ripe chilli yield (98.70% and 69.47%) and dry chili yield (97.80% and 54.11%). Low heritability coupled with low genetic advance as per cent over mean for per cent fruit set (33.40%and 6.72%).

Sharma *et al.,* (2010) conducted experiment on twenty three genetically diverse genotypes of bell pepper. Significant differences were observed among the genotypes for all the traits. On the basis of mean performance, genotypes PRC-1, SSP, Kandaghat Sel. and Ranichauri Sel-1were outperformed for fruit yield per plant, average fruit weight, and number of fruits per plant and took less number of days to 50% flowering. The PCV and GCV were high for fruit yield per plant and ascorbic acid content indicating that these traits had wide genetic variability and would respond better to selection. High heritability were recorded for average fruit weight(91.29%), fruit yield per plant, fruit diameter(84.29%), and number of lobes per fruit(78.10%), days to first harvest (77.10%), leaf area (89.24%) and ascorbic acid (90.89%)content indicating the role of additive gene action for the inheritance of these traits.

Chattopadhyay *et al.*, (2011) conducted an experiment and found thattwo genotypes namely Chaitali Pointed and BC CH Sel-4 were found most promising with respect to green fruit yield per plant (272.79 g and 221.10 g resp.) and dry fruit yield per plant (54.56 g and 44.44 g).PCV and GCV values for green fruit weight (119.95%, 111.26%), green fruit girth(89.76%, 48.93%), weight of red ripe fruit (112.02%, 111.93%), weight of dry fruit (111.63%, 110.97%) and number of fruits per plant (86.05%, 85.02%)(resp.) were recorded to be high. Green fruit yield per plant, ascorbic acid content, and number of fruits per plant also showed very high broad-sense heritability and genetic advance. From the study of correlation and path coefficient analyses, the number of fruits per plant, green fruit length for green chilli, weight of dry fruit and the number of fruits per plant for dry chilli were found to the most important selection indices.

Jogi *et al.,* (2015) studied genetic variability, heritability, and genetic advance as a per cent over mean for eleven characters in fifty chilli genotypes. High degree of variation was observed for all characters. The difference between PCV and GCV were found to be narrow for most of the traits. The high estimates of heritability was found for number of fruits per plant at first picking (98.20%), total number of fruits per plant (94.67%), early yield (94.67%), late yield (95.62%) and total yield (91.37%), fruit length (96.22%), fruit width (96.22%), stalk length (81.04%) and ten fruit weight (96.44%), ascorbic acid (98.30%), chlorophyll-a (95.45%), chlorophyll-b (97.52%) and their total chlorophyll (97.87%).

Kumari (2013) studied nineteen genotypes of bell pepper. Significant differences were observed for all the traits among nineteen diverse genotypes. Higher genotypic and phenotypic coefficients of variation were recorded for number of fruits per plant (30.49 % and 30.63 %), average fruit weight(30.85 % and 30.03 %) and fruit yield per plant (32.12 % and 32.26 %) indicating that these traits had wide genetic variability and would respond better to selection. High heritability coupled with high genetic gain was observed for number of fruits per plant (57.85 % and 57.85 %), average fruit weight (60.62 % and 60.62 %) and fruit yield per plant (65.80 % and 65.80 %) indicating the role of additive gene action for the inheritance of these traits.

Pandey *et al.* (2013) studied variability parameters in sweet pepper. Significant variation among all the genotypes was recorded for all the characters studied. High heritability along with high GCV and high genetic gain was observed in fruit weight, fruit yield per plant, number of fruits per plant, total chlorophyll and fruit width.

Magaji *et al.,* (2014) carried two experiments to study the genetic variability among chili pepper for heat tolerance and morpho physiological traits and to estimate heritability and genetic advance expected from selection. There was a highly significant variation among the genotypes in response to high temperature cell membrane thermo stability (CMT), photosynthesis rate, plant height, disease incidence, fruit length, fruit weight, number of fruits, and yield per plant. At 5%

selection intensity, high genetic advance as percent of the mean (>20%) was observed for high temperature, photosynthesis rate, fruit length, fruit weight, number of fruits, and yield per plant. Similarly, high heritability (>60%) was also observed indicating the substantial effect of additive gene more than the environmental effect.

Pandit and Adhikary (2014) evaluated forty one chilli genotypes and found that GCV and PCV estimates closely corresponded with regard to days to 50% flowering, fruit length, placenta length and 1000 seed weight; in others it differed moderately, altogether suggesting low to medium influence of environment in the expression of these characters. Close estimates of GCV and PCV were noted in all characters except fruit width, which imply that contribution towards final phenotypic expression of these characters are mostly genetic rather than environmental. Very high genetic advance as percent of mean was recorded in fruit yield per plant (75.6%) and moderately days to 50% flowering (46.3%), placenta length (45.0%), fruit length, number of fruits per plant and number of seeds per plant.

Sreelathakumary and Rajamony (2014) evaluated thirty-five chilli (*Capsicum annuum* L.) genotypes .Higher PCV and GCV were observed for leaf area (28.51% and 29.54%), fruits per plant(63.70% and 63.88%), fruit weight, fruit length, fruit girth and yield per plant (38.99% and 39.21%). High heritability coupled with high genetic advance observed for these characters imply the potential for crop improvement through selection.

Patel *et al.,* (2015) evaluated forty diverse genotypes of chilli. The analysis of variance revealed the significant differences among the genotypes for all the characters studied which indicating that presence of great deal of genetic variability for different traits. The high estimates of GCV and PCV were obtained for number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, average fruit length, average fruit girth, fruit shape index, average fruit weight, green fruit yield per plant , chlorophyll content , ascorbic acid content and capsaicin content , while it was low for moisture content. The characters like days to flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, average fruit length, average fruit girth, fruit-shape index, average fruit weight, green fruit yield per plant, chlorophyll content, ascorbic acid content and capsaicin content exhibited high genetic advance coupled with high heritability, indicating better scope for improvement of these traits by an effective selection programme.

Janaki *et al.,* (2015) evaluated 63 genotypes of chilli (*Capsicum annuum* L.) in a randomized block design with two replications. Analysis of variance revealed significant differences among the genotypes for all the traits studied indicating the presence of sufficient variability in the studied material. The PCV was higher than GCV and the difference between PCV and GCV was narrow for most of the characters revealing little influence of the environment in the expression of these traits. High magnitude of PCV and GCV were observed for per cent fruit set, number of fruits per plant, fruit diameter, average dry fruit weight, number of seeds per fruit and yield per plant suggesting the existence of wide range of genetic variability in the germplasm for these traits and thus the scope for improvement of these characters through simple selection would be better. High heritability coupled with high genetic advance as per cent of mean was observed for all the characters except days to 50 % flowering indicating the predominance of additive gene action making the simple selection more effective.

Maurya *et al*., (2015) evaluated thirty genotypes of chilli. Higher PCV and GCV were observed for days to 50 % flowering, number of fruits per plant, fruit body length, number of seeds per fruit, weight of seeds per fruit, seed husk ratio, average dry fruit weight and dry fruit yield per plant. High heritability coupled with high genetic advance were observed for seed husk ratio, average dry fruit weight and dry fruit yield per plant, so these characters imply the potential for crop improvement through selection.

Sahu *et al.* (2015) conducted an experiment comprised of nineteen genotypes of chilli and laid out in randomized block design with three replications. Data were analyzed to work out the variability, correlation coefficient, path analysis and genetic divergence for the characters for yield and its component character. The analyses of variance revealed that mean sum of squares due to genotypes were highly significant for all characters which indicated the presence of variability in the genotype. The genotype 2012/CHIVAR-5 was found to highest yield and earliest flowering was noted in 2012/CHIVAR – 8.

Aklilu *et al.,* (2016) studied forty nine hot pepper accessions collected from different agro ecologies. The genetic component analysis indicated that PCV was higher in magnitude than GCV for most characters except pericarp thickness and leaf area index. Higher magnitude of GCV was observed in leaf area index (67%) followed by pericarp thickness (34%), number of branches, internode length (23%) and plant height. Close estimates of GCV and PCV were recorded from fruit and internode length, pericarp thickness and fruiting period. Very high PCV and very low GCV estimates were obtained from fruit weight and number of fruits, fruit yield, plant height and canopy width. Broad sense heritability was high for fruiting date, fruit length, plant height, and internode length and fruit diameter. However, genetic advances percent of the mean was high to moderate for length and number of internodes, number of branches, fruit diameter and weight, pericarp thickness and leaf area index. Therefore, from this study, fruit diameter, pericarp thickness, leaf area index and internode length exhibited high to moderate genotypic and phenotypic coefficients of variation along with medium to high heritability and genetic advance and can be used as a selection criterion for pepper improvement program.

Bijalwan and Madhvi (2016) studied genetic variability, heritability, genetic advance and genetic advance as a percent of mean for fifteen characters were assessed by field evaluation of sixteen chilli genotypes. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the characters indicating the influence of environment on these characters. High GCV and PCV, heritability and genetic advance as percentage of mean were noted for fruit weight at edible maturity (61.04% & 61.37%, 99.02% and 125.09%), fruit yield per plant (47.67% & 48.24%, 97.63% and 97.03%) and number of fruits per plant (39.77% & 40.11%, 98.31% and 81.24%). Therefore, selection should be imposed considering these traits for improvement of population in chilli in temperate hills.

Kadwey *et al.* (2016) evaluated twenty five diverse hot chilli (*Capsicum annuum* L.) genotypes for assessment of genetic variability, heritability and genetic advance. The highest PCV were recorded for number of fruit per plant (42.0%), dry fruit yield per plant (30.34%), seeds yield per plant (28.94%), fruit weight of dry chilli (23.38%), number of primary branches per plant at 30 DAT (21.88%) and fruit width (21.0%). While, highest GCV was observed for number of fruit per plant (41.77%), dry fruit yield per plant (29.61%),seed yield per plant (27.67%) and fruit weight of dry chilli (21.67%), The value of heritability (h^2bs) was found to be very high for fruit yield per plant (97.91%), seed yield per plant(96.82%), dry fruit yield per plant (95.24%), days to first picking (94.88%), fruit length (93.30 %), fruit weight of green chilli (93.26%), fruit yield per plot (92.91%), fruit yield per ha(92.90%) and fruit width (92.02%). The highest estimates of genetic advance as percentage of mean was recorded for number of fruit per plant(45.59%), fruit weight of dry chilli (41.38%), fruit width (39.82%), dry fruit yield per plant (39.52%), seed yield per plant (38.70 %), fruit weight of green chilli (38.10%), fruit yield per plant (37.33%) and fruit length (36.78%) were observed for these all the above characters, imply the potential for crop improvement in chilli through selection.

Kannan *et al.* (2016) evaluated eight diverse genotypes of chilli. Analysis of variance revealed significant differences among the genotypes for all the characters studied. The higher estimates of GCV were observed for flowers per branch (21.59%), clusters per plant (19.26%), flower per branch (16.93%) and stem diameter (15.49%). While the higher estimates of PCV were found for flowers per branch (26.70%), fruits per branch (24.44%), clusters per plant (24.04%) and stem diameter (19.26%). The higher estimates of broad sense heritability along with genetic advance recorded for flowers per branch (65%), fruits per plant (64%), cluster per plant (64%), stem diameter (65%), plant weight (59%) and days to 50% flowering (50%) indicated the scope for improvement of these characters through selection.

Meena (2016) reported that the genotypes Azad mirch-1, Sel-16 and 7919 performed better in terms of leaf area had maximum value (116.38), succeeded by fruit yield per plant red ripe (85.40), fruit width (38.23), number of branches per plant (34.43), days to 50% flowering (32.46) ,days to first harvest (27.83),pedicel length (27.78) , fruit yield per plant (17.73) , fruit length (16.64) and plant height (12.76).

Mamatha *et al.* (2017) evaluated forty genotypes of chilli for find out the genetic variability, heritability, genetic advance and genetic advance as per cent of mean .The observations were recorded five plants per plot for plant height, number of branches per plant, leaf area, days to first flowering, days to 50% flowering, fruit length, fruit diameter, fruit weight, pedicel length, number of fruits per plant. Qualitative parameters viz., chlorophyll content and Ascorbic acid content. The genotypes DCC- 172, DCC–69, DCC– 164, DCC- 134, DCC- 135 and DCC –167 found better in term of chlorophyll content had maximum value (84.93%), succeeded by fruit yield per plant (58.43%), fruit weight (53.09%), number of fruit per plant (49.59%), ascorbic acid (44.33), fruit length (34.36%), fruit diameter (32.07%) and pedicel length (31.72%).

Maurya *et al.,* (2017) studied genetic variability in chilli. Analysis of variance revealed significant differences among the genotypes for all the traits studied indicating the presence of sufficient variability in the studied material. The PCV was higher than GCV and the difference between PCV and GCV was narrow for most of the characters revealing little influence of the environment in the expression of these traits. High magnitude of PCV and GCV were observed for days to 50% flowering, number of fruits per plant, average fruit weight, fruit yield per plant, fruit body length, ascorbic acid, TSS, anthracnose, leaf curl virus incidence and total fruit yield per hectare suggesting the existence of wide range of genetic variability in the genotypes for these traits. High heritability coupled with high genetic advance as percent of mean was observed for all the traits except canopy width and stalk length revealed these traits are under the control of additive gene action and lower influence of environmental factor in the expression of these traits with possibility for genetic improvement through simple selection.

Murmu *et al.* (2017) reported variability in twenty genotypes of chilli. The analysis of variance revealed the significant differences among the genotypes for almost all the characters studied which indicating that presence of great deal of genetic variability for different traits. Among these genotype Hyb-3(2)-2 one of the most promising one showed maximum fruit yield per plant, fruit length, fruit girth and pericarp thickness. Genetic variability of fruit yield per plant (45.92%), number of fruits per plant (38.92%), and fruit girth (39.37%) and seeds per fruit (32.41%) emerged as most reliable characters for selection because of their probable conditioning by the additive gene action. Moderate GCV coupled with high broad sense heritability and moderately high genetic advance was registered in three characters namely fruit yield per plant, number of fruits per plant, fruit girth and seeds per fruit.

Pandiyaraj *et al.* (2017) studied thirty three chilli germplasm. High magnitude of PCV and GCV were recorded for carotene content (36.03% and 35.73% resp.) and followed by red pod yield per plant (15.21% and 15.15% resp.), dry pod yieldper plant (33.71% and 24.06% resp.) and capsaicin (51.73% and 50.73% resp.). High values of GCV are an indication of high genetic variability among the germplasm. The heritability estimates in broad sense were found to be high for all the characters except number of secondary branches per plant (48.2%), capsaicin (97.4%), and days to first flowering (57.1%), pod girth (75.4%) and thousand seed weight (79.6%). High heritability estimates indicated the presence of large number of fixable additive factors and hence these traits can be improved by selection. The traits like carotene content, red pod yield per plant, dry pod yield per plant and mean pod weight with high phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance as percent of mean, indicating that these characters are under additive gene effects and more reliable for effective selection.

Pujar *et al.* (2017) conducted a field experiment to study the genetic variability and heritability of 63 chilli genotypes with two replications. Study revealed that, highly significant difference among the accessions for all the characters studied. Environmental influence was very less on expression of characters as it was evident by narrow gap between genotypic and phenotypic coefficients of variation. PCV and GCV were moderate to high for all the characters studied except green (5%) and dry fruit weight (5%). High heritability was observed for all characters, except 1000-seed weight (2%) and high genetic advance as per cent mean indicating that simple selection would be sufficient for these traits to bring genetic improvement.

Shobha *et al.* (2017) evaluated two hundred and sixteen mutants of chilli for genetic variability for 12 growth and fruit characters along with quantitative characters. Significant variation exists among all the M3 mutants studied for yield and its components. The least differences between genotypic and phenotypic coefficient of variation observed which indicates environmental influence for the expression of most of the traits. High heritability estimates with high genetic advance as per cent mean observed for characters like plant height, number of primary branchesper plant, number of secondary branches per plant, number of fruits per plant, fruit length, fruit width, fruit diameter and fruit yield per plant revealed that these characters are under the control of additive gene action.

Singh *et al.* (2017) evaluated 18 genotypes of chilli (*Capsicum annuum* L.) for thirteen quantitative traits. Analysis of variance revealed highly significant difference among the genotypes for all the characters studied. The PCV was higher than the GCV for all the traits. High magnitude of PCV and GCV were observed for number of fruit per plant (34.44% and 28.66% resp.) followed by average fruit weight(30.15% and 28.06% resp.), fruit yield per plant(20.10% and 18.29% resp.), while it was low for number of branches per plant(4.48% and 3.68% resp.). High heritability coupled with high genetic advance as percentage of mean were observed for average fruit weight(53.78%), number of fruit per plant(34.27%) suggested that the predominance of additive gene action indicating better scope for improvement of these traits by an effective selection programme.

2.2 Correlation coefficient and Path coefficient Analysis

The correlation coefficient analysis measures the mutual relationship between various traits and it determines the component traits on which selection can be made upon to improve the yield. There are three types of correlations i.e., phenotypic correlation, genotypic correlation and environmental correlation.

Phenotypic correlation is the observable correlation between two variables and includes both genotypic and environmental effects. Genotypic correlation contrarily, is the inherent association between two variables which may be either due to pleiotropic gene action or linkage effect or more likely both are developmentally induced relationships (Harland 1939). Genotypic correlation measures the magnitude of relationship between various characters that determines the component characters on which selection can be made for improvement in yield (Johnson *et al.*, 1955).

The path analysis is a standardized partial regression coefficient, as it measures the direct effect of one variable upon other and permits the separation of correlation coefficient into components of direct and indirect effects of a set of independent variables on a dependent variable.

The notion of path analysis was originally developed by Wright (1921), but the technique was first used for plant selection by Dewey and Lu (1959) as a means of separating direct and indirect contribution of various characters, which is not possible through other techniques like correlation coefficient.

Primarily the technique aims to improve a dependent character like yield when the independent characters have a significant relation in desirable direction and positive direct effect or indirect effect through other traits on the dependent characters. The use of this technique requires cause and effect situation among the variables (Singh and Choudhary, 1979).

A brief review on the correlation coefficient of different characters on yield and path co efficient analysis in chilli is summarized below.

Ajjapplavara *et al.* (2005) studied the correlation and path coefficient analysis in 36 genotypes of chilli for 18 different quantitative characters. The correlation study indicated that significant and desirable correlation between dry fruit yield per plant with all other characters except number of primary and secondary branches, fruit diameter, fruit volume, powdery mildew disease incidence and leaf cur complex incidence. Path analysis revealed that importance should be given to fruit weight and fruits per plant.

Smitha and Basavaraja (2006) evaluated forty chilli genotypes for correlation studies revealed that, importance should be given to number of fruits per plant, fruit weight, number of primary branches, fruit length, fruit diameter and plant height during selection process, because these characters are going to contribute directly towards the yield.

Sharma *et al.* (2010) conducted an experiment on genetically diverse twenty-three genotypes of bell pepper. At genotypic levels, the traits like fruit length, fruit diameter and number of fruits per plant revealed significant positive correlation with fruit yield per plant. Number of fruits per plant exhibited the highest positive direct effect followed by average fruit weight, number of branches per plant, pedicel length and harvest duration at genotypic level.

Jogi *et al.* (2013) revealed character association and path analysis in fifty genetically diverse indigenous and exotic genotypes of chilli for 16 important characters. The phenotypic and genotypic association of fruit yield was significantly positive with all the characters except days to first flowering and ten fruit weight. Early fruit yield and late fruit yield per plant were found highly significant and positive correlation with total fruit yield. The genotypic path co-efficient analysis revealed that ascorbic acid and chlorophyll content had high direct positive effect on total fruit yield.

Vikram *et al*. (2014) conducted an experiment on chilli (*Capsicum annuum* L.) to study the genetic correlations and path coefficients among twenty traits under study. Green yield per plant showed positive and significant correlation with average green fruit weight, fruit length and fruit breadth at middle while dry fruit yield exhibited the same with fruit length, green yield per plant and alpha carotene content indicating the effective improvement in yield (green and dry) through above characters capsaicinoid content showed positive association with number of fruits per plant while average green and dry fruit weight had negative effect on capsaicinoid content in chilli. Positive and significant associations between capsaicinoid content in green and dry chilli, ascorbic acid content in green and red ripe chilli indicated continuous increase in capsaicinoid and ascorbic acid contents with the maturity. Path analysis towards dry yield per plant revealed the importance of average dry fruit weight, number of fruits per plant, fruit length, green yield per plant and alpha carotene content in improvement of dry yield per plant.

Patel *et al.* (2015) reported the results of correlation studies which indicated that genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic correlation coefficients for all the traits. Green fruit yield per plant had high, significant and positive association with number of fruits per plant, average fruit weight, moisture content and chlorophyll content at both genotypic and phenotypic levels which indicating that these traits were main yield attributing traits. Path analysis revealed that characters like number of secondary branches per plant, number of fruits per plant and average fruit weight had high and positive direct effects on green fruit yield. For maximizing the green fruit yield per plant weightage should be given to early flowering, more number of fruits per plant, high average fruit weight, more number of secondary branches per plant and high moisture content.

Vijaya *et al*. (2015) evaluated twenty-four chilli genotypes for quality parameters, *viz.*, capsaicin, and capsanthin and oleoresin contents. Analysis of variance revealed the significance differences among the genotypes. High phenotypic and genotypic coefficient of variation along with high heritability and genetic advance was observed for all the three characters. Correlation studies indicated a negative association of capsanthin with oleoresin and capsaicin content. Oleoresin content had positive correlation with fruit length, pericarp weight, number of fruits per plant and dry fruit yield per plant.

Aklilu *et al.* (2016) studied forty nine hot pepper accessions collected from different agro ecologies. The values of genotypic correlation coefficients were higher in magnitude than phenotypic values in most instances in which fruit yield per plant showed high positive significant genotypic correlation value with pericarp thickness (r = 0.91) and number of fruits per plant (r = 0.61).On the other hand, significant negative associations were registered with days to flowering (r =-0.73) and 50% fruiting period (r =-0.75). The phenotypic correlation coefficient of most characters with yield was not significant except for flowering period, fruit length and number of fruits per plant. The path coefficient analysis indicated that pericarp thickness (5.5mm), fruit diameter (1.4mm), number of fruits per plant (0.8), number of branches (0.33) and flowering period (0.2) had the highest direct positive effect. However, fruit weight (-2.8), number of internodes (-1.66), leaf area index (-1.6) and plant height (-0.4) had a high negative direct effect on yield.

Kumari *et al.* (2017) studied 15 chilli genotypes for genetic correlation and path coefficient analysis for 15 different quantitative and qualitative traits. The correlation study revealed that plant height at 90 DAT, plant height at 120 DAT, secondary branches at 90 DAT, fruit weight, stalk length and fruits per plant had significant and positive correlation at genotypic as well as phenotypic level suggesting the direct selection of these traits as less prone to environmental factors. The path coefficient analysis had direct positive via yield through number of fruits per plant, fruit weight, number of secondary branches at 90 DAT and ascorbic acid content. Selection for these traits would be more beneficial and rewarding in concentrating the economical yield.

Murmu *et al.* (2017) calculated genetic correlations and path coefficients traits in 24 genotypes of chilli. Character associations both correlation and path co-efficient revealed that fruit weight, number of fruitsper plant, primary branches per plantand plant canopy were the most important selection criteria for improving yield of both green and dry chilli

Pujar *et al.* (2017) conducted a field experiment to study the, correlation and path analysis of 63 chilli genotypes with two replications. Fruit yield had positive and highly significant association with number of fruits per plant and fruit set percentage. Strong association of these traits revealed that selection based on these traits would ultimately improve the fruit yield and it is also suggested that hybridization of genotypes possessing combination of such characters is most useful for obtaining desirable high yielding sergeants. Path-coefficient analysis revealed that fruit set percentage and fruit weight had the highest positive direct effect on fruit yield both at genotypic and phenotypic levels and most of the fruit related traits contributed to fruit yield mainly through fruit girth and fruit weight. Hence, it would be rewarding to lay stress on these characters in selection programmes for increasing yield.

Shobha *et al.* (2017) evaluated two hundred sixteen mutants of chilli for association. Plant height, number of primary branches per plant, number of secondary branches per plant number of fruits per plant, fruit length and fruit weight were highly associated with dry fruit yield per plant. Estimates of path analysis reveals that days to 50 per cent flowering, number of fruits per Plant, fruit length, fruit weight and number of seeds per fruit were the five factors that extends the greater influence both directly and indirectly upon the dry fruit yield per plant, these five traits were important components that involved dry fruit yield per plant. The genotype Byadagi dabbi recorded highest colour value of 118.35 (ASTA) and ascorbic acid of 110.23 mg per g. Genotype Indam 5 recorded highest capsaicin of 0.41%.

Shumbulo *et al*. (2017) evaluated 55 hot pepper genotypes for character correlation and path coefficient analysis. The result revealed that, in most cases, the genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients indicating their inherent association of traits and hence more advantageous for breeding purposes. Phenotypic and genotypic correlation further confirmed that branch number per plant, fruit number per plant, fruit length, fruit diameter and fruit weight were the most important traits for improving the genotypes for higher fruit yield and may be applied for selection in hot pepper productivity. Path analysis revealed that the maximum direct effect on fresh fruit yield was exerted by dry weight (0.6686), average fruit length (0.2185), fruit diameter (0.2085) and average fruit number per plant (0.1444), Thus, on the basis of current result, fruit length, diameter and fruit number per plant could be the most important yield component characters which might be selected for yield improvement while the converse was true with plant height and stem girth (diameter) at phenotypic level.

2.3 Genetic divergence

The magnitude of divergence between two groups under consideration is provided by D^2 statistic developed by Mahalanobis (1936).Murthy and Pavate (1962) observed that D^2 analysis can be extended to the situations where overlapping species need to be discriminated and also when the discrimination at subspecies level is also needed. This technique was used in different vegetable crops subsequently.

The grouping of genotypes into different clusters was done using the Tocher's method as described by Rao (1952). The criterion was that the two varieties belonging to the same cluster at least on an average show a smaller D^2 value than those belonging to different clusters. For this purpose D^2 values of all combinations of each genotype were arranged in ascending order of magnitude in a tabular form as described by Singh and Chaudhary (1977).

To start with, two populations having the closest distance from each other were considered, to which the third population having the smallest D^2 value from the first two populations was added. Similarly, the next nearest fourth population was considered and this procedure was continued. At certain stage when it was felt that after adding a particular population there was an abrupt increase in the average D^2, that population was not considered for including in that cluster.

The genotypes of the first cluster were then eliminated and the rest were treated in a similar way. This procedure was continued till all the genotypes were included into one or other cluster.

Varalaxmi and Babu (1991) grouped thirty three chilli genotype into 11 clusters .Out of 10 characters studied, fruits per plant, leaf area index, fruit weight and total yield were reported to be the chief contributors towards genetic divergence. They did not observe firm relationship between genetic divergence and geographical distances.

Begum (2002) grouped 46 chilli genotypes into 13 clusters which showed inter cluster D^2 values ranging between 18.91 and 87.12. Seed number per fruit, dry fruit yield per plant and number of fruits per plant were the chief contributors towards diversity. Maximum diversity as revealed by inter cluster distance was observed between cluster VI and XIII with D^2 value of 82.21.

Forty chilli genotypes were grouped into clusters by Karad *et al.* (2002) the D^2 values ranged between 0.1032 and 8.7702. Cluster I was the largest containing (23 genotypes), followed by cluster II (4 genotypes). Inter-cluster distance (D^2) ranged between 7.45 (clusters II and V) and 1.15 (clusters III and VII).

Thirty six genotypes were grouped genotypes into 11 clusters by Prabhudeva (2003), the D^2 values ranging from 34.02 to 102.13. According to him genetic diversity was not an index of geographical diversity. He observed maximum inter cluster distance between cluster I and II, suggesting that the genotypes belonging to these clusters form ideal pairs for developing hybrids

Senapati *et al.* (2003) grouped twenty diverse chilli genotypes into 6 clusters .Cluster I was the largest with 13 genotypes followed by cluster III and IV with 2 genotypes each. They observed maximum genetic distance between cluster II and cluster VI with two genotypes each and maximum genetic distance between these groups and four characters *viz*., fresh fruit weight, fruit girth, fruit length and fruit number per plant were the chief contributors towards genetic divergence.

Gogate *et al.* (2006) grouped the genotypes into 11 clusters based on D^2 values. The genotypes were distributed randomly irrespective of geographic origin. The intra cluster distances ranged from 0.00 to 875.95. Number of fruits per plant, chlorophyll content, green fruit yield and ascorbic content largely influenced genetic discrimination of genotypes.

Fifty-five accessions of chilli (*C. annuum* L.) were grouped into 15 clusters with 10 solitary clusters by Vani *et al.* (2007) .It was evaluated for 15 quantitative character. Plant height and yield per plant, contributed maximum towards diversity. The D^2 values varied between 14.38 and 85.01. Cluster I was the largest containing 32 genotypes, followed by clusters II and IV with five genotypes each. The maximum intra-cluster distance was reported in cluster I, whereas inter-cluster distance was maximum between clusters VII and XI. Cluster mean analysis showed that solitary clusters, *i.e*. cluster XI (IC-32), cluster XII (Pusa Jwala) and cluster XIV (IC-16), were having high mean values for yield per plant, average fruit weight, seeds per fruit and fruit girth.

Dutonde *et al.* (2008) grouped forty accessions into 7 clusters with Cluster I comprising 17 genotypes, followed by cluster IV (11) and cluster III (8). The maximum inter cluster distance (D=104.98) was observed between cluster IV and cluster VII. Intercrossing among the genotypes belonging to cluster-II, IV and VII was suggested to develop high yielding varieties with other desirable characters.

Kadri *et al.* (2009) studied fourty eight genotypes for morphological and agronomic properties based on that it's grouped into seven groups. The first six principal components axes accounted for 54.29% of the variance among the 48 accessions and their lines. The largest group contained 29 genotypes while the smallest had only 6 genotypes.

Kumar *et al*. (2010) studied genetic diversity in 25 chilli genotypes for various characters revealed substantial differences for all the traits. Based on D^2 values, the genotypes were clustered into eight constellations. Cluster I contained nine genotypes fallowed by Cluster-II (four) cluster IV and V (two each). The maximum inter cluster distance (D=12.75) was observed between cluster VI and cluster VIII. The cluster IV recorded maximum intra cluster distance (D=5.91).Intercrossing among the genotypes belonging to cluster III, IV and I was suggested to develop high yielding varieties with other desirable characters or may be used as potential donors for future hybridization programme to develop better chilli variety with good fruit yield.

Ninety four paprika (*Capsicum annuum* L.) accessions were evaluated for 17 characters and grouped them into 10 clusters through Mahalanobis D^2 analysis by Kumari *et al*. (2010). The largest group was cluster I which comprised of 24 genotypes. The cluster distances ranged from 15789.6 (between cluster II and cluster X) to 856.7 (between cluster 1 and cluster II).

Pandit *et al.* (2010) studied forty nine diverse materials of chilli for estimation of genetic divergence through multivariate analyses using D^2 statistic. The genotypes were grouped into 17 clusters, cluster 1 having the maximum number of genotypes (9 genotypes). The intra cluster distance was low, revealing homogeneity in the genotypes in a particular cluster for expression of the 12 characters under consideration. The inter cluster divergence was maximum between cluster 11 and 16 (32.40), suggesting wide diversity between them.

Singh and Singh (2010) studied fifty chilli germplasm lines were grouped into four and three clusters in first year and second year, respectively by Highest intra-cluster D^2 values (468.96) and genetic distance (21.85) in first year was estimated for cluster III and maximum inter-cluster D^2 values (984.71) and genetic distance (31.38) were recorded between cluster II and III followed by cluster I and III (816.43 and 28.57). In second year, cluster I had maximum intra-cluster D^2 values (824.91) and genetic (28.72) were recorded between cluster II and III followed by cluster I and II (747.37 and 27.34).

Fifty five chilli genotypes were grouped into 5 groups (G_1, G_2, G_3, G_4, G_5) using Ward-MLM procedure by Sudre *et al.* (2010). Group G_1 was formed by 12 accessions of *C. annuum* var. *annuum* and only one accession of *C. baccatum* var. *pendulum*. Group G_2 was represented by six accessions, five of *C. frutescens* and one of *C. chinense*. Group G_3 consisted of 13 accessions of *C. baccatum*, of which eleven belonged to *C. baccatum* var. *pendulum* and two to *C. baccatum* var. *baccatum*.

Chattopadhyay *et al*. (2011) conducted an experiment to identify the most promising chilli variety suited for green and dry purposes, to study the genetic variability for different traits and to assess the association of different yield attributing traits with the green and dry yield of chilli. Thirty four genotypes were characterized during a 2 year period. Most of the genotypes possessed the character constellation of *C. annuum*.

Lahbib *et al*. (2012) studied eleven populations of chilli and were grouped into three clusters where cluster one contained six genotypes and cluster two and cluster three contained four and one genotypes respectively.

Srinivas *et al*. (2013) conducted experiment with 78 chilli (*Capsicum frutescens* L.) genotypes which were collected from different parts of Kerala. Fifteen quantitative characters and one qualitative character were taken into consideration. Mahalanobis D^2 statistics was employed to study genetic divergence among 78 genotypes and they were grouped into nine clusters on the basis of relative magnitude of D^2 values using Euclidean method. Cluster II accommodated maximum number (24) of genotypes and minimum with cluster III (1 genotype).The inter cluster distances (D values) ranged between 3.90 to12.68. Minimum inter cluster distance was between cluster II and IV (3.90) and maximum inter cluster distance was observed between cluster VII and VIII (12.68). The intra cluster divergence varied from 3.32 to 5.45. Maximum intra cluster distance was achieved in cluster VIII (5.45) and minimum divergence was observed in cluster V (3.32). Cluster III was showed zero intra cluster distance as it contains only one genotype. The maximum relative contribution to the total divergence was made by fruit yield per plant (61.07 %) and cluster VIII and cluster IX may be taken into consideration as better parents for an efficient hybridization programme of chilli.

Magaji *et al.* (2014) grouped chilli into eight clusters and Group VIII recorded the highest cell membrane thermo stability and yield. Group IV recorded 13 genotypes while Groups II, VII, and VIII recorded one each. The results showed that the availability of genetic variance could be useful for exploitation through selection for further breeding purposes.

Yatung *et al*. (2014) conducted genetic diversity studies with 30 chilli (*Capsicum annuum* L.) genotypes of Indian origin. Twelve quantitative characters *viz.* plant height, number of primary branch per plant, days to first flowering, fruit length , fruit diameter , number of fruit per plant, average fruit weight, green fruit yield per plant, number of seed per fruit, ascorbic acid , capsaicin content and chlorophyll content were taken into consideration. The analysis of variance revealed considerable variability among the genotypes for the character studied. Cluster analysis was used for grouping of 30 chilli genotypes under the study grouped into six clusters. Cluster III had maximum (14) and cluster IV and V had the minimum number (1) of genotypes. The highest (459.81) inter cluster distance was observed between cluster II and IV and the lowest (36.04) between cluster I and IV. Cluster III (D^2= 67.66) have exhibited highest intra cluster distance and the lowest was observed in cluster II (D^2=11.19). The characters capsaicin content and ascorbic acid contributed maximum towards divergence. Considering diversity pattern and other horticultural performance the genotypes CHFC-7 from cluster VI, genotype CHFC-27 from cluster II and

CHFC-15 from cluster III may be taken into consideration as better parents for an efficient hybridization programme of chilli.

Janaki *et al*. (2015) conducted an experiment to analyze the genetic diversity among 63 genotypes for ten quantitative and six qualitative characters in chilli. The analysis of variance revealed significant differences among the genotypes for all the characters studied. Based on hierarchical cluster analysis, the 63 genotypes were grouped into 8 clusters. Among the clusters, cluster II was the largest containing 18 genotypes followed by cluster III with 15 genotypes and cluster VIII had only one genotype. The highest inter cluster distance was observed between cluster IV and VIII (7941.63) whereas the lowest was observed between cluster VI and VIII (2836.497). The Cluster VII exhibited highest intra cluster distance (614.54) and the lowest was observed in cluster VIII (0.00). The maximum contribution towards genetic divergence was shown by fruit diameter (44.14%) followed by yellow carotenoids (16.90%), red carotenoids (10.45%), ascorbic acid (10.19%) and capsaicin (9.17%). The principal component analysis revealed that first six principal components with Eigen value more than one were observed to contribute 76.83 per cent towards the total variability. Among the six principal components, PC1 contributed maximum towards variability (25.06%). Considering diversity pattern and horticultural performance, the genotypes Warangal chapatta, LCA-702, LCA-724, LCA-756, LCA-353 and LCA-716 were identified as promising parents and could be utilized for efficient hybridization in chilli.

Zehra *et al*. (2015) evaluated 64 genotypes. Significant divergence existed among 64 chilli genotypes almost for all the traits. The genotypes under study were grouped into eight clusters as per Mahalnobis D^2 (1928) analysis employing Tocher's method with maximum number of genotypes in cluster I (37) followed by cluster IV (12), cluster II (6),cluster V (5) and rest of the clusters were monogenotypic. Maximum inter cluster distance was observed between clusters II and VI (19369.21), while maximum intra-cluster distance was observed in cluster IV (4230.34). The per cent contribution towards the total genetic divergence revealed that plant spread (29.76%), seed yield per plant (25.69%), average fruit weight (17.41%), number of fruits per plant (10.22%), days to first flower (4.01%),fruit length (4.76%), number of branches per plant (4.51%) and fruit diameter (2.88%)were the major contributing characters towards total genetic divergence. The crosses between the genotypes from cluster VI with II and VIII and cluster VIII with those of I, III and IV are likely to exhibit high heterosis and produce recombinants with desired traits in segregating generations.

Srivastava *et al*. (2016) studied genetic divergence using Mahalnobis D^2 statistics using 13 yield traits in 37 genotypes of chilli (*Capsicum annuum* L.). D^2 analysis clustered the genotypes into seven groups and indicated sufficient diversity among the genotypes tested. Cluster-I was the biggest cluster with13 genotypes followed by cluster-IV with 11 genotypes. Cluster-III recorded maximum intra-cluster distance (51.85).Maximum inter-cluster distance (345.23) was recorded between cluster-IV and VII. Cluster-VII and cluster-III recorded desirable mean values for six and three traits, respectively. Among 13 yield traits studied, fresh fruit yield per plant, number of seeds per pod and fruit diameter had the maximum contribution towards genetic diversity. The traits number of primary branches per plant, number of secondary branches per plant and fresh fruit weight per pod had no contribution towards genetic divergence. The diverse lines may be utilized in crop improvement by exploiting heterosis or by transgressive breeding.

MATERIAL AND METHODS

The present investigation entitled **"Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm.''** was undertaken to study genetic variability, heritability, genetic advance, character association, path coefficient analysis and genetic divergence of different genotypes of chilli at All India Co-ordinated Research Project on Vegetable Crops, Orissa University of Agriculture and Technology, Bhubaneswar. The Details of materials used and methodology utilized in the investigation are presented in this chapter.

3.1 Cropping history of the plot

In the experimental plot cowpea was grown in the previous season. The plot was properly ploughed, levelled and brought to proper tilth before transplanting of chilli.

3.1.1 Soil

A composite soil sample was taken from depth of 15 cm surface from the experimental field before raising the crop for investigation. The sample was subjected to lab analysis to determine the physical and chemical composition of the soil by the following methods presented in table 3.1.

Table 3.1 soil nutrient status

S. No.	Properties	Value (2017-18)	Method employed
Mechanical Composition of the soil			
1.	Sand	85.8%	Bouyoucos hydrometer
2.	Silt	6.0%	
3.	Clay	8.2%	
4.	Texture class	Loamy sand	Textural diagram(International system)
Chemical Composition of the soil			
1.	Soil reaction (pH)	4.45	1:2(soil: water) suspension using glass electrode pH meter (Jackson, 1973)
2.	Organic carbon (%)	0.31	Walkley and Black's titration method (Walkley, 1934)
3.	Electrical conductivity(dSm^{-1})	0.169	1:2(soil: water) suspension using the conductivity bridge
4.	Available nitrogen (kg per ha)	137.5	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available phosphorus (kg per ha)	10.87	Bray's method(Bray and Kurtz,1945)
6.	Available potassium (kg per ha)	462.33	Neutral normal ammonium acetate using Flame photometer (Jackson,1973)

3.2 Geographical location of the experimental site

The experiment was carried out during the *rabi* season of 2017-18 at Research plots of AICRP on Vegetable crops under Orissa University of Agriculture and Technology. The location of the farm is situated about 7 km away from the university campus.

3.3 Topography and Climate conditions

Geographically, the experimental site falls under the eleventh agro-climatic region of the country *i.e.* eastern coastal plain and is termed as sub-humid characterized by warm moist climate with mild winter and is located at the latitude of $20^0 15'$ N and longitude of $85^0 52'$E. It is about 60 km away from Bay of Bengal having an altitude of 25.5 m above mean sea level. The average annual rainfall of Bhubaneswar is 1552 mm (Based on average of preceding 10 years). Most of the rainfall i.e. 85% is received from July to September. The rainfall code of the place is D_1 E_3 $(B_1A_2B_1)$ $C_1D_1E_2$. The average temperature varies from 14^0 C in winter, 40^0 C in summer and 30^0C in rainy season. Relative humidity varies between 49 and 90%.

3.4 Experimental details

(i) Design of Layout	:	Randomized Block Design (RBD)
(ii) Number of Genotypes	:	34
(iii) Number of Replications	:	3
(iv)Total no. of plots	:	102
(v) Each Plot size in experiment		
a) Length	:	2.5m
b) Width	:	2m
c) Area	:	$5m^2$
(vi) Spacing		
a) Row to Row	:	60cm
b) Plant to Plant	:	40cm
(vii) Number of rows per plot	:	4
(viii) Number of plants per row	:	5
(ix) Number of plants per plot	:	20
(x) Width of the bund separating blocks	:	30 cm
(xi) Width of irrigation channel	:	100 cm

3.4.1 Experimental material

The experimental material consisted of thirty four genotypes collected from different regions of nation are presented in table 3.2.

Table 3.2 Sources of chilli genotypes (*Capsicum annuum* L.)

Genotypes	Name	sources
1	Utkal Rashmi	AICRP on Vegetable crop, OUAT
2	BC-7-2-2	AICRP on Vegetable crop, OUAT
3	BC-24-1	AICRP on Vegetable crop, OUAT
4	BC-7-2-1	AICRP on Vegetable crop, OUAT
5	BC-79-1	AICRP on Vegetable crop, OUAT
6	BC-27-2-2	AICRP on Vegetable crop, OUAT
7	BC-25	AICRP on Vegetable crop, OUAT
8	BC-28	AICRP on Vegetable crop, OUAT
9	BC-40-3-1-1	AICRP on Vegetable crop, OUAT
10	BC-40-2-1-1	AICRP on Vegetable crop, OUAT
11	BC-40-2	AICRP on Vegetable crop, OUAT
12	BC-21	AICRP on Vegetable crop, OUAT
13	BC-30	AICRP on Vegetable crop, OUAT
14	BC-7-1-1	AICRP on Vegetable crop, OUAT
15	BC-20	AICRP on Vegetable crop, OUAT
16	BC-70-2	AICRP on Vegetable crop, OUAT
17	BC-406	AICRP on Vegetable crop, OUAT
18	BC-5-1-7	AICRP on Vegetable crop, OUAT
19	BC-78-1	AICRP on Vegetable crop, OUAT
20	BC-78-1-2	AICRP on Vegetable crop, OUAT
21	BC-43	AICRP on Vegetable crop, OUAT
22	MANIPUR LOCAL 1	AICRP on Vegetable crop, OUAT
23	MANIPUR LOCAL 2	AICRP on Vegetable crop, OUAT
24	ARKA ABHIR	IIHR, Bengaluru
25	ARKA LOHIT	IIHR, Bengaluru
26	ARKA SUPHAL	IIHR, Bengaluru
27	BYADAGI KADDI	GKVK, Bengaluru
28	LAM -358	LAM, Guntur, AP
29	LAM-620	LAM, Guntur, AP
30	LAM-625	LAM, Guntur, AP
31	ANURAGHA(KAU)	KAU, Kerala
32	UJWALA(KAU)	KAU, Kerala
33	PUSA SADABAHAR	IARI, New Delhi
34	KUNCHINDA LOCAL	Local collection, AICRP, , OUAT

3.5 Cultural practices

3.5.1 Nursery raising

Nursery beds of 4m x 1m size were prepared after bringing the soil to a fine tilth. Each bed was mixed with 5 kg of FYM. The beds were leveled properly and seeds of 34 genotypes were sown in lines at 5 cm spacing. Mulching was done with dry paddy straw. Nursery beds were regularly watered. The mulch was removed after germination of seeds and beds were kept free from weeds. As a precaution against "Damping off" disease of the seedlings, the beds were drenched with Carbendazim 2g/L and steptocyclin 1g/10L on 12th and 21st day after sowing. Five weeks old, uniform healthy seedlings from each genotypes were transplanted in the main experimental plots.

3.5.2 Preparation of experimental plot

The experimental fields were brought to fine tilth by ploughing thrice followed by harrowing. Before final harrowing, FYM @ 25 tonnes/ha was applied as basal dose and incorporated in the soil. The recommended dose of fertilizers at 120:60:30 kg NPK/ha in the form of urea, single super phosphate and murate of potash respectively were applied. Entire dose of P was applied as basal while N and K were applied in three equal splits during the crop growth.

3.5.3 Transplanting and after care

Five weeks old seedlings were transplanted to the main field after allotting entries randomly in each replication. The field was irrigated and the seedlings were transplanted by maintaining a spacing of 60 cm between the rows and 40 cm between the plants with in a row. Immediately after transplanting the field was irrigated lightly. The plots were kept free of weeds and irrigated regularly. Need based plant protection measures were taken up to keep the plot free from pests / diseases and raise a healthy crop.

E

FARM ROAD

BOND

R1	R2	R3
1	21	34
2	22	33
3	23	32
4	24	31
5	25	30
6	26	29
7	27	28
8	28	27
9	29	26
10	30	25
11	31	24
12	32	23
13	33	22
14	34	21
15	1	20
16	2	19
17	3	18
18	4	17
19	5	16
20	6	15
21	7	14
22	8	13
23	9	12
24	10	11
25	11	10
26	12	9
27	13	8
28	14	7
29	15	6
30	16	5
31	17	4
32	18	3
33	19	2
34	20	1

PUMP HOUSE

Figure 3.1 Layout plan of experimental field

Sowing of chilli seeds

Field preparation for the experiment

transplanting of chilli seedlings

field view of the experiment

Overall view of experiment

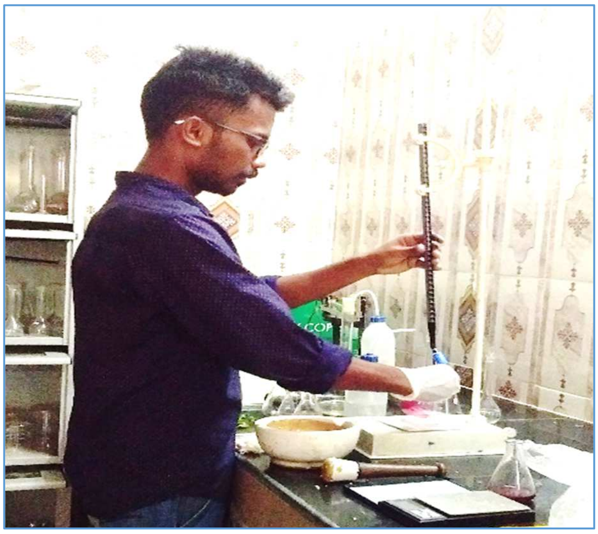
3.2 Field activities

Tagging of plants

Application of fertilizers

Spraying of pesticide

Recording the parameters



Chilli plant at fruiting stage

Estimation of quality parameters

3.2 Field activities

3.6 Biometric observations

3.6.1 Sampling procedure

Five randomly selected plants from each entry were tagged in each replication for recording observations on different characters as described below and the mean values were calculated.

3.6.2 Quantitative characters

The observations on following characters were recorded during the course of investigation.

Vegetative growth parameter

1. Number of branches per plant
2. Leaf area
3. Plant height
4. Plant spread EW
5. Plant spread NS

Flowering parameter

1. Days to initial flowering
2. Days to 50 % flowering

Yield and yield attributing parameters

1. Fruit length
2. Fruit girth
3. Pedicel length
4. Number of seeds per fruit
5. Average fresh fruit weight
6. Average dry fruit weight
7. Number of fruits per plant
8. Yield per plant
9. Yield per plot
10. Yield per hectare

Quality parameters:

1. TSS (˚Brix)
2. Ascorbic acid (mg /100g)

3.6.3 Observational procedure

The observations were recorded for the characters mentioned above using the following procedure from the five selected sample plants.

1) Days to first flowering:

Days to first flowering was recorded by the number of days taken from date of transplanting to initial flowering in a plot was recorded.

2) Days to 50 % flowering

Days to 50 % flowering was recorded number of days taken from the date of transplanting till 50% plants start flowering in a plot was recorded.

3) Plant height

Height of the plant was measured from the ground level to the tip of the plant in centimeters at the time of final harvest.

4) Number of primary branches

The number of branches produced by the five tagged plants per each treatment was counted and the average was calculated.

5) Plant spread (E-W)and (N-S)

The plant spread diameter of tagged plants was horizontally measured in cm in the east-west and north-south directions and the mean of five plants calculated separately for the east-west and north-south directions.

6) Leaf area

Five fully grown leaves were collected from five tagged plants at active growth stage and leaf area was recorded with leaf area meter in cm^2. The mean value was calculated as leaf area.

7) Fruit length

The lengths of ten fruits randomly selected from observational plot of each genotype in each replication, were measured in cm from the attachment end (stalk end) to the tip (stylar end) and the mean values were calculated as fruit length.

8) Fruit girth

Ten fruits selected randomly from each plot in a replication for recording of length were also used for noting their girth at the point of maximum thickness, which were averaged and expressed in cm.

9) Pedicel length

Pedicel length of ten fruits selected from tagged plants were used for computation of data

10) Average fresh fruit weight

Ten healthy fruits randomly selected from tagged plants of each genotype in each replication were taken for recording the average fresh weight and the mean values were calculated and expressed in grams. Fruits selected for recording weight were also used for recording the length and girth.

11) Average dry fruit weight

Ripe fruits were taken for recording fresh fruit weight and were sun dried and ten fruits were taken for weighing to average dry weight.

12) Number of seeds per fruit

The number of seeds from ten fruits from five randomly selected plants was counted and average was worked out.

13) Number of fruits per plant

The total number of fruits harvested at different pickings in the sample plants was counted and the mean values were calculated.

14) Fruit yield per plant

Observation for this character was recorded by sun drying of the total number of red ripe fruits harvested from the five tagged plants per plot at different pickings in each replication and the mean of five plants was expressed in terms of grams per plant.

15) Fruit yield per plot

Red ripe fruits harvested from each plot at different pickings till last harvest in each replication were sun dried and recorded in grams.

16) **Fruit yield per hectare**

The yield obtained from each plot was converted to yield per hectare.

3.6.4 Morphological characters

17) **Fruit position**

The fruit position of the genotype was noted as pendent and erect (upright).

18) **Mature green fruit colour**

The fruit color of the genotype at mature green stage was noted as green, dark green and light green.

19) **Fruits per axil**

Fruits per axil were noted as solitary and cluster.

3.6.5 Biochemical analysis

The following procedures were used for estimating the biochemical constituents:

20) **Ascorbic acid (mg /100 g)**

The biochemical analysis was done for ascorbic acid content, for which mature green fruits were used. Ascorbic acid content of mature green fruits was estimated by volumetric method (Sadasivam and Balasubramanian, 1987).

Dye solution: Dye solution was prepared by dissolving 42 mg of sodium bicarbonate in distilled water taken in 200 ml volumetric flask, to which 52 mg of 2-6 dichlorophenol indophenol was added and the volume was made up to 200 ml with distilled water.

Standard Stock solution: Stock solution was prepared by dissolving 100 mg ascorbic acid in 100 ml of 4% oxalic acid solution and 10 ml of this stock solution was diluted to100 ml with 4% oxalic acid to get the working standard of 100 mg per ml.

Procedure: Five milliliters of the working standard solution was pipetted into a 100 ml conical flask to which 10 ml of 4% oxalic acid was added. The contents were titrated against the dye (V_1ml) to get a pink end point. The chilli sample (5 g) was extracted in 4% oxalic acid and the volume was made up to 100 ml and the contents were centrifuged. 5 ml of this supernatant was pipetted out, to which 10 ml of 4 per cent oxalic acid was added and titrated against the dye (V_2 ml). The ascorbic acid content was calculated using the formula given below.

$$\text{Amount of ascorbic acid (mg/100 g) sample} = \frac{0.5mg}{V_1} \times \frac{V_2}{5ml} \times \frac{100ml}{\text{Wt. of the sample}} \times 100$$

21. Total soluble solids of juice (TSS, ^{0}Brix)

Fresh fruit sample from different treatments were taken and cut into four pieces. Fruits were crushed by using hand pestle. Single drop of extracted juice was put in hand refracto meter for estimation of total soluble solids (TSS). The results were expressed in ^{0}Brix.

3.7 Statistical analysis

The data recorded for various characters were subjected to statistical analysis based on their sample means (Gomez and Gomez, 1983). Observations of all the 19 characters were analyzed for variability and other genetic parameters related to fruit yield (fruit yield per plant) were taken for character association, path analysis and genetic divergence studies.

Analysis of variance

The analysis of variance for each of the characters stated was done to find out varietals differences. The analysis was carried out separately for each trait following the procedure of randomized block design analysis (Panse and Sukhatme, 1954).

Analysis of variance was done on the basis of the following model.

$$Y_{ij} = m + g_i + r_j + e_{ij}$$

Where,

Y_{ij} = Phenotypic observation in the i^{th} genotype and the j^{th} replication

m = General mean

g_i = Effect of the i^{th} genotype/treatment

r_j = Effect of j^{th} replication

e_{ij}= random error associated with i^{th} genotype and j^{th} replication

Analysis of variance and expected mean sum of square

Source of variation	D.f.	SS	MSS	F ratio
Replication	(r-1)	RSS	RMSS	RMSS/EMSS
Genotype	(g-1)	GSS	GMSS	GMSS/EMSS
Error	(r-1)(g-1)	ESS	EMSS	
Total	(rt-1)	TSS		

3.7.1 Mean, Range, Standard Error and Critical Differences

Sample mean values were calculated for each character by dividing the total by corresponding number of observations, while the highest and lowest values for each character were taken as the range. The S.E. and C.D. values were calculated by using the following formula.

Standard error mean (SEM) = $\sqrt{\frac{EMSS}{r}}$

Critical difference (C.D.)

= $\sqrt{\frac{2EMSS}{r}}$ × t value at error d.f. at 5% and 1% level of significance

Where,

r = number of replications

EMSS = Error mean sum of square

3.7.2 Co-efficient of variation

For comparing the variability of two or more than two characters, co-efficient of variation were calculated by using the formula given below:

C.V. = $\frac{SD}{X}$ ×100 = $\sqrt{\frac{EMSS}{X}}$ ×100

Where,

S.D. = Standard deviation which is the square root of mean square due to error (EMS)

X = Experimental mean

From the structure of the analysis of variance

$$\text{Error variance} = \sigma^2 e = \frac{EMSS}{r}$$

$$\text{Genotypic variance} = \sigma^2_g = \frac{GMSS - EMSS}{r}$$

$$\text{Phenotypic variance} = \sigma^2_p = \quad = \sigma 2_g + \sigma^2_e$$

Where, EMSS=error mean sum of square

GMSS=genotype mean sum of square

The genotypic co-efficient of variation (GCV) and the phenotypic co-efficient of variation (PCV) were calculated by the formula given by Burton (1952).

$$\text{GCV \%} = \frac{\text{Genotypic standard deviation}}{\text{Grand mean}} \text{X } 100$$

$$\text{PCV\%} = \frac{\text{Phenotypic standard deviation}}{\text{Grand mean}} \text{ X } 100$$

3.7.3 Heritability (broad sense)

The heritability estimates were used to measure the degree of correspondence between phenotypic value and breeding value. It is worked out by using the formula suggested by Lush (1949) and Burton and Devance (1953) and expressed in percentage according to Weber and Moorty (1952).

$$h^2 \text{ (broad sense)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

$$h^2 \text{ (broad sense in percentage)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

3.7.4 Expected genetic advance

Genetic advance was estimated as per the formula suggested by Johnson *et al.* (1955).

$$GA = K \text{ x } h^2 \text{x } \sigma_p$$

Where,

K = Selection differential in standard units (which is 2.06 per 5% selection intensity).

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

GA expressed as percentage of mean = $\frac{GA}{Mean} \times 100$

The genetic advance as percent over mean was categorized as mentioned below (Johnson et al., 1955)

Less than 10% = Low

10-20%   =Moderate

More than 20%=High

3.7.5 Estimation of correlation co-efficient

Simple correlation co-efficient were computed at phenotypic and genotypic levels between pairs of 15 important characters that contribute to fruit yield (fruit yield per plant) using the following formula.

Genotypic correlation (r_g) = $\frac{\sigma_g(xy)}{\sigma_g(x)} \times \sigma_g(y)$

Phenotypic correlation (r_p) = $\frac{\sigma_p(xy)}{\sigma_p(x)} \times \sigma_p(y)$

Where,

σ_g (xy) = Genotypic co-variance between the two traits x and y.

σ_p(xy) = Phenotypic co-variance between the two traits x and y.

σ_g(x) and σ_g (y) = Genotypic standard deviation for x and y respectively.

σ_p(x) and σ_p (y) = Phenotypic standard deviation for x and y respectively.

The estimated values were compared with the table value at (n - 2) and at 5% and 1%levels of significance in order to test the significance of correlation co-efficient at phenotypic and genotypic level.

3.7.6 Path co-efficient analysis

The cause and effect relationships among the various correlated characters are determined by path co-efficient analysis. Path co-efficient are standardized partial regression coefficients which individually provide a measure of direct effect of the causal factors on the effect variable. These permit partitioning of the correlation between causal factors and the effect of variables, into components of direct and indirect effect and thus give a better picture of the association of the causal factors with the effect variable.

In the present investigation, dry fruit yield per plant was taken as the effect with other characters like plant height, number of branches, leaf area, plant spread ,days to first flowering, days to 50% flowering, number of fruits per plant, fruit length, fruit girth, and average fruit weight related to this as the causal factors.

The path coefficients were obtained by solving the following simultaneous equations which give the basic relationship between correlations and path coefficients in a system of correlated causes. (Dewey and Lu, 1959)

$$r_{112} = r_{11}p_{112} + r_{12}p_{112} + r_{13}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + r_{111}p_{1112}$$

$$r_{212} = r_{21}p_{112} + r_{22}p_{112} + r_{23}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + r_{211}p_{1112}$$

$$r_{312} = r_{31}p_{112} + r_{32}p_{112} + r_{33}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + r_{311}p_{1112}$$

$$r_{1112} = r_{111}p_{112} + r_{112}p_{212} + r_{113}p_{312} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. + p_{1112}$$

Where, r_{ij} is the coefficient of correlation between i^{th} and j^{th} characters and p_{qi} is the path coefficient (direct effect of i^{th} character on fruit yield per plant (1, 2).

The solutions for path coefficients, direct and indirect effects of the causal factors were estimated as the values of the individual terms of the above equations in R.H.S.

The coefficient of determination (R^2) and the residual effect ($p_{12.R}$) were calculated as follows:

$$I = p^2_{12.R} + \Sigma p_{iy}r_{iy}$$

$$R^2 = \Sigma p_{iy}r_{iy}$$

$$= p_{112}r_{112} + p_{212}r_{212} + p_{312}r_{312} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. + p_{1112}r_{1112}$$

$$P_{12.R} = \sqrt{1 - R^2}$$

The path analysis at the phenotypic level with the same cause and effect relationship was computed using the phenotypic correlations as stated earlier.

3.7.8 Genetic divergence

Mahalanobis (1928) generalized distance, D^2 – statistic was used for computing genetic divergence as described by Rao (1952). The original measurements were transformed to standardized uncorrelated variables by pivotal condensation (Rao, 1952).The divergence between any two varieties was obtained as the sum of squares of the difference in the values of the corresponding transformed values (V_{ij})

$$D^2_{jk} = \Sigma^n_{i=1} Y_i j - Y_i k$$

Gives the D^2 between j^{th} and k^{th} genotypes for 'n' characters. The all possible 561 pairs of D^2 were calculated from the 34 genotypes of chilli using the formula

$$n(n-1)/2$$

Following Tocher's method as described by Rao (1952), the genotypes were grouped into clusters. The criterion of grouping was that any two genotypes belonging to the same cluster should have a smaller D^2 value than those between genotypes belonging to different clusters. Inter and intra-cluster distances were determined and represented.

RESULTS

The present experiment entitled "**Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm**" was conducted at Horticultural Research Station, AICRP on Vegetable Crops, OUAT, Bhubaneswar, India, during *rabi* season of 2017-18 with an objective to study the nature and extent of genetic variability in Chilli genotypes for yield, yield attributing traits and quality parameters. The results of the present investigation are presented under following sections.

4.1 Analysis of variance of the growth, yield and quality parameters

4.2 Mean performance of genotypes with respect to growth, yield, attributing traits and quality parameter.

4.3 Characterization of genotypes with respect to fruiting pattern and color

4.4 Estimates of genetic parameters in respect of growth, yield attributing traits and quality parameters

4.5 Character association and path analysis

4.6 Genetic divergence

4.1 Analysis of variance of the growth, yield and quality parameters

The study of genetic variability was carried out by analysis of variance for 17 characters presented in Table 4.1. Which revealed significant difference among the genotype for all the characters except plant spread EW and NS. The high degree of experimental precision was maintained during the study was evident from the CVe values which were below 18% for all the characters. the CVe was highest in fruit yield per plant (17.07%), followed by number of fruits plant plants (15.98%), ascorbic acid (11.94%), plant height (11.10%) and plant spread NS (10.55%). it can be attributed to the influence of environmental fluctuations on this character. similarly CVe values were estimated to the below for all the character being the least for pedicel length (4.78%).

Table 4.1 Analysis of variance for 17 characters of 34 genotypes of chilli.

Sl. No	character	Mean sum of square		
		Replications	**Genotypes**	**Error**
1	Plant height(cm)	58.604	292.067**	108.454
2	Number of branches per plant	0.002647	1.213**	0.05008
3	Leaf area(cm^2)	3.688	205.998**	7.050
4	Plant spread EW(cm)	72.842	66.033	41.414
5	Plant spread NS (cm)	30.439	43.781	31.483
6	Days to initial flowering	2.701	92.095**	8.378
7	Days to 50 % flowering	36.425	86.131**	12.482
8	Fruit length(cm)	0.0219	5.789**	0.2000
9	Fruit girth(cm)	0.000056	1.241**	0.0482
10	Pedicel length(cm)	0.000694	0.816**	0.024
11	Number of fruits per plant	385.138	2530.238**	246.599
12	Average fresh fruit weight(g)	0.171	2.360**	0.072
13	Average dry fruit weight(g)	0.001518	0.0865**	0.002215
14	Number of seeds per fruit	28.778	250.99**	10.06
15	Yield per plant(g)	110.911	1080.66**	71.24
16	TSS (˚Brix)	0.003039	1.954**	0.0255
17	Ascorbic acid (mg/100g)	1.729	269.737**	23.941

*: significant at 5 percent level, **: significant at 1% level

4.2 Mean performance of genotypes with respect to growth, yield, attributing traits and quality parameter

The mean performance of 34 chilli genotypes is presented in Table 4.2.

4.2.1 Growth parameters

Plant height

Significantly wide variation was observed for plant height. Plant height varied from 70.47 to 110.33 cm, with an average plant height of 93.76 cm. The genotype BC-20 (110.33) recorded the highest plant height and it was found to be at par with BC-43 (107.07 cm), BC-25(106.4 cm) BC-40-3-1-1(105.53 cm). The lowest plant height was observed in Pusa Sadabahar (70.47 cm) followed by Ujwala (KAU) (70.73)

Number of branches per plant

The genotype LAM-625 recorded significantly maximum number of primary branches per plant (5.83) followed by Kunchinda local (5.12 cm), LAM-620(4.93).The lowest number of primary branches was observed in BC-20 (2.68). The average mean value of the character was 3.94 which ranges from 2.68 to 5.83

Leaf area

The genotype Pusa Sadabahar recorded significantly maximum leaf area (46.92 cm^2) than other genotype except Ujwala (KAU) (46.66 cm^2), BC-78-1(44.2cm^2) and Arka suphal (42.7cm^2) which where statistically at par. Whereas the lowest leaf area was observed in the genotypes Utkal Rashmi (21.12cm^2). Leaf area varied from 21.12 $cm^2$to 46.9 cm^2 with a mean value of 36.15cm^2

Plant spread EW

Plant spread for East-West ranges from 41.42 to 60.31 cm with a mean value of 51.24 cm. The maximum plant spread was recorded in BC-27-2-2. (60.31 cm) followed by Kunchinda local (58.72cm) Byadgi kaddi (58.06cm). The lowest value of plants spread was observed in Ujwala (41.42cm) followed by Pusa Sadabahar (42.64cm).

Plant spread NS

Plant spread from North-South ranged from 44.44 to 60 cm with an average mean of 53.18cm. The maximum plant spread was recorded in BC-79-1(60.00cm) followed by BC-70-2(58.61cm).The lowest plant spread was recorded in Ujwala (KAU) (44.44cm), followed by Pusa sadabahar (45.84cm).

4.2.2 Yield and yield attributing character

Days to initial flowering

The days to initial flowering ranged from 37.33 days to 60.33 days. BC-28 (37.33), BC-43 (39.30), BC-25 (39.67) and Arka Suphul (39.67) were earlier in flowering than the rest of the genotypes. The genotype Pusa Sadabahar (60.33) was found to be late in flowering along with Ujwala (KAU) (55.67) and LAM-625 (54.67).

Days to 50% flowering

The results on days to 50% flowering revealed significantly variation exist among the tested genotypes. Days to 50% flowering varied from 46.0 to 69.97 days. The genotype BC-43 (46.00) is found to be earliest in days to 50% flowering followed by BC-25 (46.67), BC-28(46.67) and Manipur local-1(46.67).The genotype Pusa Sadabahar (69.97) was found to late in days 50% flowering, along with Ujwala (64.70), LAM-625(60.33) and LAM-620(60.33)

Fruit length

Fruit length was varied from 2.98 cm to 9.72 cm with an average value of 6.49 cm. the highest fruit length was recorded in Arka Abhir (9.72 cm) followed by BC-7-1-1 (6.98 cm). The lowest fruit length was observed in BC-7-2-2 (2.98 cm) genotype.

Fruit girth

Fruit girth ranged from 2.00 cm to 5.08 cm. The highest fruit girth was observed in genotype BC 7-2-2 (5.08 cm) followed by BC- 79-1 (5.03 cm) and these two were statistically at par with each other. The lowest fruit girth was recorded in LAM-625 (2.00 cm). The average fruit girth was 3.5cm.

Pedicel length

Significant variation was observed for pedicel length and which varied from 1.83 cm to 4.53 cm with an average pedicel length of 3.24 cm. Significantly highest pedicel length was recorded in genotype LAM-620 (4.53 cm) followed by Byadgi Kaddi (4.1 cm) and Ujwala (KAU) (4.0 cm). The lowest pedicel length was observed in BC-27-2-2 (1.83 cm).

Number of fruits per plant

Results on number of fruits for plant recorded significant variation among the genotypes which ranges from 38 to 147.20, with a mean value of 98.41. Significantly highest fruits per plant observed in BC-43 (147.20) except Utkal Rashmi (140.20) BC-25 (138), BC-78-1-2 (131.20), BC-79-1 (131.20), BC-406 (126.5), BC-27-2-2 (127.5) and BC-24-1 (126.20) which were *statistical at par* for number of fruits per plant the lowest 120 of fruit per plant observed in Manipur local-2 (38).

Average fresh fruit weight (g)

The genotype Arka Abhir recorded maximum average fresh fruit weight of 5.91 g followed by BC-5-1-7 (4.08 g), BC-7-2-1 (3.61 g), and LAM-620 (3.60 g). On the other hand the lowest fruit weight was observed in Pusa Sadabahar (1.36 g). However the range varied from 1.36 to 5.91 cm with mean of 2.69 g of average fresh fruit weight.

Average dry fruit weight (g)

Significant variation were observed for average dry fruit weight. Which ranged from 0.27 to 1.15 g with a mean of 0.50g. The highest average of dry fruit weight was observed in genotype Arka Abhir (1.15 g) followed by Byadgi kaddi (0.74 g), BC-28 (0.68 g). The lowest average dry fruit weight recorded in Pusa Sadabahar (0.27 g).

Number of seeds per fruit

Seeds for fruits ranged from 33.63 to 72.60 with an average of 46.55, significantly highest seeds per fruit was recorded in BC-21 (72.60), followed by BC-30 (60.6), Manipur local 2 (64.07) and Arka Suphul (62.40). The lowest seeds per fruit was recorded in Ujwala (KAU) (33.63) genotype.

Dry fruit yield per plant (g)

The results revealed that significant difference between the genotype for fruit yield per plant which varied from 13.67 to 78.71 with mean value of 49.55 g, Nineteen number of genotypes recorded more than the average value of 49.55 g. per plant .Among the genotypes BC-28 (78.71) produced significantly maximum fruits per plant whereas BC-5-1-7(76.91), BC-78-1-2 (73.47), BC-78-1 (69.74), BC-24-1 (69.41), Utkal Rashmi (65.89) and LAM-620 965.32) were *statistically at par*. The lowest fruit yield per plant were observed in genotype Manipur local-2 (13.67).

Fruit yield per plot (g)

There was significant difference found in genotype which ranges from to 228.60 g to 1529.20 g. fruit yield per plot. The highest fruit yield per plot was recorded in genotype BC-28 (1529.20 g) which significantly differed with other genotypes except BC-7-2-1 (1404.50 g), BC-5-1-7 (1493.24 g), BC-78-1-2 (1424.44 g), BC-78-1 (1349.82 g), BC-24-1 (1343.20 g), Utkal Rashmi (1272.8 g) and Arka Abhir (1335.0 g) which were *statistically at par*.The lowest fruit yield per plot were recorded in Manipur local 2 (228.60 g) genotypes

Fruit yield per hectare (q)

The fruit yield per plant is ranged from 4.11 q/ha (Manipur local) to 27.53 q/ha (BC-28).

4.2.3 Quality parameters

TSS (^{0} brix)

Significantly highest TSS (^{0}brix) of 4.7 was observed in Utkal Rashmi and BC-20 closely followed by Pusa Sadabahar (4.5), Anuragha (4.4). Similarly significantly lowest TSS was observed in the genotype BC-25 (2.1) and Manipuri local (2.1).

Ascorbic acid (mg per 100g)

The ascorbic acid (mg per 100g) content of chilli fruits among genotypes varied significantly ranging from 22.64 to 66.66 with an mean value of 40.97.The result indicates that significantly highest ascorbic acid content in BC-40-2 (66.66) followed by BC-21 (61.69) and Utkal Rashmi (52.27). The lowest ascorbic acid content was recorded in BC-20(22.64)

4.3 Characterization of genotypes with respect to fruiting pattern and color

Morphological characters like fruit position, mature green fruit color and number of fruits per axil of all accessions are given in Table 4.3

Fruit position

All the 34 genotypes, based on fruit position were divided into two group's *viz.*, Pendent and Erect. Among them, maximum number of genotypes had pendent fruits while only eight (BC-7-2-1, BC-40-2-1-1, BC-40-2, BC-7-1-1, BC-20, BC-43, Ujwala (KAU) and Pusa Sadabahar) genotypes produced erect fruits.

Mature green fruit colour

Based on immature fruit colour, the 34 genotypes were divided into three group's *viz.*, Green, light Green and Dark Green. Among them, maximum genotypes had green fruits, 13 genotypes had Light green fruits and 4 genotypes had dark green fruits.

Fruits per axil

The genotypes, based on fruits per axil were divided into two groups *viz.*, solitary and cluster. Among them, maximum genotypes produced solitary fruits except pusa sadabahar and Ujwala which had cluster bearing habit.

4.4 Estimates of genetic parameters in respect of growth, yield attributing traits and quality parameters

The estimates of genetic parameters such as mean, range, GCV, PCV, heritability, GA and GA as percentage of mean of different characters are presented in the Table 4.4

Range of variation

The data presented in the Table 4.4 revealed that range was the highest in case number of fruits per plant (38 to 147.20) followed by fruit yield per plant (13.67g to 78.71g), plant height (70.47 cm to 110.33 cm) and ascorbic acid content (22.64 to 66.66 mg per gram). The lowest range was observed in average dry fruit weight (0.27-1.15), pedicel length (1.83-4.53), fruit girth (2.00-5.08), fruit length (2.98-9.72) and TSS (2.10-4.70).

Regard the Grand mean results indicated wide variation ranging from average dry fruit wait (0.506 g) to number of fruits for plant (98.41).

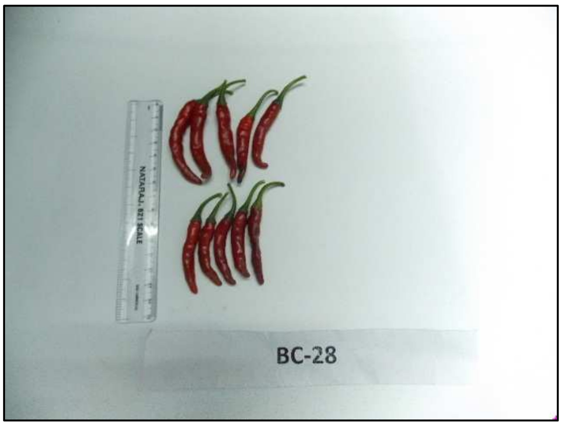
Table. 4.2 Mean performance for different charatcterin 34 chilli genotypes

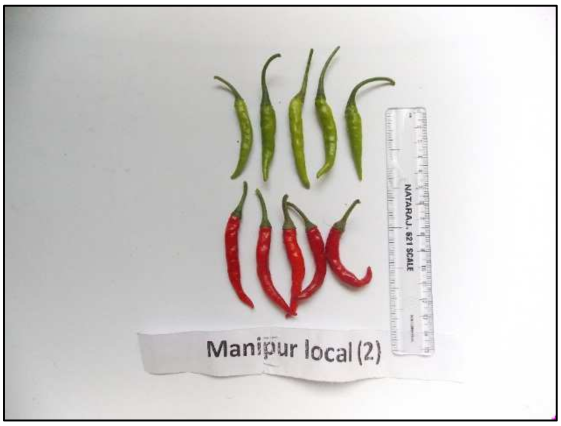
Genotypes	Plant Height (cm)	Branches/ plant	Leaf Area (cm²)	Plant Spread EW (cm)	Plant Spared NS (cm)	Days to initial flowering	Days to 50% Flowering	Fruit Length (cm)	Fruit Girth (cm)	Pedicel Length (cm)
Utkal Rashmi	90.07	3.17	**21.12**	48.89	53.33	41.00	47.33	7.40	3.60	2.28
BC-7-2-2	84.53	4.28	22.50	58.00	56.89	43.67	47.33	**2.98**	**5.08**	3.00
BC-24-1	98.47	3.30	23.68	55.19	58.89	43.67	48.67	6.22	4.13	2.73
BC-7-2-1	97.40	3.17	24.32	52.33	56.72	46.00	52.67	6.09	3.88	3.01
BC-79-1	87.87	4.00	23.90	56.78	**60.00**	43.33	49.33	5.80	5.03	**1.83**
BC-27-2-2	85.63	4.33	22.82	**60.31**	50.47	40.67	48.67	6.53	3.08	2.75
BC-25	106.40	4.17	22.08	48.22	56.11	39.67	46.67	7.00	3.70	2.90
BC-28	98.73	4.50	25.06	54.42	47.11	**37.33**	46.67	7.58	4.03	3.50
BC-40-3-1-1	105.53	3.50	34.46	51.44	50.67	40.00	48.33	6.32	4.08	3.10
BC-40-2-1-1	98.13	4.00	41.80	52.44	55.67	41.00	47.00	7.78	3.83	3.75
BC-40-2	92.53	3.67	41.52	50.44	53.31	41.33	49.67	5.88	3.27	3.20
BC-21	92.67	4.00	46.14	48.67	49.78	40.00	47.33	8.60	3.43	3.00
BC-30	81.53	3.83	41.44	44.67	55.33	47.67	52.00	6.98	3.85	3.37
BC-7-1-1	80.53	3.37	40.02	48.33	50.44	43.33	51.00	5.62	3.07	3.33
BC-20	**110.33**	**2.68**	40.16	44.89	49.31	42.67	50.00	5.92	3.50	3.75
BC-70-2	90.27	3.83	40.14	45.17	58.61	41.67	48.00	6.58	3.70	3.22
BC-406	103.20	4.00	37.14	54.44	50.33	40.33	48.33	7.13	3.50	3.14
BC-5-1-7	101.53	4.60	39.98	50.44	56.94	40.67	49.00	9.68	3.82	3.20
BC-78-1	93.07	4.00	44.20	48.61	50.14	41.67	47.67	6.65	4.18	3.75
BC-78-1-2	105.00	3.93	38.88	48.78	55.89	40.00	48.00	7.03	3.77	3.50
BC-43	107.07	3.50	39.40	48.56	53.89	39.30	**46.00**	5.36	4.16	2.85
Manipur Local 1	101.33	4.30	37.66	52.17	46.61	40.30	46.67	6.05	2.93	3.33
Manipur Local 2	100.60	3.23	36.32	49.00	54.56	41.33	47.33	5.94	2.90	3.00
Arka Abhir	90.60	4.17	41.72	50.36	53.58	41.67	49.67	**9.72**	4.47	3.45
Arka Lohit	94.27	3.67	38.92	54.78	52.44	40.67	49.33	5.88	2.73	3.20
Arka Suphal	86.27	3.95	42.70	54.06	53.42	39.67	46.67	6.56	3.37	3.45
Byadagi Kaddi	93.40	3.20	40.84	58.06	53.39	47.33	49.67	7.80	3.50	4.10
LAM -358	95.00	4.20	39.82	53.44	57.33	54.00	50.00	6.03	2.95	3.90
LAM-620	93.67	4.93	42.40	48.14	52.22	53.67	60.33	6.93	3.30	**4.53**
LAM-625	103.53	**5.83**	38.06	50.61	54.81	54.67	60.33	7.18	**2.00**	3.20
Anuragha (kau)	79.40	3.07	42.20	57.78	55.44	44.67	49.33	6.62	2.93	2.87
Ujwala (kau)	70.73	4.30	46.66	**41.42**	**44.44**	55.67	64.00	4.75	3.03	4.00
Pusa Sadabahar	**70.47**	4.20	**46.92**	42.64	45.84	**60.33**	**69.97**	3.92	3.37	3.45
Kunchinda Local	98.40	5.12	24.00	58.72	54.33	40.67	47.33	4.30	2.75	2.60
C.V.	**11.11**	**5.68**	**7.35**	**12.56**	**10.55**	**6.61**	**7.02**	**6.90**	**6.17**	**4.78**
C.D. 5%	**16.98**	**0.36**	**4.33**	**10.49**	**9.15**	**4.72**	**5.76**	**0.73**	**0.36**	**0.25**

Table. 4.2 continued

Genotypes	Number of Fruits Per Plant	Average Fresh Fruit Weight (g)	Average Dry Fruit Weight (g)	No.of Seeds/ Fruit	Dry Fruit Yield Per Plant (g)	Yield Per Plot (g)	Yield Per hacter(q)	TSS	Ascorbic acid(mg/100g)
Utkal Rashmi	140.20	2.62	0.47	43.50	65.89	1272.88	22.91	**4.70**	52.17
BC-7-2-2	105.60	2.92	0.52	38.83	54.91	1053.24	18.96	4.30	41.50
BC-24-1	126.20	3.07	0.55	42.33	69.41	1343.20	24.18	3.23	49.27
BC-7-2-1	111.50	3.61	0.65	52.67	72.47	1404.50	25.28	4.30	46.37
BC-79-1	131.20	2.72	0.49	40.83	64.29	1240.76	22.33	3.13	31.88
BC-27-2-2	127.50	2.04	0.36	44.73	45.90	873.00	15.71	3.23	34.99
BC-25	138.00	2.71	0.47	43.50	64.86	1252.20	22.54	**2.10**	37.33
BC-28	115.75	3.77	0.68	43.83	**78.71**	**1529.20**	**27.53**	2.90	40.56
BC-40-3-1-1	102.80	3.16	0.58	42.67	59.62	1147.48	20.65	2.30	43.47
BC-40-2-1-1	107.36	3.18	0.59	44.60	63.34	1221.85	21.99	2.30	56.60
BC-40-2	111.20	2.15	0.38	38.20	42.25	800.12	14.40	3.43	**66.66**
BC-21	98.20	2.82	0.51	**72.60**	50.08	956.64	17.22	3.23	61.69
BC-30	80.20	2.74	0.49	66.60	39.30	740.96	13.34	2.70	43.47
BC-7-1-1	78.20	2.46	0.40	42.13	31.28	580.60	10.45	3.23	34.78
BC-20	88.20	3.34	0.60	45.13	52.92	1013.40	18.24	**4.70**	**22.64**
BC-70-2	116.40	2.57	0.46	44.43	53.54	1025.88	18.47	2.30	40.37
BC-406	126.50	2.37	0.42	44.90	53.13	1017.60	18.32	2.20	46.37
BC-5-1-7	101.20	4.08	0.76	58.50	76.91	1493.24	26.88	3.80	33.96
BC-78-1	110.70	3.28	0.63	46.70	69.74	1349.82	24.30	3.33	26.88
BC-78-1-2	131.20	2.74	0.56	43.07	73.47	1424.44	25.64	3.23	28.98
BC-43	**147.20**	2.14	0.39	36.10	57.41	1103.16	19.86	4.30	37.73
MANIPUR LOCAL 1	45.00	1.60	0.33	47.00	14.85	252.00	4.54	**2.10**	30.11
MANIPUR LOCAL 2	**38.00**	2.00	0.36	64.07	**13.68**	**228.60**	**4.11**	3.33	41.50
ARKA ABHIR	60.00	**5.91**	**1.15**	40.43	69.00	1335.00	24.03	2.30	43.47
ARKA LOHIT	58.00	2.41	0.50	56.40	29.00	535.00	9.63	4.30	37.73
ARKA SUPHAL	64.00	2.35	0.43	62.40	27.52	505.40	9.10	2.70	43.47
BYADAGI KADDI	45.00	3.18	0.74	46.23	33.30	621.00	11.18	3.03	35.20
LAM -358	95.26	1.90	0.43	44.90	40.96	774.24	13.94	3.80	44.50
LAM-620	100.50	3.60	0.65	45.73	65.32	1261.50	22.71	3.90	40.55
LAM-625	120.40	1.80	0.41	37.17	49.36	942.28	16.96	4.10	46.20
ANURAGHA(KAU)	78.64	1.84	0.40	47.17	31.45	584.12	10.51	4.40	26.41
UJWALA(KAU)	90.60	1.73	0.31	**33.63**	28.09	516.72	9.30	3.33	38.96
PUSA SADABAHAR	80.20	**1.36**	**0.27**	**33.63**	21.65	388.08	6.99	4.50	40.96
KUNCHINDA LOCAL	75.20	1.57	0.28	48.40	21.05	376.12	6.77	2.70	46.37
C.V.	**15.96**	**9.97**	**9.29**	**6.81**	**17.03**	**16.87**	**12.83**	**4.79**	**11.94**
C.D. 5%	**25.60**	**0.44**	**0.08**	**5.17**	**13.76**	**260.20**	**3.56**	**0.26**	**7.98**

Fig. 4.1 Fruits of different genotypes of chilli

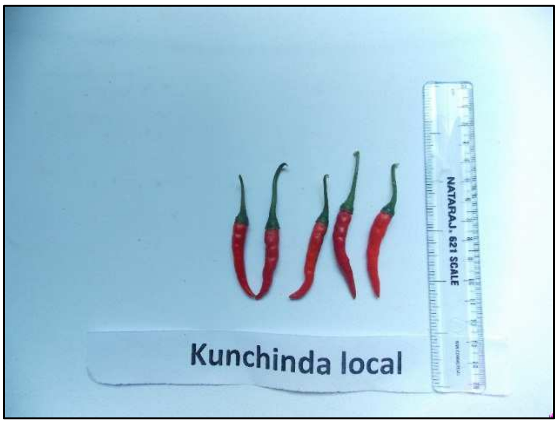

NATARAJ. 621 SCALE
BC-28


NATARAJ. 621 SCALE
Manipur local (2)


NATARAJ. 621 SCALE
BC-20


Pusa sadabahar


NATARAJ. 621 SCALE
Byadagi


NATARAJ. 621 SCALE
Kunchinda local


NATARAJ. 621 SCALE
BC-25


NATARAJ. 621 SCALE
BC-30


NATARAJ. 621 SCALE
BC-40-2-1-1

Table 4.3. Variation in morphological features of chilli

Genotypes		Fruit position	Fruit per axil	Mature green fruit Color
1.	Utkal Rashmi	Pendent	Solitary	Green
2.	BC-7-2-2	Pendent	Solitary	Green
3.	BC-24-1	Pendent	Solitary	Light green
4.	BC-7-2-1	Erect	Solitary	Light green
5.	BC-79-1	Pendent	Solitary	Green
6.	BC-27-2-2	Pendent	Solitary	Green
7.	BC-25	Pendent	Solitary	Light green
8.	BC-28	Pendent	Solitary	Green
9.	BC-40-3-1-1	Pendent	Solitary	Light green
10.	BC-40-2-1-1	Erect	Solitary	Light green
11.	BC-40-2	Erect	Solitary	Dark green
12.	BC-21	Pendent	Solitary	Green
13.	BC-30	Pendent	Solitary	Light green
14.	BC-7-1-1	Erect	Solitary	Green
15.	BC-20	Erect	Solitary	Light green
16.	BC-70-2	Pendent	Solitary	Light green
17.	BC-406	Pendent	Solitary	Green
18.	BC-5-1-7	Pendent	Solitary	Light green
19.	BC-78-1	Pendent	Solitary	Green
20.	BC-78-1-2	Pendent	Solitary	Green
21.	BC-43	Erect	Solitary	Green
22.	MANIPUR LOCAL 1	Pendent	Solitary	Light green
23.	MANIPUR LOCAL 2	Pendent	Solitary	Green
24.	ARKA ABHIR	Pendent	Solitary	Dark green
25.	ARKA LOHIT	Pendent	Solitary	Green
26.	ARKA SUPHAL	Pendent	Solitary	Green
27.	BYADAGI KADDI	Pendent	Solitary	Dark green
28.	LAM -358	Pendent	Solitary	Light green
29.	LAM-620	Pendent	Solitary	Dark green
30.	LAM-625	Pendent	Solitary	Light green
31.	ANURAGHA(KAU)	Pendent	Solitary	Light green
32.	UJWALA(KAU)	Erect	Cluster	Green
33.	PUSA SADABAHAR	Erect	Cluster	Green
34.	KUNCHINDA LOCAL	Pendent	Solitary	Green

Coefficient of variation

The estimation of Coefficient error variation CV ranged from pedicel length (4.78%) to dry fruit yield per plant (17.03 %) relatively high CV value were observed for number of fruits for plant (15.95 %) and plants spread (12.55 %) and plant height (11.10 %) then rest of characters recorded lower CV

The phenotypic coefficient of variation (PCV) ranged from 11.22% in case of plants spread EW to 40.75% in case of fruit yield per plant. PCV was moderate (10 to 20%)for 8 characters viz., plant spread NS (11.22%), Days to 50% flowering (12.10%), Days to initial flowering (13.75%), plant spread (13.75%), plant height (13.89%), number of primary branches (16.79%) and fruit girth (18.78%). Relatively higher PCV (>20%) was observed in rest of the characters.

The GCV values were lower than PCV with range of 3.81% (plant spread NS) to 37.02 %(dry fruit yield per plant).This happened because PCV estimates include the variation due to environment (E) and genotype and environment (GE) interaction. The maximum difference in magnitude of GCV and PCV was found in plant spread EW (5.59%-13.75%) , plant spreads NS (3.81%-11.22%), plant height (8.34%-13.89%), fruit yield per plant (37.02-40.75%) and ascorbic acid (22.09-25.11%),similarly relatively low different of GCV and PCV for primary branches, leaf area, Days to initial flowering, days to 50% flowering, fruit length, fruit girth, pedicel length, Average fresh fruit weight, average dry fruit weight, number of seeds per fruit and TSS indicated that there are mostly governed by genetic factors and minor effect of environments. Hence simple selection followed on the phenotypic variation mean most given worth while improving there fruits.

Relatively higher value for GCV for character fruit yield per plant (37.02%), average dry fruit weight (33.10%), Average fresh fruit weight (32.37%) and number of fruit per plant (28.08%) indicated better scope for genetic important in the character through simple selection

Heritability

The heritability estimates for 17 characters ranged from 11.52 % in case of plant spread (NS) to 96.18 % in TSS. Average dry fruit weight (92.69 %), pedicel length (91.66 %), average fresh fruit weight (91.33 %), leaf area (90.39 %) and fruit length (90.27 %) recorded above 90% heritability. Similarly, fruit girth (89.19 %), number of seeds per fruit (88.87 %) and number of branches per plant (88.87 %), ascorbic acid (77.39%) and number of fruits per plant (75.33 %) and days to 50 % flowering (66.29 %) showed above 60 % but below 90 % heritability. Plant height (36.08 %), plant spread EW (16.54 %) and plant spread NS (11.52 %) showed low heritability.

Genetic advance

The range of genetic advance (GA) among different character varied from 0.33% in dry fruit weight to 49.90% in number of fruits per plant (Table 4.4)

The GA as % of mean was found to be range of 2.66% (plant spread NS) to69.28% (fruit yield per plant). Expected GA was found to be low (<10%) for traits like plant spreads EW (4.68 %). Similarly moderate value of expected GA (10-20%) was recorded for plant height (10.32 %), days to 50% flowering (16.52 %), whereas relatively higher value of GA as % of mean (>20%) was recorded for rest of the characters.

4.5 Character Association

The relationship of different characters with yield at genotypic and phenotypic level is presented in Table 4.5. The correlation estimates at phenotypic level (r_p) and at genotypic level (r_g) showed close correspondence for all character understudy. It was evident from the Table 4.5 that for most of the character pairs, the genotypic and phenotypic association were in same direction.

4.5.1 Phenotypic and genotypic correlations

The data presented in the Table 4.5 and Figure 2 revealed that phenotypic correlation r_p ranged from 0.236 (between fruit length and plant height) to 0.913 (between average fresh fruit weight to average dry fruit weight). Out of 105 estimates of r_p only 43 were found significant and among that 23 were positively significant, 20 were negatively significant and all other remaining r_p were recorded as non-significant

Table 4.4. Estimation of mean, range, component of variance, heritability and genetic advance for 17 characters in 34 genotypes in chilli (*Capsicum annuum* L.)

Sl. No	Character	Mean	Range		ECV (%)	GCV (%)	PCV (%)	h^2 (b) (%)	GA	GAM
			Min	max						
1.	Plant height (cm)	93.77	70.47	110.33	8.34	11.10	13.89	36.08	9.68	10.32
2.	Number of branches per plant	3.94	2.68	5.83	15.80	5.67	16.79	88.57	1.21	30.64
3.	Leaf area (cm^2)	36.15	21.12	46.92	22.53	7.34	23.70	90.39	15.95	44.12
4.	Plant spread EW (cm)	51.24	41.42	60.31	5.59	12.55	13.75	16.54	2.40	4.68
5.	Plant spread NS (cm)	53.18	44.44	60.00	**3.81**	10.55	**11.22**	**11.52**	1.42	**2.66**
6.	Days to initial flowering	43.81	37.33	60.33	12.06	6.60	13.75	76.91	9.54	21.78
7.	Days to 50% flowering	50.30	46.00	69.97	9.85	7.02	12.10	66.29	8.31	16.52
8.	Fruit length (cm)	6.49	2.98	9.72	21.02	6.90	22.12	90.27	2.67	41.13
9.	Fruit girth (cm)	3.56	2.00	5.08	17.73	6.17	18.78	89.19	1.23	34.50
10.	Pedicel length (cm)	3.24	1.83	4.53	15.85	**4.78**	16.56	91.66	1.01	31.27
11.	Number of fruits per plant	**98.42**	38.00	147.20	28.03	15.95	32.26	75.53	**49.40**	50.19
12.	Average fresh fruit weight (g)	2.70	1.36	5.91	32.37	9.96	33.87	91.33	1.72	63.72
13.	Average dry fruit weight (g)	**0.51**	0.27	1.15	33.10	9.29	34.38	92.69	**0.33**	65.64
14.	Number of seeds per fruit	46.56	33.63	72.60	19.25	6.81	20.42	88.87	17.40	37.38
15.	Fruit yield per plant (g)	49.55	13.67	78.71	**37.02**	**17.0**	**40.75**	82.53	34.33	**69.28**
16.	TSS (^{0} brix)	3.34	2.10	4.70	24.02	4.79	24.50	**96.18**	1.62	48.54
17.	Ascorbic acid(mg/100 g)	40.97	22.64	66.66	22.09	11.94	25.11	77.39	16.40	40.03

The genotypic correlation coefficient presented in Table 4.5 and Figure 3 value ranged from 0.224 (between fruit length and plant spread NS (cm) to 1.643 between plant spread EW to plants spread NS). Out of 105 r_g estimates of r_g 67 were significant and among that 37 were positively significant, 30 were negatively significant and all the remaining r_g were recorded as non-significant.

4.5.2 Correlation of fruit yield with other yield component

At phenotypic level dry fruit yield per plant was positively and significantly correlated with fruit length, fruit girth, average fresh fruit weight, average dry fruit weight, number of fruits for plant, plant height. However it had positive and non-significant correlation with other characters like number of primary branches, plant spread EW and plant spread NS.

The traits like days to flower initiation and leaf area exhibited significantly negative correlation with dry fruit yield per plant and characters like pedicel length, seeds per fruit, and days to 50% flowering showed negative and non-significant correlation with dry fruit yield per plant component at phenotypic level.

At genotypic level dry fruit yield per plant was positive and significantly correlated with fruit length (0.507), fruit girth (0.646), average fresh fruit weight (0.726), average dry fruit weight (0. 659), number of fruits per plant (0.767), plant height (0.530) and plants spread NS (0.759). However it had positive and non-significant correlation with other characters like number of fruits per plant and number of branches. Significantly negative correlation was observed with days to initial flowering, days to 50% flowering and leaf area with dry fruit yield per plant.

4.5.3 Correlation among other yield attributing traits

Fruit length showed positive and significant correlation with number of seeds per fruit (0.338 and 0.378), average fresh fruit weight (0.597 and 0.639), average dry fruit weight (0.633 and 0.681), and plant height (0.236 and 0.378) at both phenotypic and genotypic level respectively.

Fruit girth at both phenotypic and genotypic level produced positive and significant relation with average fresh fruit weight (0.545 and 0.599), average dry fruit weight (0.474 and 0.510), and fruits per plant (0.320 and 0.380). Fruit girth shows negative and significant correlation with the days to initial flowering (-0.269

and -0.335) days to 50 percent flowering (-0.267 and - 0.334), leaf area (-0.282 and -0.313) and number of primary branches (- 0.219 and -0.238) at both phenotypic and genotypic level indicating that simultaneous selection for these traits is not possible.

Pedicel length showed significant and positive correlation with dry fruit weight (0.253 and 0.278), days to initial flowering (0.377 and 0.441), days to 50% flowering (0.323 and 0.398) and leaf area (0.612 and 0.664) at both PCV and GCV level. It shows negative and significant with the character number of fruits per plant (-0.318 and -0.385) and plant spread NS (-0.232 and -0.741) at both PCV and GCV level indicating that these characters associated very strongly at genotypic level.

Number of seeds per fruit at both phenotypic and genotypic level produced negative and significant correlation with fruits per plant (-0.351 and -0.412), days to initial flowering (-0.251 and -0.338), days to 50% flowering (-0.273 and -0.390). Whereas, it was positively and significantly correlated with plant spread NS (0.266) at genotypic level

Average fresh fruit weight recorded positive and significant correlation with fruit length (0.597 and 0.639), fruit girth (0.545 and 0.599) and fruit yield per plant (0.646 and 0.726) at both phenotypic and genotypic level. It was negative and significantly correlated with the days to initial flowering (-0.226 and -0.302) at both phenotypic and genotypic level. It is positively non-significantly correlated with pedicel length and plant height (0.159) at genotypic level

Average dry fruit weight (g) at both phenotypic and genotypic level expressed significant and positive association with the fruit length (0.633 and 0.681), fruit girth (0.474 and 0.510) and pedicel length (0.253 and 0.278).At both phenotypic and genotypic level it showed positive and non-significant association with number of seeds per fruit(0.068 and 0.078), leaf area (0.041 and 0.034), plant spread EW (0.051 and 0.088) which clearly indicated the independent nature of two characters and selection for average dry fruit weight is not reliable.

Number of fruits for plants recorded positive and significant correlation with fruit girth (0.320 and 0.380) at both genotypic and phenotypic level. But, it is negatively and significantly correlated with pedicel length (-0.318 and -0.385), number of seeds per fruit (-0.351 and -0.412), and leaf area (-0.383 and -0.452).it was found positively and non-significant with the fruit length (0.036 and 0.025)

Table4.5 Phenotypic and Genotypic correlation coefficient between all pairs of quantitative characters studied in chilli

No	Character		Fruit Length (cm)	Fruit Girth (cm)	Pedicel Length (cm)	Number of Seeds/ Fruit	Avg. Fresh Fruit Weight (g)	Avg. dry Fruit Weight (g)	Number of Fruits Per Plant	Days to initial flowering	Days to 50% Flowering	Leaf Area (cm²)	Plant Height (cm)	Primary Branches	Plant Spread EW (cm)	Plant Spread NS (cm)	Fruit Yield Per Plant (g)
1	Fruit Length (cm)	**p**	**1**	0.033	0.112	0.338**	0.597**	0.633**	0.036	-0.256**	-0.223*	0.191	0.236*	0.044	-0.045	0.088	**0.396****
		g	**1**	0.048	0.152	0.378**	0.639**	0.681**	0.025	-0.318**	-0.297**	0.187	0.376**	0.047	0.02	0.224*	**0.507****
2	Fruit Girth (cm)	**p**		**1**	-0.19	-0.124	0.545**	0.474**	0.320**	-0.269**	-0.267**	-0.282**	0.002	-0.219*	0.077	0.178	**0.586****
		g		**1**	-0.239*	-0.142	0.599**	0.510**	0.380**	-0.335**	-0.334**	-0.313**	0.039	-0.238*	0.072	0.608**	**0.646****
3	Pedicel Length (cm)	**p**			**1**	-0.037	0.185	0.253*	-0.318**	0.377**	0.323**	0.612**	0.005	0.114	-0.185	-0.232*	**-0.059**
		g			**1**	-0.035	0.200*	0.278**	-0.385**	0.441**	0.398**	0.664**	-0.102	0.136	-0.642**	-0.741**	**-0.078**
4	Number of Seeds/ Fruit	**p**				**1**	0.084	0.068	-0.351**	-0.251*	-0.273**	0.129	0.023	-0.124	0.014	0.061	**-0.158**
		g				**1**	0.099	0.078	-0.412**	-0.338**	-0.390**	0.154	0.135	-0.147	0.094	0.266**	**-0.168**
5	Avg. Fresh Fruit Weight (g)	**p**					**1**	0.913**	0.027*	-0.226*	-0.188	-0.036	0.159	-0.076	0.009	0.085	**0.646****
		g					**1**	0.991**	0.034	-0.302**	-0.241*	-0.051	0.300**	-0.1	-0.025	0.384**	**0.726****
6	Avg. dry Fruit Weight (g)	**p**						**1**	-0.056	-0.19	-0.162	0.041	0.181	-0.066	0.051	0.091	**0.580****
		g						**1**	-0.065	-0.197*	-0.206**	0.034	0.288**	-0.072	0.068	0.402**	**0.659****
7	Number of Fruits Per Plant	**p**							**1**	-0.121	-0.05	-0.383**	0.183	0.101	0.094	0.106	**0.605****
		g							**1**	-0.147	-0.128	-0.452**	0.308**	0.114	-0.217*	0.627**	**0.767****
8	Days to initial flowering	**p**								**1**	0.779**	0.323**	-0.323**	0.215*	-0.202*	-0.02	**-0.243***
		g								**1**	0.986**	0.349**	-0.655**	0.326**	-0.604**	-0.426**	**-0.282****
9	Days to 50% Flowering	**p**									**1**	0.335**	-0.380**	0.279**	-0.239*	-0.263**	**-0.175**
		g									**1**	0.386**	-0.634**	0.348**	-0.911**	-0.665**	**-0.257****
10	Leaf Area (cm²)	**p**										**1**	-0.193	-0.022	-0.354**	-0.228*	**-0.295****
		g										**1**	-0.266**	-0.010	-0.827**	-0.652**	**-0.336****
11	Plant Height (cm)	**p**											**1**	-0.032	0.082	0.184	**0.251****
		g											**1**	0.019	0.210*	0.329**	**0.530****
12	Primary Branches	**p**												**1**	-0.011	-0.055	**0.038**
		g												**1**	0.190	-0.126	**0.034**
13	Plant Spread EW (cm)	**p**													**1**	-0.035	**0.06**
		g													**1**	0.991**	**-0.091**
14	Plant Spread NS (cm)	**p**														**1**	**0.136**
		g														**1**	**0.759****

*Significance level @ 5% and ** Significance level @ 1%

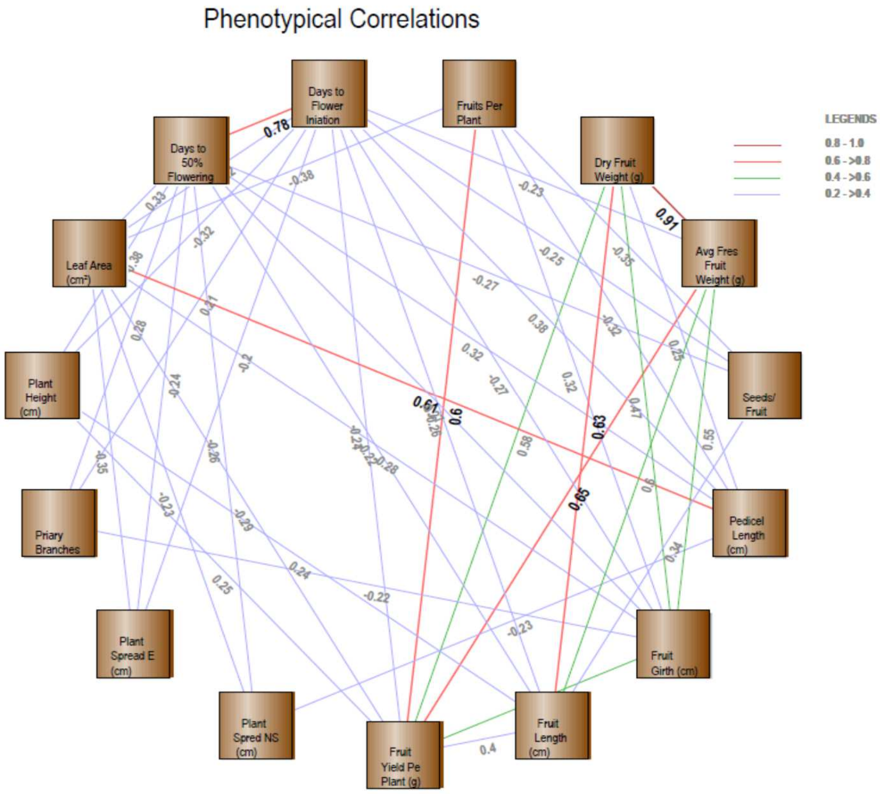


Fig. 4.2 Phenotypic correlation coefficient between all pairs of characters studied in chili

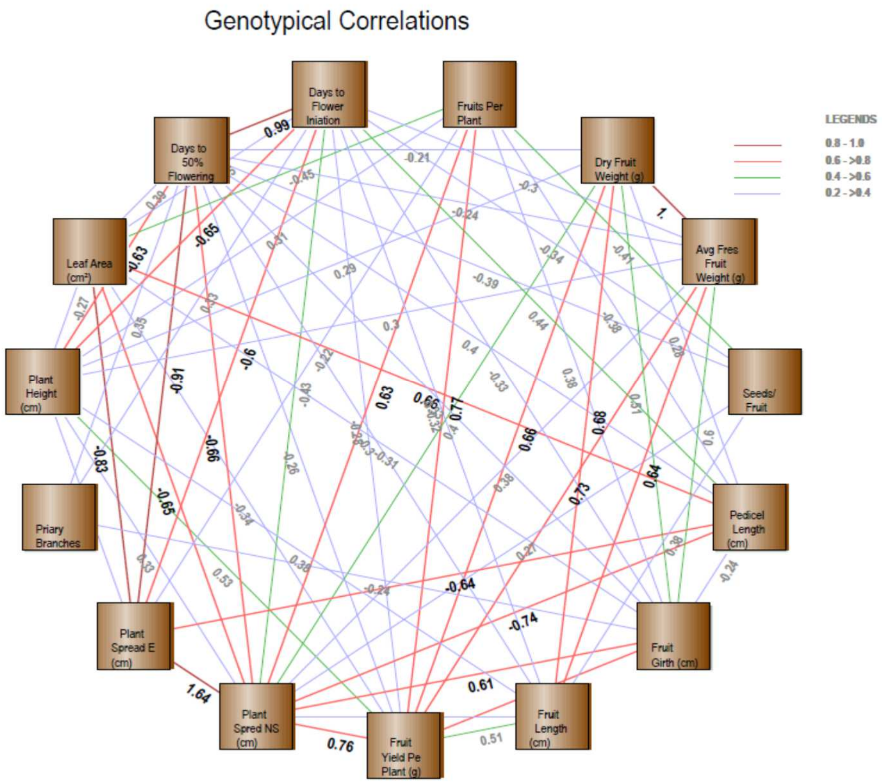


Fig. 4.3 Genotypic correlation coefficient between all pairs of characters studied in chili

Days to initial flowering at both phenotypic and genotypic level it showed negative and significant correlation with fruit length (-0.256 and -0.318), fruit girth (-0.289 and -0.335), number of seeds per fruit (-0.251 and -.0.251), average fresh fruit weight (-0.226 and -0.302), plant height (-0.323 and -0.655). It is positively and significantly correlated with the characters like leaf area (0.323 to 0.349) and number of primary branches (0.215 and 0.326).

Days to 50% flowering was positively and significantly correlated with character like leaf area (0.335 and 0.385), number of primary branches (0.279 and 0.348) and days to initial flowering (0.779 and 0.906) at both phenotypic and genotypic level respectively. Whereas, it is negatively and significantly correlated with character like fruit girth (-0. 267 and -0.334) and number of seeds per fruit (-0.273 and - 0.390) at both phenotypic and genotypic level.

Leaf area showed negative and significant correlation with the characters fruit girth (-0.282 and -0.313), number of fruits per plant (0.383 and -0.452), plant spread EW (-0.354 and -0.827) at both phenotypic and genotypic level. At the genotypic level it is negatively and significant correlated with plant height (-0.266)

4.5.4 Path coefficient analysis

In the present study direct and indirect effect of different quantitative characters on dry fruit yield per plant were estimated through path analysis at phenotypic level presented in Table: 4.6 and Figure 4

Number of fruits per plant had the direct positive effect (0.544) on dry fruit yield per plant. It exhibited high correlation with yield (0.605) via fruit girth (0.044) and leaf area (0.044).

The direct effect of average fresh fruit weight (0.302) was positive and it showed significant positive correlation with yield (0.646) via average dry fruit weight (0.201), fruit girth (0.075) and fruit length (0.026).

Average dry fruit weight showed positive direct effect (0.220) on fruit yield per plant and it exhibited high correlation with yield (0.580) viaaverage fresh fruit weight (0.276),fruit girth (0.065),and fruit length (0.028) andpedicel length (0.022).

Fruit length showed positive direct effect (0.044) on fruit yield per plant and it exhibited high positive correlation with yield (0.396) via average fresh fruit weight (0.180) and average dry fruit weight (0.139).

Fruit girth shows positive direct effect (0.137) on fruit yield per plant and it exhibited positive correlation with yield (0.586) via average fresh fruit weight (0.165), average dry fruit weight (0.104) and number of seeds per fruit (0.174).

Pedicel length showed positive direct effect (0.086) on fruit yield per plant and it exhibited negative correlation with yield (-0.059) via number of seeds per fruit (-0.173).

Number of seeds per fruit recorded positive direct effect (0.015) on fruit yield per plant and it exhibited negative correlation with yield (-0.158) via number of fruits per plant (-0.191),

Leaf area showed the negative direct effect (-0.114) on yield per plant and it exhibited negative correlation with the yield (-0.295).

Days to flower initiation showed negative direct effect on fruit yield per plant (-0.038) and it exhibited negative correlation with the (-0.243).

Days to 50% flowering showed positive direct effect (0.026) and negative correlation with the yield (-0.175).

Plant height showed a positive direct effect (0.033) and positive correlation with yield (0.251)

Number of branches showed positive direct effect on dry fruit per plant (0.039) and positive correlated with the yield (0.038)

Plant spread EW showed negative direct effect (-0.042) and exhibited positive correlation with yield (0.060)

Plant spread NS showed negative direct effect (-0.002) on dry fruit yield per plant and positive correlated with the yield (0.136)

Table4.4.6: Estimate of direct (diagonal) and indirect effect of component characters on yield in chilli genotypes

No	Character	Fruit Length (cm)	Fruit Girth (cm)	Pedicel Length (cm)	Seeds/ Fruit	Avg Fresh Fruit Weight (g)	Avg. Dry Fruit Weight (g)	No. Fruits Per Plant	Days to initial Flowering	Days to 50% Flowering	Leaf Area (cm²)	Plant Height (cm)	Primary Branches	Plant Spread EW (cm)	Plant Spread NS (cm)	Fruit Yield Per Plant (g)
1.	Fruit Length (cm)	**0.044**	0.005	0.010	0.005	0.180	0.139	0.020	0.010	-0.006	-0.022	0.008	0.002	0.002	0.000	**0.396**
2.	Fruit Girth (cm)	0.002	**0.137**	-0.017	-0.002	0.165	0.104	0.174	0.010	-0.007	0.032	0.000	-0.009	-0.003	0.000	**0.586**
3.	Pedicel Length (cm)	0.005	-0.026	**0.086**	-0.001	0.056	0.056	-0.173	-0.014	0.008	-0.070	0.000	0.005	0.008	0.000	**-0.059**
4.	Seeds/ Fruit	0.015	-0.017	-0.003	**0.015**	0.025	0.015	-0.191	0.010	-0.007	-0.015	0.001	-0.005	-0.001	0.000	**-0.158**
5.	Avg. Fresh Fruit Wt. (g)	0.026	0.075	0.016	0.001	**0.302**	0.201	0.015	0.009	-0.005	0.004	0.005	-0.003	0.000	0.000	**0.646**
6.	Avg.Dry Fruit Weight (g)	0.028	0.065	0.022	0.001	0.276	**0.220**	-0.031	0.007	-0.004	-0.005	0.006	-0.003	-0.002	0.000	**0.580**
7.	Fruits Per Plant	0.002	0.044	-0.028	-0.005	0.008	-0.012	**0.544**	0.005	-0.001	0.044	0.006	0.004	-0.004	0.000	**0.605**
8.	Days to initial flowering	-0.011	-0.037	0.033	-0.004	-0.068	-0.042	-0.066	**-0.038**	0.020	-0.037	-0.011	0.008	0.009	0.000	**-0.243**
9.	Days to 50% Flowering	-0.010	-0.037	0.028	-0.004	-0.057	-0.036	-0.027	-0.030	**0.026**	-0.038	-0.012	0.011	0.010	0.001	**-0.175**
10.	Leaf Area (cm²)	0.008	-0.039	0.053	0.002	-0.011	0.009	-0.208	-0.012	0.009	**-0.114**	-0.006	-0.001	0.015	0.000	**-0.295**
11.	Plant Height (cm)	0.010	0.000	0.000	0.000	0.048	0.040	0.100	0.012	-0.010	0.022	**0.033**	-0.001	-0.004	0.000	**0.251**
12.	Primary Branches	0.002	-0.030	0.010	-0.002	-0.023	-0.015	0.055	-0.008	0.007	0.003	-0.001	**0.039**	0.000	0.000	**0.038**
13.	Plant Spread EW (cm)	-0.002	0.011	-0.016	0.000	0.003	0.011	0.051	0.008	-0.006	0.040	0.003	0.000	**-0.043**	0.000	**0.060**
14.	Plant Spread NS (cm)	0.004	0.024	-0.020	0.001	0.026	0.020	0.058	0.001	-0.007	0.026	0.006	-0.002	0.002	**-0.002**	**0.136**

4.6 D^2 Analysis

The genetic divergence study was done following Mahalanobis D^2 statistics as described by Rao (1952). The magnitude of D^2 values indicated considerable genetic diversity among genotypes. D^2 value for all the 561 combinations ranged from 17.99 to 1116.72. The least value 17.99 was observed between BC-70-2 and BC-406. Where maximum D^2 value of 1116.72 was found between Pusa Sadabahar and Arka Abhir.

4.6.1 Group constellation using D^2 statistics

The 34 genotypes of chilli were grouped into 6 cluster on the basis of D^2value (Table 4.7). Cluster II was found to be largest with 12 genotypes namely, BC-40-2-1-1(10), BC-78-1(19), BC-78-1-2(20), BC-25(7), BC-28(8), BC-24-1(3), BC-7-2-1(4), Utkal Rashmi(1), BC-27-2-2(6), BC-20(15), BC-43(21) and BC-5-1-7. Cluster I was the second largest cluster with the 9 genotypes namely BC-70-2(16), BC-406(17), BC-40-2(11), BC-7-1-1(14), Anuragha(31), Arka Lohit(25), BC-40-3-1-1(9), BC-30(13) and Arka Suphal (26), followed by cluster IV (08 genotypes) namely, Ujwala (32), Pusa Sadabahar (33), LAM-358(28), Manipur local 1 (22), Kunchinda local (34), LAM-625 (30), LAM-620(29) and Byadagi Kaddi (27), cluster VI (03 genotypes) namely BC-7-2-2(2), BC-79-1(5) and Arka Abhir (24). The remaining two clusters i.e. cluster III (Manipur local 2) and cluster V (BC-21) comprised of single genotype.

4.6.2 Characterization of clusters

The cluster means in respect of 15 quantitative character is presented in Table 4.8amongclusters, cluster 3 and 5 included only a single genotype.

Cluster II recorded the highest mean value in respect of number of fruits per plant (120.41) and dry fruit yield per plant (65.92 g).

The genotypes included in cluster III was found to be superior in character plant height (100.60cm) and be earlier in days to 50% flowering (47.33 days)

In cluster IV recorded highest mean in respect of pedicel length (3.63 cm) and number of branches (4.51)

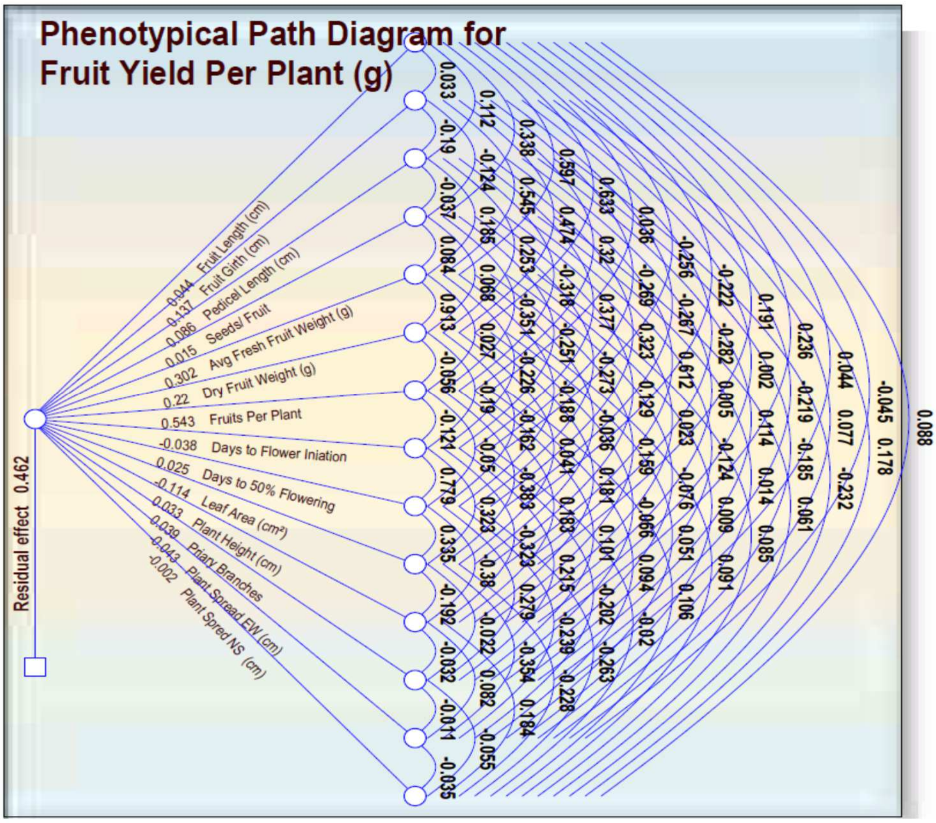


Fig.4. 4 Phenotypic path coefficient diagram for fruit yield per plant (g)

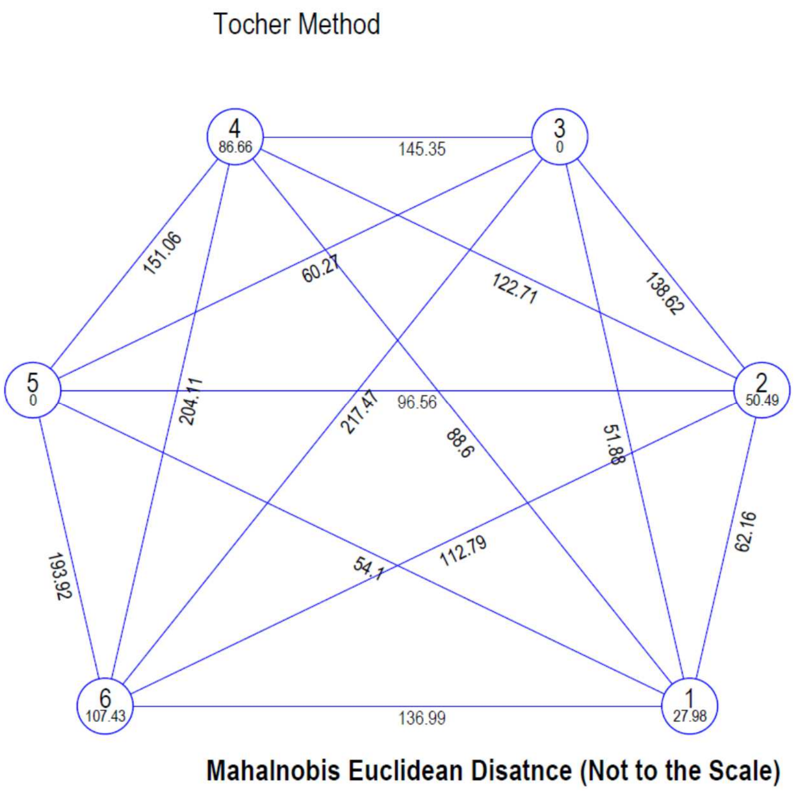


Fig. 5 Intra and inter cluster distance between six clusters of chilli genotypes

Cluster V recorded highest mean value for fruit length (8.6cm), number of seeds per fruit (72.6), leaf area (46.14cm^2) and earliest in days to initial flowering(40.00 days) as well as days to 50 % flowering (47.33 days)

Cluster VI was characterized with maximum plant spread both in EW (55.047) and NS (56.82) direction, maximum fruit girth (4.86cm), average fresh fruit weight (3.85g) and average dry fruit weight (0.72).

4.6.3 Intra and inter cluster distance

The estimates of intra and inter cluster distance based D^2 values is presented in Table 4.9and Figure 5.

Intra cluster distance was the highest in case of cluster VI (107.43) and the lowest was observed in cluster I (27.976). The intra cluster distance III and V was found to be zero as these two cluster contain single genotype.

The spectrum of inter cluster distances ranged from 51.88 (between I and III) to 217.46 (between cluster III and cluster VI).

The maximum inter cluster distance was observed between cluster III and VI followed by cluster IV and VI (204.108). The minimum inter cluster distance was observed between cluster I and III

4.6.4 Relative contribution of character towards divergence

For D^2 analysis 15 characters including (growth and yield parameter) were considered at a time (Table 4.10). Among the characters the maximum divergence was contributed by pedicel length (19.96 %) flowed by leaf area (16.40 %), number of branches (13.40 %), and average dry fruit weight (10.70 %) and number of seeds per fruit (9.45 %).

Table 4.7. Clustering of genotypes based on D^2 values (Genotypes serial number in parenthesis)

Sl.no.	clusters	No. of genotypes	Genotypes
1.	I	9	BC-70-2(16) BC-406(17) BC-40-2(11) BC-7-1-1(14) Anuragha (31) Arka Lohit(25) BC-40-3-1-1(9) BC-30(13) Arka Suphal(26)
2.	II	12	BC-40-2-1-1(10) BC-78-1(19) BC-78-1-2(20) BC-25(7) BC-28(8) BC-24-1(3) BC-7-2-1(4) Utkal Rashmi(1) BC-27-2-2(6) BC-20(15) BC-43(21) BC-5-1-7
3.	III	1	Manipur Local 2
4.	IV	8	Ujwala (KAU) 32 Pusa Sadabahar (33) LAM-358(28) Manipur Local 1 (22) Kunchinda Local (34) LAM-625 (30) LAM-620(29) Byadagi Kaddi (27)
5.	V	1	BC-21
6	VI	3	BC-7-2-2(2) BC-79-1(5) Arka Abhir(24)

Table 4.8: cluster mean values of 34 genotypes of chilli for 15 quantitative character

clusters	Plant Height (cm)	Primary Branches	Leaf Area (cm²)	Plant Spread EW (cm)	Plant Spread NS (cm)	Days to initial flowering	Days to 50% Flowering	Fruit Length (cm)	Fruit Girth (cm)	Pedicel Length (cm)	Avg Fresh Fruit Weight (g)	Dry Fruit Weight (g)	Number of Seeds per Fruit	Number of fruits per plant	Fruit Yield Per Plant (g)
I(9)	90.392	3.654	39.838	51.234	53.332	42.149	49.184	6.397	3.389	3.209	2.450	0.451	49.433	90.660	40.789
II(12)	99.319	3.779	31.958	51.090	53.706	41.138	48.196	6.937	3.807	3.164	3.048	0.559	45.388	**120.417**	**65.920**
III(1)	**100.600**	3.230	36.320	49.000	54.560	41.330	**47.330**	5.940	2.900	3.000	2.000	0.360	64.070	38.000	13.677
IV(8)	90.816	**4.510**	39.545	50.650	51.121	50.830	56.037	5.870	2.979	**3.639**	2.092	0.428	42.086	81.520	34.325
V(1)	92.670	4.000	**46.140**	48.670	49.780	**40.000**	**47.330**	**8.600**	3.430	3.000	2.820	0.510	**72.600**	98.200	50.083
VI(3)	87.667	4.150	29.373	**55.047**	56.823	42.890	48.777	6.167	**4.860**	2.760	**3.850**	**0.720**	40.030	98.933	62.733

Table 4.9: Average intra-cluster (diagonal) and inter –cluster (D^2value) of 34 genotypes of chilli.

	1 Cluster	2 Cluster	3 Cluster	4 Cluster	5 Cluster	6 Cluster
1 Cluster	**27.976**	62.157	**51.880**	88.603	54.097	136.986
2 Cluster		50.491	138.622	122.710	96.560	112.788
3 Cluster			0.000	145.346	60.265	**217.467**
4 Cluster				86.655	151.056	204.108
5 Cluster					0.000	193.916
6 Cluster						**107.433**

Table.4.10: Relative contribution of different characters to genetic divergence among 34 genotypes of chilli.

Sl. No	Source	Contribution %	Times Ranked 1st
1	Fruit Length (cm)	6.95	39.000
2	Fruit Girth (cm)	3.74	21.000
3	Pedicel Length (cm)	19.96	112.000
4	number of Seeds per Fruit	9.45	53.000
5	Average Fresh Fruit Weight (g	0.53	3.000
6	Average Dry Fruit Weight (g)	10.70	60.000
7	Number of fruits Per Plant	0.00	0.000
8	Fruit yield Per Plant (g)	0.89	5.000
9	Days to initial Flowering	2.85	16.000
10	Days to 50% Flowering	0.36	2.000
11	Leaf Area (cm^2)	16.40	92.000
12	Plant Height (cm)	0.53	3.000
13	Number of Branches	13.90	78.000
14	Plant Spread EW (cm)	3.03	17.000
15	Plant Spread NS (cm)	0.71	4.000

Table: 4.11. Incidence of Thrips and Mites on chilli genotypes

Genotypes	Genotypes	Thrips and Mite incidence (%)
1	Utkal rashmi	42
2	BC-7-2-2	45
3	BC-24-1	50
4	BC-7-2-1	45
5	BC-79-1	40
6	BC-27-2-2	65
7	BC-25	29
8	BC-28	25
9	BC-40-3-1-1	32
10	BC-40-2-1-1	35
11	BC-40-2	52
12	BC-21	55
13	BC-30	45
14	BC-7-1-1	65
15	BC-20	42
16	BC-70-2	45
17	BC-406	38
18	BC-5-1-7	25
19	BC-78-1	28
20	BC-78-1-2	25
21	BC-43	35
22	MANIPUR LOCAL 1	85
23	MANIPUR LOCAL 2	87
24	ARKA ABHIR	56
25	ARKA LOHIT	75
26	ARKA SUPHAL	78
27	BYADAGI KADDI	87
28	LAM -358	83
29	LAM-620	75
30	LAM-625	68
31	ANURAGHA(KAU)	86
32	UJWALA(KAU)	83
33	PUSA SADABAHAR	86
34	KUNCHINDA LOCAL	55

Very high : >80 %
High :> 60 % to < 80 %
Moderate : >40% to < 60 %
Comparatively less : 0-40%

Incidence of Thrips and mites on chilli germplasm.

During the experiment in *rabi* season it was observed that the Thrips and mite population were quite high in most of the varieties collected from Lam and Karnataka. The Byadagi Kaddi variety which is popular in Karnataka did not performed well due to more incidence of Thrips and mites and also less flower production and fruit set. Similarly the varieties like LAM-358, LAM-620, and LAM-625 collected from Lam, Guntur and local type collected from Manipur did not performed well. However the local type were found moderately affected and performed well. It was observed that the climatic factor in a particular season affected the pest incidence and overall performance of the varieties

DISCUSSION

The effectiveness of any crop improvement programme involving selection and hybridization depends on the existence of genetic variability among the tested materials (genotypes) and extent to which the characters are heritable (heritability).Therefore, it is a pre-requisite to assess the nature and magnitude of variability as one of the basic principles for achieving success in a breeding programmes. Variability refers to the presence of differences among the individuals of plant population. Variability results due to differences either in the genetic constitution of the individual of a population or in the environment in which they are grown. The existence of variability in essential for a crop improvement .Selection is effective when there is genetic variability among the individual in population .hence, insight into the magnitude of variability particularly genetic variability present in a population is of paramount important to a plant breeder for starting a judicious breeding programme.

Further, information on association of various components for the desirable character for selection is of immense importance. The cause and effect relationships among the various correlated characters play an important role. It has been observed that selection of parents for hybridization on the basis of D^2 analysis was more effective for improvement of yield that based on other method.

Considering the importance of the above factors for improvement in chilli, the present experiment was conducted during the *Rabi* season of 2017-18 at All India Co-ordinated Research Project on Vegetable Crops (AICRP), Bhubaneswar, to select the superior genotypes on the basis of their performance and adaptability under Bhubaneswar condition of Odisha. The experimental findings of the above study have been discussed and interpreted hereafter.

Pattern of variation in plant attributes

On examining the ANOVA Table 4.1, the nature and magnitude of variability for different quantitative and qualitative characters were significant except plant spread (EW) and plant spread (NS) are clearly observed among the chilli genotypes. The values indicate highly significant differences for all the characters under study, thereby suggesting existence of large amount of variations among the genotypes. So, there is scope for considerable improvement in this crop through the characters studied. Similar to the present findings, investigations carried out earlier also revealed wide variations for various characters (Patel *et al*., 2015. Janaki *et al*., 2015 and Mishra *et al.*, 2015).

It may be contemplated from the statistics of range and general mean values of the characters that there is a great deal of variability for characters under study. These statistics quite hopefully provide a strong impetus for selecting promising genotypes for specific objectives, because of the magnitude and wide to moderately wide spectrum of variations observed in each character among the genotypes under evaluation. Further, the coefficient of variation (C.V.) being less than 18% for all the characters studied, indicates that good precision was maintained in conducting the experiment.

Among the genotypes evaluated, BC-28 had the highest fruit yield per plant followed by BC-25 and BC-78-1-2 performed better than the rest, suggesting suitability and better adaptability of these genotypes for cultivation at Bhubaneswar in Odisha. But highest number of fruits per plant was observed in the genotype BC-43 followed by Utkal Rashmi. Other researchers (Srilakshmi, 2006; Jyothi *et al.*, 2008; Sharma *et al*., 2010) have also indicated better suitability of some varieties over the rest.

For understanding the breeding principles in any crop improvement programme, two aspects are most important i.e. (i) selection cannot create variability but act only on that which is already in existence (ii) selection can act effectively only on heritable differences (Allard, 1960). Thus the first and foremost necessity for selection is to ascertain whether the genetic variability for these characters is present in the population at significant level or not. Further, the phenotypic mean values which are the basis of comparison, may fall far short of requirement and may even be misleading as the phenotypic expressions are sometimes influenced by environment and thereby may not necessarily represent the genotypic values. To avoid this misleading information for the correct interpretation of data, on the sound genetic principle, statistics such as variance and coefficient of variation etc. are to be computed for proper evaluation.

The estimates of genetic parameters such as phenotypic and genotypic variance computed here as per method suggested by Burton and Devane (1953) along with the coefficients of variation presented in Table 4.4 ,permits a sound basis to determine the variability components as well as to know the relative amounts of heritable and non-heritable variation for each of these characters.

From the present study, it is clearly observed that there exists a wide range of phenotypic as well as genotypic coefficient variation for majority of the 17 quantitative and qualitative characters in chilli. Minimum differences were observed between the values of GCV and PCV for most of the traits studied except the traits plant height, plant spread (EW) plant spread (NS), days to 50% flowering, and fruit yield per plant, this type of observation was also represented by Gogoi (2002). The existence of minimum variation between these two parameters indicated that environment has a little effect in expression of these characters and phenotype truly represents the genotype it has been also reported by Shivkumar and Hosamani (2006).

In the present study, presence of moderate to high coefficients of variation in case of dry fruit yield per plant, number of fruits per plant, ascorbic acid, plant height, plant spread NS indicated the presence of good amount of variability among the materials evaluated and therefore, selection for these characters may be quite hopefully used in chill improvement programme. Cherian (2000), Shivkumar and Hosamani (2006), Bharadwaj *et al*. (2007) and Shirshat *et al.* (2007) observed similar trends, which are in agreement with the present findings. Rest of the characters showing low values for this parameter may be of least significance for chilli improvement programme.

Heritability is an index of transmissibility and is of primary interest to plant breeder. The ratio of genotypic variance to the phenotypic variance or total variance is known as heritability.it is generally expressed in percent. Thus, heritability is the heritable portion of phenotypic variance.it is a good index of the transmission of characters from parents to their offspring’s. The estimate of heritability help the plant breeder in selection of elite genotypes from diverse genetic population. Poehlman and Borthakur (1972) opined that the characters not influenced by environment will have high heritability. According to Randhawa *et al*. (1975) higher the heritability value of a character, less will be the environmental influence on expression of that character, thereby indicating better opportunity for selecting a genetically good individual.

In the present experiment, heritability (bs) >90 % for TSS (96.18%), average dry fruit weight (92.69%), pedicel length (91.66%), average fresh fruit weight (91.33%), leaf area (90.39%) and fruit length (90.27%).The number of fruits (75.53%) and fruit yield per plant (82.53%) > 80 % heritability. Majority of the traits showed >70 % of heritability suggesting that these characters might be highly heritable and less influenced by environment and selecting genotypes on the basis of such characters would be worthwhile in chill improvement. The results obtained are in agreement with the findings of Ukkund *et al*. (2007), Sharma *et al.* (2010) and Chattopadhyay *et al.* (2011).

Though the studies of heritability estimates are important, their scope is limited since they are estimated in broad sense and are prone to change with changes in environment and the testing material. Further, the heritability estimate by itself may not be alone a useful index of genetic potentiality of a character. According to Eswro *et al*. (1963), genetic advance (GA) indicates the potentiality of selection at particular level of selection intensity. Thus, heritability estimates along with genetic advance are more valuable than heritability alone in predicting the response of selection (Johannsen *et al*., 1955; Robinson, 1963).

High heritability does not necessarily mean that the character will show high genetic advance, but when such compatible association exists (high heritability and high GA) additive genes come into prominence because no genetic advance is due to non-additive genes. The selection based on a character showing high genetic gain (GA) may be desirable particularly in case of directional selection, when the main aim of the selection is to change the mean value of a character to have better standards. Improvement in the mean genotypic value of selected plants over the parental population is known as genetic advance.it is the measure of genetic gain under selection. If the value of genetic advance is high, it shows that the character is governed by additive gene as selection will be rewarding for improvement of such traits. If the value of genetic advance is low, it indicate that the character is governed by non-additive genes and heterosis breeding may be useful. On the other hand, high heritability accompanied with low genetic advance indicates the prominence of non-additive gene effect, suggesting the adoption of heterosis breeding (hybridization) instead of direct selection. Low heritability accompanied with high genetic advance reveal that the character is governed by additive gene effects. The low heritability is being exhibited due to high environmental effects. Selection may be effective in such cases

In the present investigation, high estimates of heritability coupled with high genetic advance over mean observed for characters like leaf area, fruit length, pedicel length, average fresh fruit weight, average dry fruit weight and TSS may be ascribed to effect of additive genes (Panse and Sukhatme, 1954; Liang and Walter, 1968) and may be amenable for selection. However operation of both additive and non-additive gene action was indicated for plant height and days to 50 % flowering through moderate genetic advance. Further improvement of this character would be easier through mass selection, progeny selection or any modified selection procedure aiming to exploit the additive gene effect rather than simple selection the character like plant spread EW and NS have low heritability with low GAM indicating that there is no scope for selecting this traits. Similar observations were also reported by Patel *et al.,* (2015), Janaki *et al*., (2015), Ukkund *et al*., (2007), Patil *et al*., (2008) and Sharma *et al*., (2010)

Character association

In chilli, dry fruit yield is the economic character. The total fruit yield is the ultimate effect of interaction of several quantitative characters that are highly susceptible to changes in the environment. Hence, selection based on yield alone may not be a very sound proposition for effective selection. Various component characters which are directly and positively correlated with yield often act as useful indicators in the selection. Thus, sound knowledge of such associations among the various characters particularly in relation to total yield is of prime importance in planning successful and effective breeding programmes. According to Robinson (1966), correlation studies are helpful in choosing superior genotypes from the phenotypic expression.

The perusal of results of the present investigation exhibited that the genotypic correlation coefficients showed higher values for most of the variable pairs than the phenotypic correlation coefficients presented in Table 4.5, suggesting that there is a strong inherent association between the various characters studied. Further, as the genotypic correlation coefficients showed a parallel value to the phenotypic correlation coefficients, it may be assumed that there is not much influence of environment in determining the association of these attributing characters with total yield and possibly due to a strong genitical makeup of the evaluated materials (genotypes).Wigan and Mather (1942) suggested that strong positive association of character with yield may be attributed to linkage and pleiotropy.

In the present finding significant and high positive correlation both at genotypic and phenotypic level for fruit dry yield per plant ,fruit length, fruit girth, average fresh fruit weight, average dry fruit weight, number of fruits for plant, plant height. Low positive correlation was observed with the number of branches at both genotypic and phenotypic level and plant spread NS and EW at phenotypic level. However significant and negative correlation was observed with days to initial flowering days to 50% flowering and leaf area with both level. The present findings also corroborate the findings with Ajjappalavara *et al.* (2015), Smitha and Basavaraja (2006), Sharma *et al*. (2010) and Vikram *et al.* (2014)

Average fresh fruit weight it shows positive and significant correlation with fruit length, fruit girth and fruit yield per plant. However at both phenotypic and genotypic level it was negatively and significantly correlated with the days to initial flowering at both phenotypic and genotypic level. It is positively non-significantly correlated with pedicel length and plant height, plant spread.

The number of fruits for plants showed positive and significant correlation with fruit girth at both genotypic and phenotypic level. But it is negatively and significantly correlated with the traits like pedicel length, number of seeds per fruit, and leaf area genotypic, at level it is positively and non-significant correlate with character like fruit length, average fresh fruit weight, number of branches.it is evident from the observation that when number of fruits and average fresh fruit weight increases other component characters had also positive relation with them contributing to increase in yield. The present finding is in accordance with Smitha and Basavaraja (2016) and Sharma *et al.,* (2010)

The correlations of above character suggest that selection for these component traits simultaneously will be effective in improving the yield in chilli**.** Other pairs of characters showing significant negative correlation value and insignificant value either positive or negative at phenotypic and genotypic levels, have least importance for effective selection based on these characters.

Direct and indirect effects of characters

Correlation coefficient which measures the association between any two characters may not give a true comprehensive picture in a complex situation. The associations between any two characters which are measured do not exist by themselves alone but are part of complicated pathway in which other traits are also interwoven. The indirect association becomes complex and important due to number of variables in correlation study. In addition to this, the mutual relationship among different characters which may be positive or negative make the situation complicated. In such situation, path coefficient analysis devised by Wright (1921) provides a better knowledge as it reveals direct and indirect causes of association and permits a critical examination of specific forces acting to produce a given correlation and measure the relative importance of each causal factor.

In the present study data presented in Table 4.6, number of fruits per plant was found to exert maximum positive direct effect on yield followed by average fresh fruit weight, average dry fruit weight and fruit girth. These findings are in agreement with the observations of Pujar *et al.,* (2017), Shumbulo *et al.*, (2017) and Shobha *et al.,* (2017)

Fruit length, fruit girth and average dry fruit weight showed moderate positive indirect effect on dry fruit yield per plant. Thus direct selection through the characters like average fruit weight and number of fruits per plant would be very effective in chilli improvement programme.

Genetic divergence

The multivariate analysis based on Mahalanobis D^2 statistics is being employed as a powerful tool for measuring genetic divergence among the tested genotypes. Ramanujan *et al*. (1974) have categorically suggested the merits of D^2 statistics for genetic grouping of germplasm.

In the present investigation, the grouping by multivariate technique has shown good results. Being a numerical estimate, the multivariate technique has the added advantage over other criteria of permitting precise comparison among all possible pairs of population in any given group. Since, the estimates are obtained from study of potential parents themselves, the required information is available before deciding parents for future recombination breeding, thus, can be used with advantage. It is well established that hybrid derivatives from divergent parents are found to be promising, probably because of complementary interaction of divergent genes in the parents taken for cross in the parents.

In the present study out of the six cluster, where cluster II(12) has the highest number of genotypes, followed cluster I(9),cluster IV(8),cluster VI(3) and cluster III and cluster V had one genotypes each. Cluster III and VI had highest inter cluster distance followed by cluster IV and VI. So, promising hybrid derivatives can be obtained by crossing the parents selected from these two divergent groups. Cluster VI had the highest intra cluster distance followed by cluster IV where cluster I showed lowest intra cluster distance. In the present study, genotypes obtained from different geographical locations were grouped into a single cluster (Cluster III and V). Therefore, it is apparent that genetic diversity and geographical diversity do not tally. This is in agreement with the findings of other researches by Senapati *et al.* (2003) and Srinivas *et al.* (2013)

It was also observed that the contribution of pedicel length, leaf area, number of branches and average dry fruit weight to genetic divergence of genotypes in chilli was the maximum as was also reported by Varalaxmi and Babu (1991) and Senapati *et al.* (2003).

So, selection of parents differing in these quantitative traits may be proved useful for heterosis breeding programme in chilli.

Cluster II had the highest mean value for the trait number of fruits per plant and frit yield per plant, where cluster VI showed highest mean value for average fresh fruit weight and average dry fruit weight. As per the cluster mean, the cluster having more yield is more desirable than a divergent cluster with less mean yield in the cluster.

From the experiment it was observed that some of the popular varieties like LAM-358, LAM-620, LAM-625, Byadagi Kaddi, Arka Lohit, Arka Supal, Ujwala , Anuragha and Pusa Sadabahar did not perform well due to more incidence of insect and pest and due to effect of climatic condition.

SUMMARY AND CONCLUSION

The present investigation entitled, **"Genetic variability, character association and divergence studies in chilli (*Capsicum annuum* L.) germplasm"** was conducted at AICRP on Vegetable crops of Orissa University of Agriculture & Technology at Bhubaneswar, Odisha, India during *Rabi* season of 2017-18 with an objective to study the nature and extent of genetic variability in chilli genotypes for improvement of desirable genotype for fruit yield and yield attributes. 34 genotypes were evaluated by adopting RBD with three replication. The genotypes were evaluated on the basis of 17 parameters including, vegetative growth, flowering, fruit yield attributing, fruit yield and fruit quality parameters etc. The silent findings of the present investigation are summarized below.

- The analysis of variance revealed significant differences among the 34 genotypes for all the characters studied indicating the presence of variability in the studied material except the characters plant spread NS and plant spread EW.
- The observations on three morphological characters revealed high variation among the genotypes. Maximum number of genotypes (26) were observed to be with pendent fruit position, 17 genotypes had green mature fruits while 32 genotypes recorded solitary fruit bearing habit.
- Significantly highest plant height was observed in genotype BC-20(110.33 cm) followed by BC-43 (107.07 cm).
- Number of branches per plant was significantly highest in genotype LAM-625(5.83).
- Highest leaf area is observed in pusa sadabahar (46.92 cm^2) and lowest in Utkal rashmi (21.12 cm^2).
- Significantly highest plant spread EW was recorded for genotype BC-27-2-2(60.31 cm^2).
- BC-79-1 recorded highest plant spread for plant spread NS (60.00 cm^2).
- The genotype BC-28 (37.33 days) recorded earliest for days to initial flowering
- BC-43 recorded significantly earliest for days to 50 % flowering (46.00 days)

- Arka abhir had significantly longest fruit length (9.72 cm)
- The genotype BC-7-2-2 recorded maximum for fruit girth (5.08 cm)
- LAM-620 recorded longest pedicel length (4.53 cm).
- The number of fruits was found significantly highest in BC-43(147.20)
- Arka Abhir was found significantly highest for average fresh fruit weight (5.91g) and average dry fruit weight (1.15g).
- Number of seeds were found significantly highest in BC-21(72.60).
- BC -28 found significantly highest dry fruit yield per plant (78.71 g), yield per plot (1529.20 g) and yield per hacter (27.52 q/ha).
- Highest TSS was recorded in BC-20 (4.70)
- BC-40-2 recorded highest ascorbic acid (66.66 mg per 100g)

The genotypic coefficients of variation for all the characters studied were lesser than the phenotypic coefficients of variation indicating the interaction of genotypes with environment. High magnitude of PCV and GCV were observed for number of branches, leaf area ,days to initial flowering, days to 50% flowering, fruit length, fruit girth, pedicel length, average fresh fruit weight, average dry fruit weight, number of seeds per fruit and TSS. Indicating the existence of wide range of genetic variability in the germplasm for these traits. This also indicated broad genetic base, less environmental influence and these traits are under the control of additive genes and hence there is a good scope for the further improvement of these characters through selection.

Moderate (> 30% - < 60%) heritability coupled with moderate genetic advance as per cent of mean was observed for days to plant height indicating the role of additive and non-additive gene action and further improvement of this character would be easier through mass selection, progeny selection or any modified selection procedure aiming to exploit the additive gene effects rather than simple selection. High (> 60 %) heritability with high genetic advance observed for number of branches, fruit girth, number of fruits per plant, average fresh fruit weight, average dry fruit weight, number of seeds per fruit, fruit yield per plant, ascorbic acid and TSS. All the other characters except above mentioned characters showing high heritability with high genetic advance showing additive gene action so simple selection is enough to exploit these traits.

Studies on character association indicated fruit length, fruit girth, average fresh fruit weight, average dry fruit weight, number of fruits per plant and plant height had positive significant association with yield per plant at both phenotypic and genotypic level indicating the importance of these traits in selection for yield and were identified as yield attributing characters on which selection can be relied upon for the genetic improvement of yield of chilli

The path analysis revealed number of fruits per plant, average fresh fruit weight, average dry fruit weight, fruit girth ,fruit length, pedicel length, plant height and number of branches shows positive and direct effect on yield per plant indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of chilli

From the results of multivariate analysis, the presence of considerable genetic divergence among the 34 genotypes was revealed. The 34 genotypes were grouped into 6 clusters by D^2 analysis as highest genotypes was in Cluster-II (12 nos.) followed by Cluster I (09 nos.), Cluster IV (08 nos.), Cluster VI (03 nos.), and Cluster III & V (1 no. each) clearly indicated that the genetic diversity and geographical diversity were not related. By Mahalanobis D^2 statistic, it could be inferred that pedicle length, number of seeds per fruit, fruit length, fruit girth, average dry fruit weight, leaf area, number of branches contributed maximum towards genetic divergence. Based on intra and inter-cluster distance, Cluster I had minimum intra cluster distance whereas maximum intra cluster distance was observed in cluster VI. The most divergent clusters were Cluster III and VI, followed by cluster IV and VI, cluster V and VI.

From the experimental result it was observed that some of the popular varieties like LAM-358,LAM-620,LAM-625, Byadagi Kaddi, Arka Lohit, Arka Suphal, Ujwala, Anuragha and Pusa Sadabahar did not perform well due to more incidence of insect and pest due to effect of climatic condition.

CONCLUSION

The following conclusions were made from the present investigation

- ❖ Among the 34 genotypes studied BC-28 was identified as best genotype for flowering, yield and yield attributing traits. BC-43 can be used for trait, number of fruits per plant.

- Direct selection on number of fruits per plant, average fresh fruit weight and average dry fruit weight and fruit girth will be effective for improvement of chilli.

- Number of fruits per plant, average fresh fruit weight and average dry fruit weight and fruit girth being positively and significantly correlated ,hence will be considered for improvement of chilli.

- Being most divergent cluster III (Manipur local) and cluster V (BC-21),but cluster II had highest mean value for yield per plant, hence expected hybridization between these clusters might result in highly heterotic hybrid and thus, produced wide spectrum variations in future generation for effective selection of new genotype (s) for fruit yield and yield attributing in chilli.
- By observing the yield performance and insect pest incidence it can be concluded that the popular varieties did not performed well due to more pest incidence and also due to influence of climate on flowering and fruiting, low yield, which may be taken into consideration during commercial cultivation and also during crop improvement programme.

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APPENDIX

Weather data during the cropping season

Month	Max temp (^{0}C)	Min temp (^{0}C)	RH Max (%)	RH Min (%)	RF (mm)	Evaporation (%)
Sep-17	32.925	25.775	91.5	75.5	81.6	20.825
Oct-17	32.85	25.525	92	71	58.6	22.25
Nov-17	32.35	23.5	92.25	65.25	31.7	23.125
Dec-17	29.425	18.2	89	53.5	13.8	23.175
Jan-18	27.8	12.05	92.5	35.5	0	25.525
Feb-18	32.85	15.15	92	29.25	0	29.1
Mar-18	36.925	21.125	91.75	29.75	0	35.85
Apr-18	37	25.7	91	47	0	37.7
May-18	38.375	27.075	84.75	47.5	6.875	60.025