STUDIES ON GENETIC VARIATION AND ASSOCIATION AMONG VARIOUS MORPHOLOGICAL AND QUALITY TRAITS IN CHILLI (*Capsicum annuum* L.)

THESIS

By

MADHU SHARMA

Submitted to

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IN

Partial fulfilment of the requirements for the degree

OF

MASTER OF SCIENCE IN AGRICULTURE
(VEGETABLE SCIENCE)

2006

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Vegetable Breeder

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CERTIFICATE – I

This is to certify that the thesis entitled, **"Studies on genetic variation and association among various morphological and quality traits in chilli (*Capsicum annuum* L.)"**, submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Vegetable Science** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Ms. Madhu Sharma (Admission No. A-2004-30-32)** daughter of **Shri Raghubir Chand Sharma** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

(Yudhvir Singh)
Chairman
Advisory Committee

Place : Palampur
Dated: 7th December, 2006

CERTIFICATE – II

This is to certify that the thesis entitled, **"Studies on genetic variation and association among various morphological and quality traits in chilli (*Capsicum annuum* L.)"**, submitted by **Ms. Madhu Sharma (Admission No. A-2004-30-32)** daughter of **Shri Raghubir Chand Sharma** to Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Vegetable Science**, has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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ACKNOWLEDGEMENT

With unending humility, at the very outset, I would like to thank "The Almighty", who blessed me with limitless internal strength and favourable circumstances, to face and pass through all odds successfully at this juncture.

I wish there could be really more befitting way than words for acknowledging the indebtedness and to express my loyal and venerable thanks and divulge my deep sense of heartfelt gratitude to Dr. Yudhvir Singh, Vegetable Breeder and chairman of my Advisory Committee for opening my way to new horizons. His painstaking efforts, praiseworthy guidance, scientific acumen and ever helping attitude steered the completion of this work. I owe to him more than I could care to admit.

It is my sole prerogative to place on record my indebtedness and everlasting gratitude to the members of my Advisory Committee Dr. N.K. Pathania, Head, Department of Vegetable Science and Floriculture, Dr. Akhilesh Sharma, Associate Professor, Dept. of Vegetable Science and Floriculture, Dr. (Mrs.) S. Bhateria, Professor, Department of Plant Breeding and Genetics and Dr. Desh Raj, Head, Department of Entomology for their counsel, valuable suggestions and advisement. I am also thankful to Dr. Mondal, Asstt. Scientist, Dept. of Plant Pathology for his cooperation.

I avail myself of this rare opportunity to express my ecstatic thanks to all the teaches of the Department of Vegetable Science and Floriculture for their kind cooperation and impeccable guidance during the course of the study. Thanks are duly acknowledged to the Dean, Postgraduate Studies and CSK Himachal Pradesh Krishi Vishvavidyalaya authorities for providing necessary facilities.

I am thankful to the College authorities for providing academic assistance in the form of college merit scholarship which facilitated smooth running of my studies.

I appreciate the whole hearted co-operation extended by my seniors and dear friends. I express my heartfelt thanks to Susheel Sir, Pathak Sir and Meenakshi di for rendering me help and guidance during course of investigation.

All the words in the lexicon will be futile and meaningless if I fail to divulge my extreme sense of regards to adorable parents for their sacrifice, prayers and blessings without which this work would have been a sweet dream. I am yet to find suitable words to express my heartiest affection for my brothers, bhabhi, sister, jijaji and Nibhaa for their tender attachment and constant encouragement during the course of investigation.

A word of appreciation should be credited to Sh. Ajay Walia for his painstaking efforts in typing this manuscript.

I express my appreciation for all the quarters individually, which have not been mentioned here.

Place: Palampur
Dated: 7th December, 2006

Madhu Sharma
(MADHU SHARMA)

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Introduction

INTRODUCTION

History indicates the extreme fascination of the world for the fabled wealth of India, especially its spices. The most common and remunerative spice/cash crop of Indian subcontinent is chilli. It forms an indispensable adjunct in every house of the tropical world. No other cultivated spice is used in as many ways as red pepper : as spice, as pickle, as condiment and also for medicinal and ornamental purposes.

Chillies originated in Latin American regions of New Mexico and Guatemala as a wild crop in around 7500 BC. The people native to these places domesticated this crop in 5000 BC as per the remains of prehistoric Peru. At that time, chillies were cultivated by the farmers with main crop to protect the primary crop from birds and slowly, it gained popularity in the American continent as a flavouring agent (Anonymous, 2006a). It was introduced into India from Brazil at the end of 15^{th} century by the Portuguese (Pruthi, 1976) and became adapted to the Indian conditions so much that India is considered as secondary centre of origin (Deshpande, 2001).

India today has emerged as the major producer, consumer and exporter of chilli, contributing almost one fourth of the world production. During 2005-06, 1,38,419 tonnes of chillies worth Rs. 500 crores have been exported (Anonymous, 2006b). Chilli ranks first by constituting about 33% of the total spice export in India, while in the world spice trade it accounts to an approximate of 16 per cent share, second after black pepper. The major chilli exporting countries alongwith their percentage share in the world total export are India (25%), China (24%), Spain (17%), Mexico (8%), Pakistan (7.2%), Morocco (7%) and Turkey (4.5%).

Andhra Pradesh, Karnataka, Maharashtra, Punjab, Tamil Nadu and Himachal Pradesh are the major chilli growing states in the country occupying an area of 8.84 lakh ha with an annual production of 10.60 lakh tonnes (Anonymous, 2006c). In H.P., it is cultivated on an area of 1000 ha with an annual production of 190 tonnes (Anonymous, 2004a).

The green chilli fruits are valuable on account of their richness in ascorbic acid, carotenoids and rutin which are of immense pharmaceutical need (Purseglove, 1977). The green fruits are used in salad and curries. The red fruits are characterized by pungency and colouring matter. The red pigment/capsanthin currently used as natural colour additive in food, drugs and cosmetic industry is rich in bioflavonoids – the most powerful antioxidants that offer protection against oxidation-induced deteriorative changes in the body. Its role in inhibiting the progression of chronic disease conditions such as macular degeneration, cardiovascular disease and cancer is well documented.

The pungency is due to the presence of a crystalline volatile alkaloid called capsaicin. It helps in relieving nasal congestion and has also emerged as a potent anti-inflammatory and analgesic agent such as balms for external human use, shows antioxidant, anti-tumour and anti-cancerous activities (Kanwar, 2000). Capsaicin as anticoagulant helps in preventing blood clots that can lead to a heart attack or stroke, alleviate the pain of arthritis and mouth pain associated with chemotherapy. Contrary to general misconception, chillies do not cause ulcers or digestive problems (Anonymous, 2004b). A non-conventional use of chilli is in the self defence sprays which are gaining popularity in USA. The spray consists of capsicum oleoresin at ultra high emulsion rate which temporarily immobolises the attacker (Deshpande, 2001).

The chilli can be processed into paste, powder, dry chilli etc. but chilli oleoresin, a processed product is gaining more importance especially from export point of view because it offers uniform quality, longer shelf-life, freedom from micro-organisms and lesser freight charges. Due to above said reasons, most of the western countries are shifting towards chilli oleoresin rather than exporting whole chilli or chilli powder. Oleoresin of high, medium or low pungency can be produced according to market demand. Chilli oleoresin has vast demand in pharmaceutical and food industry.

India has immense potential to grow and export different types of chillies required by various markets around the world. Indian chilli export though showing satisfactory trends but nowadays, is facing severe competition in the international market from other chilli growing countries and high domestic consumption. On the other hand, the average yield is low due to various constraints such as non-availability of suitable cultivars/hybrids, biotic and abiotic stresses, genetic drift in cultivars and development of new pathogenic races. Thus, for enhancing the productivity there is a pressing demand to develop high yielding varieties/hybrids enriched with good quality attributes through genetic restructuring of the chilli germplasm.

The improvement in any crop is proportional to the magnitude of genetic variability present in the germplasm (Dhankhar and Dhankhar, 2002). In chilli, a wide range of variability is available due to its often-cross pollinated nature, which provides a great scope for improving fruit yield through a systematic and planned breeding programme. Further, partitioning of this variability into heritable and non-heritable components enable us to understand the effectiveness of selection (Singh and Mittal, 2003). It is equally imperative to assess the nature and extent of association between different yield attributes and relative importance of direct and indirect influence of each of the component traits on yield so as to improve the plant as a whole rather than individual trait. For this, the first and foremost step is the evaluation of available variability in germplasm so as to identify the potential genotypes for their use either directly or indirectly as donor in the future breeding programme.

Based on the afore-mentioned reasons, the present investigation "Studies on genetic variation and association among various morphological and quality traits in chilli (*Capsicum annuum* L.)" was therefore carried out at the research farm of Vegetable Science and Floriculture, CSKHPKV, Palampur with the following broad objectives:

1. To assess the nature and magnitude of genetic variability,
2. to understand the association among various horticultural and quality traits,
3. to work out their direct and indirect contributions to the yield, and
4. to identify the promising genotypes.

Review of Literature

Chapter II

REVIEW OF LITERATURE

The relevant literature available on various aspects included in the present study is briefly reviewed under following heads:

2.1 Variability studies

2.2 Heritability and genetic advance

2.3 Correlation studies

2.4 Path coefficient analysis

2.5 Quality parameters

2.1 Variability studies

Exploration of genetic variability in the available germplasm is a pre-requisite to any breeding programme. Greater the diversity in the material, more are the chances of getting desired type. Vavilov (1951) was probably the first to perceive the importance of a wide range of variability in the initial material to ensure better chances of producing genotypes with desirable traits. The extent of improvement expected by selection in any population depends on the genetic variability present in the population. The genotypic variation in population is due to genotypic differences among individuals for particular character. On the other hand, phenotypic variation is the observable differences present in individual for a character due to the effect of both genotype and environment.

Singh *et al.* (1972) studied variability for ten characters among twenty different strains of chilli and found significant differences among genotypes for all the traits. High genotypic and phenotypic coefficients of variation for primary and tertiary branches, fruit number, fresh fruit weight and yield were observed. Dutta *et al.* (1979) revealed high genotypic and phenotypic coefficient of variation in chilli for fruit weight, fruit number per plant, fruit yield per plant, number of primary branches and plant height. A wide range of variation for fruit girth, fruit length, number of fruits per plant and fruit weight in thirty diverse genotypes of chilli was noticed by Elangovan *et al.* (1981), whereas Bavaji *et al.* (1982) observed maximum variation for fruit weight and fruits per plant only.

Gopalakrishnan *et al.* (1985) reported varietal differences for fruit yield per plant and six related traits in ten chilli cultivars. Ghai and Thakur (1987) recorded highest genotypic coefficients of variation for fruit weight and lowest for fruits per plant in chilli.

Adamu and Ado (1989) studied genetic variability of fruit characteristics and observed a high level of variation for fruits per plant, fruit weight, and yield per plant. Barai and Roy (1989) observed wide range of variability for fruit weight and fruits per plant in six varieties of chilli.

Vijayalakshmi *et al.* (1989) found high level of genotypic and phenotypic coefficients of variation for number of fruits per plant, number of seeds per fruit and total fruit yield in chilli. Acharya *et al.* (1992) revealed that improvement should be based on selection for fruits per plant, yield per plant, fruit length and seeds per fruit. Nandi (1993) reported high genotypic coefficient of variation for fruit length, fruit weight and yield per plant.

Natarajan *et al.* (1993) indicated the influence of environment on the characters and revealed that the fruit length, dry fruit weight and number of seeds per fruit offer scope for phenotypic selection on the basis of estimates of genotypic coefficient of variation, heritability and genetic advance. Rani and Singh (1996) examined seventy three genotypes and observed significant differences for all the twenty one characters studied. Ambarus (1998) indicated low variation for plant height and fruit yield per plant in *Capsicum annuum.*

Nayeema *et al.* (1998) reported moderate phenotypic and genotypic variability for fruit number, average fruit weight and fruit yield per plant in seventy one genotypes of chilli. Singh and Singh (1998) observed considerable genetic variability for fruit yield and other traits.

Kumar *et al.* (1999a) found high genotypic and phenotypic coefficient of variation for fresh fruit weight, fruit number, dry fruit weight, fruit yield per plant and number of seeds per fruit, indicating greatest diversity for these traits. Ascorbic acid content and 100-seed weight, however, exhibited low magnitude of variation. Das and Choudhary (1999a) observed significant differences for all the characters under study and reported high genotypic and phenotypic variances for fruit length in twenty five genotypes of chilli.

Munshi and Behera (2000) exhibited high values of genotypic and phenotypic coefficient of variation for number of fruits per plant, fruit length and yield per plant. Mishra *et al.* (2001) observed wide range of variability for fruits per plant, fruit length, dry fruit weight and red chilli yield per plant in nine genotypes of chilli. Phenotypic coefficient of variation was slightly higher than genotypic coefficient of variation indicating negligible effect of environment on the fruit characters. Moderate genotypic and phenotypic coefficients of variation for fruit length, dry fruit yield and number of branches per plant were noticed by Mohammed *et al.* (2001).

Dipendra and Gautam (2002) reported high genotypic and phenotypic coefficients of variation for fresh fruit yield per plant and dry fruit yield per plant. Rathod *et al.* (2002a) observed high genotypic coefficient of variation for number of fruits per plant, fresh red chilli yield per plant and plant height.

Sreelathakumary and Rajamony (2002) found higher phenotypic and genotypic coefficients of variation for fruits per plant, fruit weight, fruit length, fruit girth and yield in both shaded (25%) and open areas in seventy diverse genotypes of chilli. A wide range of variability for different horticultural traits in ninety two accessions of wild and cultivated *Capsicum* species was observed by Buso *et al.* (2003). Khurana *et al.* (2003) recorded high genotypic coefficient of variation for fruit number, fruit yield per plant and peel:seed ratio.

Nandadevi and Hosamani (2003) reported high degree of genotypic and phenotypic coefficients of variation for number of primary branches per plant, fruit length, fruit number and green fruit yield per plant in twenty six chilli genotypes. Nehru *et al.* (2003) revealed significance of genotype x environment interaction in sixteen genotypes of chilli. Mishra *et al.* (2004) observed variability in capsicum and reported high magnitude of phenotypic and genotypic coefficient of variation for ascorbic acid, fruit number and fruit yield per plant.

Mini and Khader (2004) found high genotypic coefficient of variation for green yield per plant, fruit number and average fruit weight in wax type chilli. Similarly, Sheela *et al.* (2004) reported wide range of variability among twenty five accessions of bird pepper for all the morphological traits. Sreelathakumary and Rajamony (2004a) showed high phenotypic and genotypic coefficients of variation for fruits per plant, fruit weight, fruit length, fruit girth and yield per plant. Considerable variability was observed by Verma *et al.* (2004) for plant height, number of branches per plant, fruit length, fruit girth and fruits per plant in twelve genotypes of *Capsicum annuum.* Wasule *et al.* (2004) conducted variability studies in seventeen genotypes of chilli and reported wide variation for percentage fruit rot incidence, number of fruits per plant, wet red chilli yield, fruit girth and number of branches per plant while, Raikar *et al.* (2005) observed considerable variation in chilli.

2.2 Heritability and genetic advance studies

Fisher (1918) was the first to partition continuous variation exhibited by metric traits into heritable and non-heritable components. Heritability is the proportion of phenotypic variation which is transmitted from parents to offspring. Genetic variability largely depends upon heritable variation. The extent of contribution of a genotype to the phenotypic variation for a trait in the population is ordinarily expressed as the ratio of genetic variance to the total variance i.e. phenotypic variance and this ratio is known as heritability.

Higher the heritable variations, greater is the possibility of fixing the characters through selection. Hence, heritability studies are of foremost importance to judge whether the observed variation for a particular character is heritable or non-heritable (environmental). Estimation of genetic advance is important to have an idea about the effectiveness of selection. High heritability alone does not necessarily mean high genetic advance.

Johnson *et al.* (1955) reported that heritability estimates together with genetic advance would give reliable indications of the amount of improvement to be expected from selection. Singh *et al.* (1972) studied twenty different lines of chillies and found that fruit size had high expected genetic advance and heritability. Awasthi *et al.* (1976a) observed high heritability coupled with low genetic advance for number of branches per plant, fruit diameter and average fruit weight, while both components were high for plant height, fruit length and fruit yield per plant and moderate for fruits per plant.

Singh and Singh (1977) found high heritability and genetic advance for number of fruits per plant and yield per plant in chilli. Dutta *et al.* (1979) estimated highest heritability for fruit weight followed by days to first flowering, plant height and fruit number per plant. Similarly, Elangovan *et al.* (1981) reported high heritability for fruit girth, fruit length, number of seeds per fruit and fruit weight. Number of fruits per plant and fruit weight exhibited high genetic advance in addition to heritability.

Ramakumar *et al.* (1981) observed high heritability with high genetic advance in chilli genotypes for plant height, fruits per plant and fruit girth. Singh *et al.* (1981) reported high heritability estimates for average fruit weight and number of fruits per plant. Singh and Rai (1981) recorded highest heritability estimates for plant height followed by days to flowering, fruit length, number of branches and fruits per plant in chilli. Bavaji *et al.* (1982) reported high heritability and genetic advance for number of branches, fruit length, fruit weight and fruits per plant.

Gupta and Yadav (1984) found high heritability and genetic advance for fruits per plant and ascorbic acid content. Achal *et al.* (1986) recorded high heritability alongwith high genetic advance for plant height, number of primary branches, fruit length and fruits per plant and advocated their use in selection programme. Ghai and Thakur (1987) observed high estimates of heritability and genetic advance for fruit weight and number of branches.

Gopalakrishnan *et al.* (1987) observed high heritability coupled with high genetic advance for fruit length and moderate for fruits per plant, while days to flowering, days to red chilli harvest and fruit girth had high heritability with low expected genetic advance. Meshram (1987) found that fruit length and days to first flower had high expected genetic advance alongwith heritability. Sahoo *et al.* (1989) reported high heritability and genetic advance for dry yield per plant, number of fruits per plant, fruit weight and number of seeds per fruit in chilli. Similarly, Vijayalakshmi *et al.* (1989) observed high heritability associated with high genetic advance for fruits per plant, average fruit weight, fruit length, fruit girth and seeds per fruit.

Bhagyalakshmi *et al.* (1990) reported high heritability for days to 50 per cent flowering, fruit length, fruit girth, fruits per plant, fruit weight and ascorbic acid content, and moderate heritability for plant height, branches per plant, fresh fruit weight, seeds per fruit and 100-seed weight. Das *et al.* (1990) recorded high heritability for fruit yield and number of fruits per plant in thirty genotypes of chilli.

Kumar *et al.* (1993) found high values of heritability coupled with high genetic advance for number of fruits per plant, number of seeds per fruit, ascorbic acid content and fruit yield per plant in chilli. Nandi (1993) revealed high to medium heritabilities and high genetic advance for fruit length and fruit weight. Bhatt *et al.* (1996) recorded highest heritability and genetic advance estimates for fruits per plant, average fruit weight and fruit diameter. Pitchaimuthu and Pappiah (1996) estimated high values of heritability linked with high genetic advance for number of fruits per plant, fruit length and fruit girth in all the F_6 progenies.

Rani and Singh (1996) reported high estimates of heritability and genetic advance for capsaicin content and fruit length. Kataria *et al.* (1997) observed high heritability and genetic advance for fruits per plant, fresh fruit weight and fruit length, indicating their importance for selection in chilli. Warade *et al.* (1997a) reported high heritability for plant height, number of primary branches, days to 50 per cent flowering, fruit length, fruit girth, fruit weight, number of seeds per fruit and fruit yield per plant in sixty cultivars of chilli, indicating good scope for improvement through selection.

Nayeema *et al.* (1998) recorded high heritability for days to 50 per cent flowering, plant height, fruit length, number of fruits per plant, average fruit weight and fruit yield per plant alongwith high genetic gain for number of fruits per plant and fruit yield per plant. Singh and Singh (1998) showed high heritability estimates linked with moderate genetic advance for fruits per plant, fruit yield, fresh and dry fruit weight. Das and Choudhary (1999a) reported high heritability estimates for fruit length, fruits per plant, average fruit weight and yield per plant.

Kumar *et al.* (1999a) observed high heritability for days to 50 per cent flowering, number of fruits per plant, fruit length, fruit yield per plant, plant height, fresh fruit weight, dry fruit weight, number of seeds per fruit, 100-seed weight and ascorbic acid content, while high heritability coupled with high genetic advance was recorded for number of fruits per plant, fresh and dry fruit weight and moderate heritability alongwith low genetic advance for 100-seed weight and ascorbic acid content. They also reported high heritability alongwith moderate genetic advance for number of seeds per fruit and yield per plant.

Munshi and Behera (2000) estimated high values of heritability and genetic advance for fruit length, fruit number per plant and yield per plant and suggested their improvement through selection. Mohammed *et al.* (2001) observed highest heritability for plant height followed by fruit length and fruits per plant, while higher genetic advance was noticed for number of branches per plant, fruit girth and dry fruit yield per plant in chilli. Dipendra and Gautam (2002) reported high heritability and genetic advance for fruit length, fruit number, fresh and dry fruit yield, indicating the importance of these traits in selection for high yield.

Rathod *et al.* (2002a) found high heritability and genetic advance for number of fruits per plant, plant height and fresh red yield per plant. Sreelathakumary and Rajamony (2002) observed high heritability and genetic advance for fruits per plant, fruit weight, fruit length, fruit girth and yield. Khurana *et al.* (2003) showed high heritability estimates for fruit yield, number of fruits per plant, fruit length, fruit diameter and number of seeds per fruit, while high heritability coupled with moderate genetic advance was recorded for capsaicin content and colouring matter.

High heritability coupled with genetic advance was observed for fruit length and fruit yield per plant by Nandadevi and Hosamani (2003) and for fruit yield by Nehru *et al.* (2003). Das and Maurya (2004) recommended selection based on phenotypic observations for fruit number, fruit weight and yield per plant as these traits exhibited high heritability coupled with high genetic advance. Mishra *et al.* (2004) recorded high heritability alongwith high genetic advance for ascorbic acid content, fruit number, fruit yield per plant and fruit length. Mini and Khader (2004) observed high heritability alongwith high genetic advance for 100-seed weight, fruit length, average fruit weight, fruit number, green fruit yield per plant and number of secondary branches in wax type chilli.

Sreelathakumary and Rajamony (2004a) revealed high heritability estimates coupled with high genetic advance for fruits per plant, fruit weight, fruit length, fruit girth and yield per plant in thirty five genotypes of chilli. Similarly, high heritability coupled with high genetic gain for fruits per plant, plant height and fruit length was reported by Verma *et al.* (2004). Wasule *et al.*

(2004) estimated high heritability and genetic advance for number of fruits per plant, indicating prevalence of additive gene action which offer scope of improvement through selection.

2.3 Correlation studies

Yield is a quantitative character as it is influenced by number of its components, therefore, selection for yield should be based on its component characters rather than yield alone. Thus, study of correlation between characters is very much essential for a plant breeder in improving the efficiency of selection. If significant correlation values are found between yield and other economic traits, considerable improvement could be made through selection. Galton (1889) developed the basic concept of correlation and this was later elaborated and discussed by Fisher (1918, 1936) and Wright (1921) for plant breeding programmes. In plant breeding, correlation analysis provides information about yield components and thus helps in the selection of superior genotypes from diverse genetic populations.

Johnson *et al.* (1955) proposed that the phenotypic correlation indicates the extent of observed relationship between the two characters and these include both hereditary and environmental influences, while genotypic correlation provides a real association between the two characters and is most useful in selection. Hays *et al.* (1955) stated that correlation coefficient is a measure of the degree of association between two traits worked out at the same time.

Singh *et al.* (1972) revealed that yield per plant was positively associated with plant height, number of primary and tertiary branches, fruit number and fresh fruit weight. Similarly, fruit number was positively correlated with fresh fruit weight, number of branches, plant height and days to flowering.

Hwang and Lee (1978) observed that yield in chilli was positively correlated with plant height. Capsaicin content was negatively correlated with fruit weight and size, while it had positive association with days to first flowering, plant height and fruits per plant. Depestre *et al.* (1981) reported significant and positive association of fruit yield per plant with fruits per plant and fruit weight, however, it was negative between fruits per plant and fruit weight.

Ramakumar *et al.* (1981) showed positive correlation between yield per plant and number of fruits per plant, plant height and plant spread. Sharma *et al.* (1981) reported negative correlation of fruit breadth with fruits per plant. Rao and Chhonkar (1981) and Bavaji *et al.* (1982) observed that yield was positively correlated with fruits per plant and branches per plant.

Veerapa (1982) reported positive correlation between yield and other characters like days to flowering, fruits per plant and fruit weight. Gopalakrishnan *et al.* (1985) found that yield was significantly and positively correlated with fruit length and fruit number per plant.

Meshram (1987) revealed that fruit length and days to first flower had high genetic correlation with yield in chilli. Ghai and Thakur (1987) reported that yield was significantly correlated with fruit length, number of branches and fruit number but there was a negative phenotypic correlation between yield and plant height. Barai and Roy (1989) observed positive correlation for fruit weight and days to maturity in chilli.

Bhagyalakshmi *et al.* (1990) found positive and significant association of yield per plant with number of fruits and branches per plant in chilli, but it was negative and significant with days to 50 per cent flowering. Das *et al.* (1990) reported significant positive correlation for fruit yield per plant with number of primary branches per plant and number of seeds per fruit. Gupta and Singh (1992) observed positive correlation between dry yield and plant height, fruit length, fruit weight and ripe fruit yield per plant. They also reported positive correlation of capsaicin content and vitamin C with number of fruits per plant. Xu *et al.* (1992) revealed that fruit weight had positive correlation with yield.

Pawade *et al.* (1995) showed positive correlation of yield with fruits per plant, number of branches per plant, plant height, fruit length and fruit weight in chilli. Rani (1996) observed that fruit diameter, seed weight, number of seeds per fruit and 1000-seed weight had significant positive correlation with fruit weight.

Deka and Shadeque (1997) found that branches per plant had a significant positive association with yield per plant. Rani (1997) revealed positive correlation for fruit yield per plant with number of fruits per plant, number of primary and secondary branches per plant, plant height and seed weight per fruit. Warade *et al.* (1997b) obtained positive correlation of yield per plant with plant height, fruit weight, seeds per fruit, fruit length and fruit girth and negative correlation with days to 50 per cent flowering and maturity. Das and Choudhary (1999b) reported that fruit yield exhibited positive significant correlation with fruit weight, fruit number and primary branches per plant.

Devi and Arumugam (1999) observed positive and significant correlation between dry fruit yield per plant and number of fruits per plant; capsaicin content and plant height. Kumar *et al.* (1999b) recorded positive correlation for fruit yield with fruit length and fresh fruit weight. Aliyu *et al.* (2000) observed highly significant positive correlation between fresh fruit yield and dry fruit weight. They also reported positive and significant association between yield and fruit number, number of seeds per fruit and seed yield.

Munshi *et al.* (2000) reported positive correlation for yield per plant with fruit number and fruit weight; fruit weight with fruit length and number of fruits per plant and negative correlation for days to first fruit harvest with fruit number and yield per plant.

Mishra *et al.* (2001) obtained positive correlation for red chilli yield with fruit per plant and negative with seeds per fruit. Mohammed *et al.* (2001) revealed that dry fruit yield exhibited significant positive correlation with all the characters under study. They obtained positive correlation of fruits per plant with number of branches and plant height and negative correlation with fruit length and width.

Rangaiah *et al.* (2001) observed positive correlation between days to maturity and plant height and number of primary and secondary branches with fruits per plant in M_2 and M_3 populations of chilli. Leaya and Khader (2002) evaluated thirty seven genotypes of chilli and found that yield per plant had positive correlation with average fruit weight, fruit number, fruit length and plant height.

Rathod *et al.* (2002b) found that yield was positively and significantly associated with number of fruits per plant and 100-seed weight. Sreelathakumary and Rajamony (2002) obtained high phenotypic and genotypic correlations for yield with fruits per plant, fruit weight, fruit length and fruit girth in chilli. Dipendra and Gautam (2003) reported positive correlation for fresh fruit yield with dry fruit yield, fruits per plant, fresh fruit weight, dry fruit weight, 1000-seed weight, plant height, fruit length, number of primary branches and seeds per fruit. Khurana *et al.* (2003) found that fruit yield was positively correlated with number of fruits, fruit length, peel:seed ratio, plant height, capsaicin content and colouring matter.

Kumar *et al.* (2003a) revealed positive correlation for fruit yield with number of primary and secondary branches and fruit number per plant; fruit weight with fruit length and girth; capsaicin content with fruit number per plant, ascorbic acid content with fruit length, fruit girth and fruit weight. They also observed negative associations for fruit number with fruit length, fruit girth and ascorbic acid content and capsaicin content with fruit length, fruit girth and fruit weight in chilli.

Nandadevi and Hosamani (2003) reported positive association of yield per plant with fruits per plant. Nehru *et al.* (2003) indicated significant correlations of fruit yield with number of fruits per plant in chilli. Mathew *et al.*

(2004) observed positive correlation of yield per plant with fruit length, fruit width, fruit weight, number of seeds and 1000-seed weight. Sujata *et al.* (2003) revealed positive correlation of fruit yield with fruit number and fruit length.

Nowaczyk and Nowaczyk (2004) indicated that fruit weight was positively correlated with biological weight, whereas biological performance was negatively correlated with fruit weight and number of seeds. Singh and Singh (2004) revealed positive correlation for yield per plant with number of fruits and plant height. Sreelathakumary and Rajamony (2004b) reported positive correlation for yield per plant with fruit number, fruit length, fruit girth and fruit weight. They also found that fruit weight had a positive correlation with fruit length and fruit girth in chilli.

Verma *et al.* (2004) observed positive correlation between number of fruits per plant and plant height and negative correlation between days to 50 per cent flowering and number of fruits per plant. Raikar *et al.* (2005) on the basis of inter-relationships demonstrated that tall spreading plants with higher number of secondary branches and early maturity would be high yielding types.

2.4 Path coefficient analysis

Path coefficient is simple standardized partial regression coefficient which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variables. The studies on correlation coefficient merely indicate the nature of association and this alone does not provide an exact insight of relative influence of each of the component characters towards yield because a character may not be directly correlated with yield but may influence it through other characters. Hence, the knowledge of direct and indirect effects of yield components is of prime importance to select the suitable genotype for improving yield.

Wright (1921) coined the term path coefficient to denote the direct influence of one variable (cause) upon another (effect). Dewey and Lu (1959) were the first to demonstrate the utility of path coefficient analysis in breeding using crested wheat grass progenies. Korla and Rastogi (1977) carried out path coefficient analysis in chilli and found that fruits per plant had maximum direct effect on yield followed by fruit weight and plant height.

Dutta *et al.* (1979) reported that fruit number per plant and days to 50 per cent flowering had direct contribution towards yield. Further they suggested that these two attributes should be given greater importance, while formulating selection indices in chillies. Sharma *et al.* (1981) showed that fruit length and fruit number had the direct positive effect on yield. Rao and Chhonkar (1981) found that fruit number, fruit weight, dry yield per plant had direct positive effects on ripe fruit yield per plant in *Capsicum fruitescens.* Nair *et al.* (1984) revealed that fruit number, number of secondary branches, fruit girth, fruit weight and duration had positive direct effect on yield per plant.

Solanki *et al.* (1986) observed that number of fruits, number of primary branches per plant, fruit length and plant height had positive direct effect towards yield in chilli. Kaul and Sharma (1989) showed that fruits per plant, TSS and branches per plant were main contributors towards yield in bell pepper. Sarma and Roy (1995) revealed the importance of fruit diameter, fruit length and days to 50 per cent flowering as selection criteria for improving chilli genotypes. Pawade *et al.* (1995) reported that fruits per plant and fruit weight contributed directly, while plant height, number of branches, fruit length and maturity contributed indirectly to the yield.

Das and Choudhary (1999b) concluded that fruit number, fruit weight and primary branches should be selected while breeding for higher yields, as these traits exhibited high positive effect on yield. Devi and Arumugam (1999) observed that number of fruits per plant had the highest positive direct effect and plant height had negative direct effect on dry fruit yield per plant but influenced yield indirectly through number of fruits per plant, number of secondary branches, capsaicin content and number of seeds per fruit.

Kumar *et al.* (1999b) concluded number of fruits per plant, fresh and dry fruit weight as the major yield contributing factors in chilli. They also reported negative contribution of fruit length towards green yield. Aliyu *et al.* (2000) reported that dry weight and number of seeds per fruit had positive direct effects on yield in pepper. Path analysis of yield and its components revealed that fruit number, fruit weight and fruit girth had direct positive effects on yield as per the findings of Munshi *et al.* (2000).

Rangaiah *et al.* (2001) indicated that the characters to be looked in for improving yield are medium duration, maximum height, higher number of primary and secondary branches, medium to higher number of fruits and moderate fruit length and girth. Leaya and Khader (2002) revealed that fruit weight, fruits per plant and early flowering might lead to increase in yield.

Rathod *et al.* (2002b) reported that 100-seed weight had the highest positive direct effect on wet red chilli yield per plant followed by seed percentage, days to 50 per cent flowering and number of primary branches per plant. Dipendra and Gautam (2003) observed that fruit number exerted highest positive direct effect on yield followed by fruit length. Kumar *et al.* (2003a) revealed that fruit length and fruits per plant had high degree of direct effects on yield followed by days to first fruit harvest.

Nandadevi and Hosamani (2003) found that improvement in *Capsicum annuum* can be done by selection criteria of number of fruits per plant. Sujata *et al.* (2003) revealed that the characters *viz.,* fruit number per plant, fruit length and fruit girth had the highest direct effects toward fruit yield.

Mathew *et al.* (2004) reported that fruit number per plant had a direct positive effect on dry yield in *Capsicum* species. Singh and Singh (2004) found number of fruits per plant and fruit weight as major yield components. Sreelathakumary and Rajamony (2004b) revealed that fruits per plant, fruit weight and fruit girth exerted high positive direct effects whereas, fruit length had negative effect on yield in chilli.

2.5 Quality parameters

Quality parameters such as good pungency, bright red colour, high oleoresin concentration and few seeds in the fruit are the main characters on which quality and price is based.

Ramiah and Rayappapillai (1935) stated that pungent varieties are generally small fruited and contain large number of seeds while non-pungent types are big fruited, more fleshy and contain less number of seeds. Kamalam and Rajamani (1966) recorded considerable variation for pungency and yield and indicated possibilities to combine high yield with high capsaicin content.

Ramanujam and Thirumalachar (1967) studied the genetic variability in twelve red pepper varieties and observed considerable genotypic and phenotypic variability for placenta per fruit, capsaicin content of placenta and whole fruit. Continuous variation and high heritability for capsaicin content was reported by Thirumalachar (1967). Gorde (1969-70) observed a negative correlation between vitamin C and capsaicin content in chilli.

Saimbhi *et al.* (1972) reported continuous increase in ascorbic acid with the increase in maturity from green to red stage in chilli. Gill *et al.* (1973) showed a significant and negative correlation between capsaicin content and fruit shape index; smaller fruits usually having higher capsaicin content in chilli. Awasthi *et al.* (1976b) recorded highest content (289.07 mg/100 g) of ascorbic acid in red chilli at mature stage. They also reported its positive correlation with age, length and diameter of the fruits.

Arya and Saini (1977) obtained negative association of capsaicin content with yield and significant positive correlation with fruit number. They also concluded that high capsaicin content cultivars had small fruits with profuse bearing whereas, large sized fruits with less number of fruits per plant had a lower capsaicin content. Saimbhi *et al.* (1977) reported (206.00 mg/100 g) ascorbic acid in fresh red chilli and (127.00 mg/100 g) in mature green chilli. Bajaj *et al.* (1978) observed varietal variation in capsaicin content of twenty five chilli genotypes. Bajaj *et al.* (1980) concluded that there was wide variation in dry matter, ascorbic acid, capsaicin, oleoresin, total extractable colour, total alcoholic extract and ash percentage among different genotypes of chilli.

Sharma *et al.* (1981) showed significant positive association between number of fruits per plant and capsaicin content. Gupta and Yadav (1984) observed high genotypic coefficient of variation for ascorbic acid content in chilli. Khadi (1984) reported that ascorbic acid content of ripe fruit was greatly influenced by the number of days to fruit ripening, fruit length and ascorbic acid content of green fruit in chilli. Nair *et al.* (1984) revealed significant positive correlation for ascorbic acid with fruit weight, number of seeds, length and girth of fruit but was negatively correlated with number of days taken for blooming and duration. However, capsaicin and vitamin C content showed significant negative correlation.

Jinap and Daud (1990) studied and determined capsaicin content in chilli at two stages of maturation (25 and 40 days after flowering) and found significant differences among cultivars for both maturities. Rani (1994) reported significant variation for capsanthin (0.126-0.407%), ascorbic acid (58.73-193.1 mg/100 g) and capsaicin (0.056-1.81%) in chilli. Rani (1995) revealed negative association of fruit length and fruit weight with capsaicin, while ascorbic acid was positively correlated with 1000-seed weight, fruit length and capsanthin but was negatively correlated with fruits per plant. Rani and Singh (1996) obtained high heritability and genetic advance for capsaicin content in chilli germplasm.

Ishikawa *et al.* (1997) studied ascorbic acid content in the fruits of deep green cultivars of chilli and suggested that the deep green colour is due to its relatively high ascorbic acid content. Khan *et al.* (1999) studied genetic analysis on nutritional characteristics of chilli and revealed highest amount of vitamin C in green chillies and beta-carotene in ripe chillies.

Nawalagatti *et al.* (1999) evaluated chilli genotypes for quality parameters. The capsaicin and total colouring matter contents were significantly higher in varieties followed by the hybrids and least in lines. The ascorbic acid and oleoresin contents were significantly higher in hybrids followed by varieties and least in the lines, indicating large genotypic variation among the various quality parameters studied. However, no definite relationship between quality parameters and yield was observed. Jha *et al.* (2001) reported highest capsaicin and ascorbic acid content at maturity in chilli genotypes.

Manju and Sreelathakumary (2002) evaluated chilli for quality parameters namely capsaicin, oleoresin and ascorbic acid content. The analysis of variance revealed significant differences among the accessions. High phenotypic and genotypic coefficients of variation alongwith high heritability and genetic advance were observed for all the characters. Correlation studies indicated the positive association of capsaicin with oleoresin and primary branches per plant and a negative association with fruit weight.

Mini and Vahab (2002) reported that oleoresin yield was positively correlated with number of fruits per plant and negatively with number of days to fruit set, flowering and harvesting. Number of days to flowering had a positive direct effect on oleoresin yield whereas, number of days to harvesting and number of fruits per plant had negative direct effects on oleoresin yield. Sathiyamurthy *et al.* (2002) observed significant differences for capsaicin content in mature green and dry fruit.

Gupta and Tambe (2003) found wide range of variation for physiochemical characteristics *viz.,* moisture content, protein, ash, fibre, fat, carbohydrate, capsaicin, ascorbic acid, chlorophyll and phosphorus contents, fruit weight, pericarp weight and number of seeds per fruit in chilli. Kumar *et al.* (2003b) observed that capsaicin content ranged from 0.33 mg/100 g – 0.49 mg/100 g, ascorbic acid content from 78.30 mg/100 g and total carotenoids from 1475.3 μg/100 g – 4208 μg/100g in chilli.

Singh *et al.* (2003) observed wide range of variation for various quality parameters *viz.,* oleoresin, capsaicin, colouring matter and dry matter in all the genotypes studied. Robi and Sreelathakumary (2004) revealed significant variation among most of the chilli genotypes for capsaicin content at colour changing stage (1.26 to 3.02%), at red ripe stage (1.32 to 3.18%) and at withering stage (1.48 to 3.36%). They reported maximum ascorbic acid content in red ripe stage than colour changing and withering stage.

Materials and Methods

Chapter III

MATERIALS AND METHODS

The present investigation was undertaken at the Experimental Farm of Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during *Kharif*, 2005 and 2006. The details of materials used and methods employed in the present study are presented below:

3.1 Experimental site

3.1.1 Location

The experimental farm is situated at 32°6' N latitude and 76°3' E longitude at an elevation of 1290.8 m above mean sea level.

3.1.2 Climate

The place is characterized by severe winters and mild summers with high rainfall. Agroclimatically, the location represents the mid-hill zone 2.2 of Himachal Pradesh (Appendix-I) and is characterized by humid sub-temperate climate with high rainfall (2500 mm), of which 80% is received during June to September.

The week-wise meteorological data recorded in the department of Agronomy during the cropping seasons are given in Appendices II & III.

3.2 Materials and design

3.2.1 Experimental material

The experimental material for the present study comprised of 30 diverse genotypes of chilli. All the genotypes were available in the Department of Vegetable Science. The genotypes along with their sources have been presented in Table 3.1.

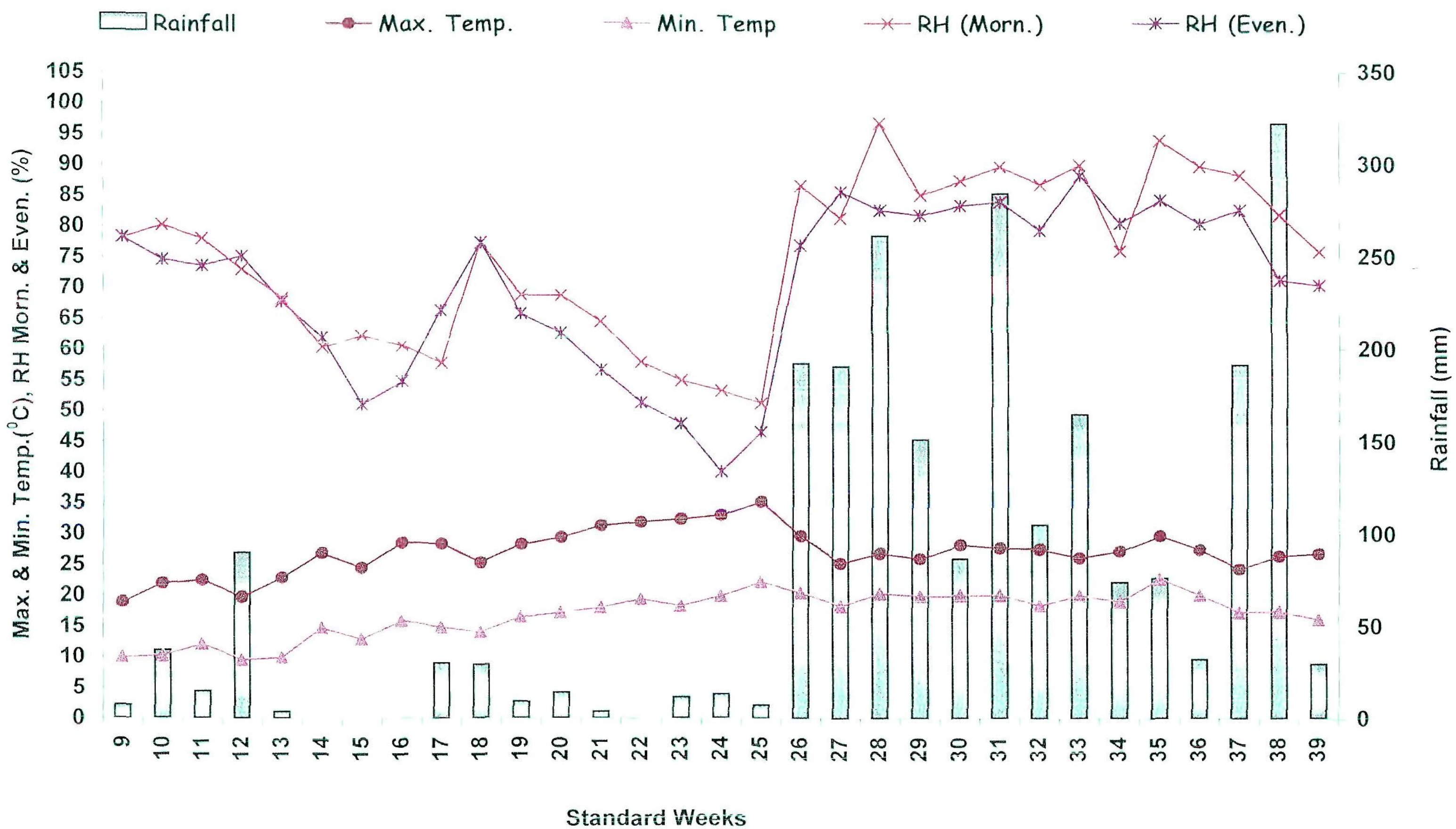

Fig. 3.1 Weather parameters during the experimental period of 2005

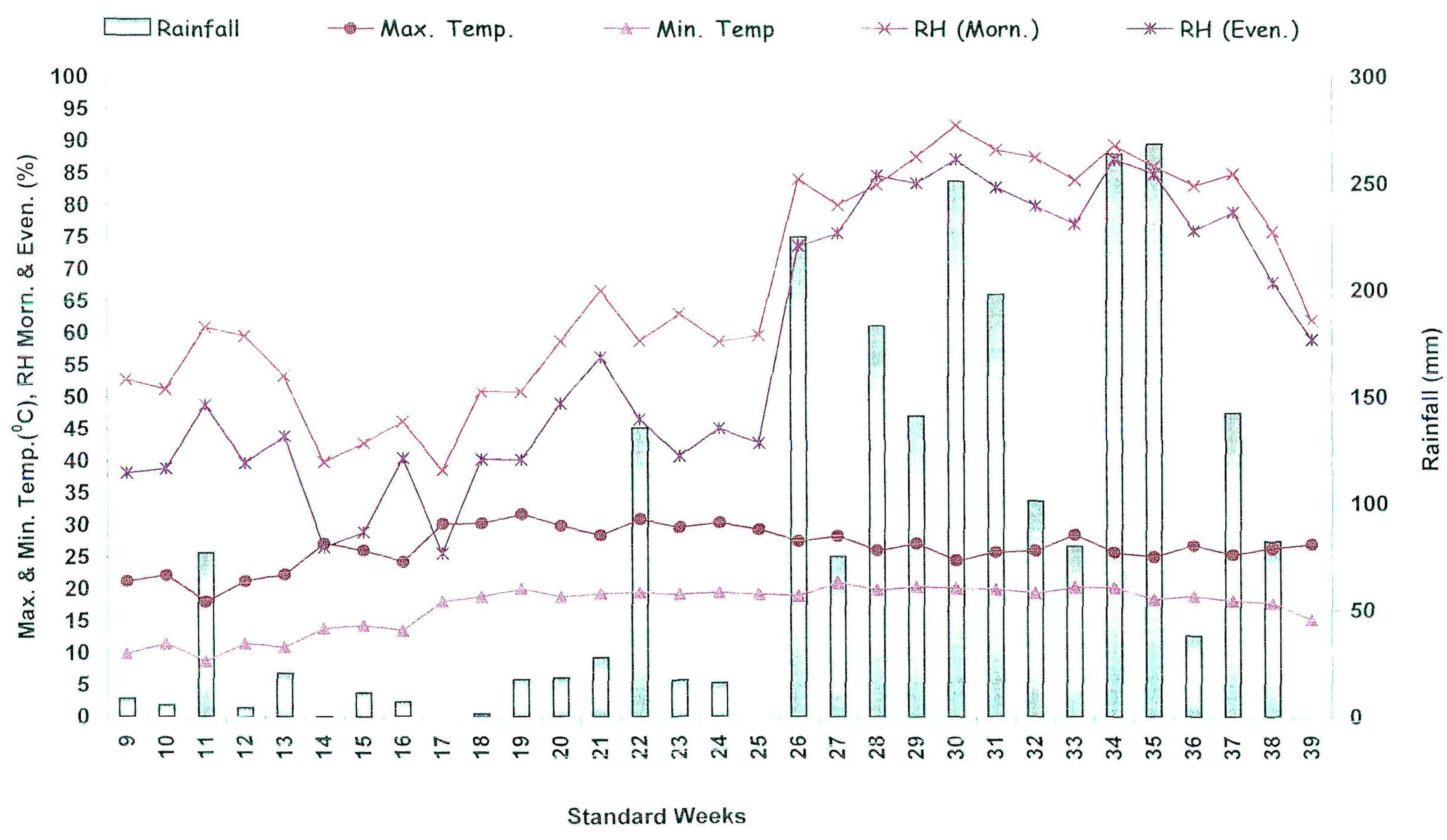

Fig. 3.2 Weather parameters during the experimental period of 2006

Table 3.1 List of chilli (*Capsicum annuum* L.) genotypes and their sources

Sr. No.	Genotype	Source
1.	G-4 (Bhagyalakshmi)	Agricultural Research Station, Lam, Guntur
2.	Anugraha	KAU, Kerala
3.	Ujwala	-do-
4.	CO-3	TNAU, Coimbatore
5.	Kadyavallur Local	-do-
6.	PKM-1	-do-
7.	KCA-190	-do-
8.	KCA-171	-do-
9.	K-1	Kovilpatti, Tamil Nadu
10.	Palam Yellow	Department of Vegetable Science and Floriculture, CSK HPKV, Palampur
11.	Surajmukhi	-do-
12.	DPCH-1	-do-
13.	LCA-357	IARI, New Delhi
14.	NCH-162	-do-
15.	DCL-352	-do-
16.	ACH-201	-do-
17.	HCH-9639	-do-
18.	BC-25	-do-
19.	DCL-520	-do-
20.	ACS-2000-2	-do-
21.	DCL-524	-do-
22.	Pusa Sada Bahar	-do-
23.	Ajeet-1	-do-
24.	SKAU-SC-304-1	Division of Olericulture, SKUAST(K), Shalimar, Srinagar, J&K
25.	Kashmir local	-do-
26.	SKAU-SC-23-1	-do-
27.	SKAU-SC-578-1	-do-
28.	SKAU-SC-101	-do-
29.	Arka Lohit	IIHR, Bangalore
30.	Pant C-1	G.B. Pant University of Agriculture and Technology, Pantnagar

3.2.2 Layout plan

The 30 diverse genotypes replicated thrice were planted in a randomized block design. Ten plants of each genotype were planted with inter and intra plant distance of 45 cm each.

3.2.3 Nursery sowing and transplanting

The nursery was sown on 1st March, 2005 and 28th February 2006 and transplanting of seedlings was done on 23rd April 2005 and 20th April 2006, respectively.

3.2.4 Cultural practices

The intercultural operations i.e. nutrients application, irrigation and weeding etc. were carried out in accordance with the recommended package of practices to ensure a healthy crop growth and development.

3.3 Recording of data

The observations were recorded on five competitive plants taken at random in each entry and replication for group of following traits.

I. Horticultural traits

(a) Fresh crop

(b) Seed crop

II. Quality traits

III. Morphological characterization

IV. Disease reaction

I. Horticultural traits

(a) Fresh crop

(1) Days to 50 per cent flowering

Days were counted from date of transplanting to the opening of the flower on 50 per cent of the total plant population (5 plants) for each genotype.

(2) Days to first fruit picking

Number of days from date of transplanting to the first harvest for market at mature green stage in each case were counted.

(3) Primary branches per plant

Number of branches arising from the stem were counted in five randomly selected plants and then mean values were computed.

(4) Secondary branches per plant

Number of branches arising from the primary branches in case of five randomly selected plants were counted and then mean values were computed for each entry.

(5) Fruit length (cm)

Polar distance of ten randomly taken fruits was measured from the pedicel end to the blossom end.

(6) Fruit girth (cm)

The fruits used for recording the fruit length were used for measuring the girth at pedicel end with the help of vernier caliper.

(7) Average fruit weight (g)

Average fruit weight was worked out by dividing the marketable green yield with number of marketable fruits from each plant.

(8) Number of marketable fruits per plant

Number of marketable fruits picked from individual plant were counted at each picking and finally summed up to work out the marketable fruits per plant.

(9) Total number of fruits per plant

Number of fruits picked in all harvests from each plant were counted and finally added to work out the total number of fruits per plant for each genotype.

(10) Plant height (cm)

The plant height was measured from the base of the plant to the tip of the main axis at the time of final harvest.

(11) Marketable green yield per plant (g)

Weight of fresh marketable fruits harvested from five selected plants at mature green stage was averaged to work out the marketable green yield per plant.

(12) Harvest duration (days)

Total number of days from first picking to final picking of marketable fruits for each genotype were recorded.

(b) Seed crop

(1) Days to ripe fruit picking

Number of days from date of transplanting to the first harvest at red ripe stage in each case were counted.

(2) Average dry fruit weight (g)

Average dry fruit weight was worked out by dividing the dry yield per plant with number of marketable fruits per plant in each entry.

(3) Dry fruit yield per plant (g)

Marketable fruits harvested from five randomly selected plants at red ripe stage were dried and weighed to work out the average dry fruit yield per plant.

(4) Number of seeds per fruit

The seeds of ten healthy fruits harvested at red ripe stage in each treatment were extracted to calculate seed number per fruit.

(5) Seed weight per fruit (g)

The seeds extracted from ten healthy fruits harvested at red ripe stage were dried and used to work out seed weight per fruit (g).

(6) 100-seed weight (g)

Weight of randomly taken 100 dried seeds in each treatment was measured by electronic balance to work out the 100-seed weight.

(7) Peel:seed ratio

Average fruit and seed mass of ten randomly taken red ripe fruits was taken to work out peel:seed ratio as :

$$\text{Peel : seed ratio} = \frac{F - S}{S}$$

where,

F - Fruit mass

S - Seed mass

II. Quality traits

(1) Asorbic acid content (mg/100 g)

Ascorbic acid content was estimated by '2,6-dichlorophenol-indophenol Visual Titration Method' as described by Ranganna (1979).

Reagents:

(a) 3% metaphosphoric acid (HPO_3) : Prepared by dissolving the sticks or pellets of HPO_3 in glass distilled water.

(b) Ascorbic acid standard : 100 mg of L-ascorbic acid was weighed accurately and volume made up to 100 ml with 3% HPO_3. 10 ml of this solution was further diluted to 100 ml with 3% HPO_3. (1 ml = 0.1 mg ascorbic acid)

(c) Dye solution : 50 mg of the sodium salt of 2,6-dichlorophenol-indophenol was dissolved in approximately 150 ml of hot glass distilled water containing 42 mg of sodium bicarbonate. The solution was cooled and diluted with glass distilled water to 200 ml. Stored in a refrigerator and standardized every day.

Procedure

Standardization of dye

5 ml of standard ascorbic acid solution was taken in a beaker and 5 ml of HPO_3 was added to it. This solution was titrated with the dye solution to a pink colour which persisted for 15 seconds. Dye factor (mg of ascorbic acid per ml of the dye) was determined by using the formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

Here,

0.5 means 0.5 mg of ascorbic acid in 5 ml of 100 ppm standard ascorbic acid solution,

Titre = Volume of dye used to neutralize 5 ml of 100 ppm standard ascorbic acid solution along with 5 ml of metaphosphoric acid.

Ten grams of macerated sample was blended with 3 per cent metaphosphoric acid and the volume was finally made upto 100 ml. Out of this 100 ml solution, 10 ml of solution was taken and titrated against 2,6-dichlorophenol indophenol dye till the appearance of rose pink colour. The results, thus obtained were expressed in terms of mg of ascorbic acid per 100 g of sample.

The ascorbic acid content was calculated by using the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre X Dye factor X Volume made up}}{\begin{array}{c}\text{Aliquot of extract} \\ \text{taken for} \\ \text{estimation}\end{array} \text{ X } \begin{array}{c}\text{Weight of sample} \\ \text{taken for} \\ \text{estimation}\end{array}} \text{ X } 100$$

Here,

Titre = Volume of dye used to titrate the aliquot of extract of a given sample.

(2) Oleoresin (ASTA Units)

Oleoresin was calculated as per procedure given by A.O.A.C. (1980).

Requirements : Spectrophotometer, acetone.

Procedure

100 mg of powered sample was transferred to 100 ml volumetric flask. The final volume was made up with acetone, shaken and allowed to stand for two minutes. 10 ml extract was pipetted into another 100 ml volumetric flask and final volume made up with acetone and was shaken again. Absorbance of this solution was measured at 460 nm against acetone as blank.

Calculations

ASTA colour value for oleoresin = [(A_{ext} at 460 nm) X (164 I_f]/g sample

where,

$$I_f \text{ (correction factor)} = \frac{\text{Declared OD of NBS std. at 465 nm}}{\text{Observed OD of NBS std at 465 nm}}$$

Standard of NBS (National Board of Spice) is 1 M Ferrous ammonium sulphate and declared OD is 0.64. In the Spectronic, declared OD is equal to observed so, there was no need to multiply with I_f.

(3) Capsanthin/colouring matter (ASTA units)

Capsanthin was determined as per procedure given by A.O.A.C. (1980).

Requirement : Spectrophotometer, Acetone

Procedure

100 mg of powered sample was taken in 100 ml volumetric flask, diluted to volume with acetone and corked tightly. The solution prepared was shaken well and allowed to stand in dark for sixteen hours at room temperature. The mixture was shaken again and particles were allowed to settle for two minutes. A clear portion of the extract was transferred to cell and absorbance was measured at 465 nm using acetone as blank.

Calculations

ASTA colour value for capsicum = [(A_{ext} at 465 nm) X (16.4 I_f)]/g sample

(4) Capsaicin content (%)

The capsaicin content in the fruits was determined by Colorimetric method using Folin-Ciocalteau reagent described by Bajaj (1980). The capsaicin concentration in different samples was noted from the standard capsaicin curve and finally the results were converted into percentage.

Reagents

(i) Acetone

(ii) Aluminium oxide active basic

(iii) Folin and ciocalteau phenol reagent (available as 2N; diluted with equal volume of distilled water just before use).

(iv) Sodium carbonate anhydrous. 35 g of anhydrous sodium carbonate was dissolved in 100 ml of water at 70^{o}-$80^{o}C$, filtered and allowed to cool overnight. Super saturated solution with crystals of $Na_2CO_3.10H_2O$ was filtered through glass wool to obtain the mother liquid.

(v) Methanol (CH_2O)

Procedure

(a) Standard curve : 0 to 1.5 ml of standard capsaicin were taken in small beakers and evaporated to less than 0.5 ml at room temperature. 0.5 ml FC reagent and 6.5 ml of distilled water were added to the beaker and allowed to stand for three minutes. Then 1 ml of Na_2CO_3 solution was added and mixed well. Whole quantity was transferred to 10 ml volumetric flask and final volume was made up with distilled water. Centrifugation for 10-15 minutes at 10,000 rpm was done. Absorbance was measured at 760 nm after one hour rest at room temperature.

(b) **Extraction :** 0.5 g of dried powdered capsicum fruits were extracted with 25 ml acetone. Mixture was shaken for 10 minutes and allowed to stand for four hours. After that mixture was filtered through glass wool plugged in a short stemmed funnel. Volume was made upto 25 ml. 2 ml of this extract was passed through basic alumina column. Column is 1.5 g basic alumina (have layers of Glasswool, Aluminium oxide and Sodium sulphate of 2 finger height each) in to 10 x 0.9 cm column which is washed with 5 ml of acetone. Column was washed with 3 x 5 ml of acetone after loading. These washings were discarded. Pure capsaicin was eluted with acetone : methanol : water (75:25:1) mixture and final volume made upto 50 ml. 10 ml volume was evaporated to dryness at temperature less than 65^{o}C and the colour was developed as for calibration curve.

(c) **Calculations :** Suppose OD of sample = x. Then from standard curve, concentration of capsaicin against x = y mg. This y mg is in 10 ml which is taken from 50 ml. So in 50 ml, concentration of capsaicin = 5 y. Again this 5 y is from 2 ml extract which is taken from 25 ml of extract made at first step. So, in 25 ml, concentration of capsaicin = (5y x 25 mg)/2. This 25 ml extract was prepared from 0.5 g of sample.

Therefore, 0.5 g (500 mg) of sample has 125/2 y mg of capsaicin

1 g of sample has 125 y mg of capsaicin

100 g of sample has 12500 y mg of capsaicin

Therefore, 100 g of sample contains 12500 y mg of capsaicin

In per cent capsaicin content will be 12.5 y

(5) Total soluble solids

Total soluble solids were determined at green and red stages.

(a) TSS at green stage (%)

Green fruits were crushed in pestle mortar and the liquid extract obtained was used to record TSS with the help of ERMA hand refractometer.

(b) TSS at red stage (%)

Red mature fruits were crushed in the pestle-mortar and the liquid extract obtained was used to record TSS with the help of ERMA hand refractometer.

(6) Moisture content (%)

100 gram of fruit samples of each genotype were kept in oven at $60^{\circ}C \pm 2^{\circ}C$ and dried till the weight of sample became constant and per cent moisture content was computed as follows:

$$\text{Moisture content (\%)} = \frac{\text{Fresh fruit weight} - \text{Dry fruit weight}}{\text{Fresh fruit weight}} \times 100$$

III. Morphological characterization

In addition to quantitative traits, the efforts were made for characterization of these genotypes on the basis of their morphology as per the minimal descriptors of vegetable crops for chilli suggested by Srivastava *et al.* (2001) as well as on visual observation for the following characters:-

(1) Mature fruit colour

The colour of the fruits at mature green stage was observed and classified into different colour groups on the basis of visual observation such as yellow, light green, green and dark green fruits.

(2) Ripe fruit colour

The colour of fruits at mature ripe stage was recorded and classified into different colour groups on the basis of visual observation such as bright red, red and deep red.

(3) Fruit shape at pedicel attachment

The mature fruits were observed to categorize the genotypes into acute, obtuse, truncate, cordate and lobate groups (Fig. 3.3).

(4) Fruit shape at blossom end

Blossom end fruit shape was recorded at mature fruit stage. The genotypes were divided into pointed, blunt, sunken, sunken and pointed groups (Fig. 3.4).

(5) Fruit position

Fruit position was recorded at mature fruit stage to classify genotypes as pendent, semi-pendent and erect.

(6) Fruit bearing habit

Fruit bearing habit was recorded at mature fruit stage and genotypes were divided into solitary and cluster groups.

(IV) Disease reaction

(1) Bacterial wilt (%)

Bacterial wilt disease incidence in chilli was recorded as per Sinha *et al.* (1990) scale. Total mortality (confirmed by ooze test) in each genotype was recorded and expressed in per cent to categorize the genotypes into resistant, moderately resistant, moderately susceptible, susceptible, highly susceptible as per scale:

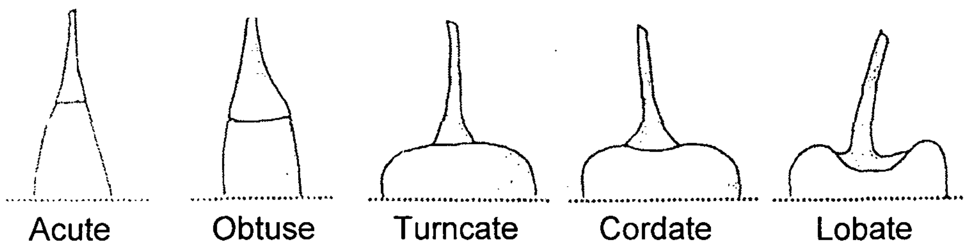

Fig. 3.3 Fruit shape at pedicel attachment

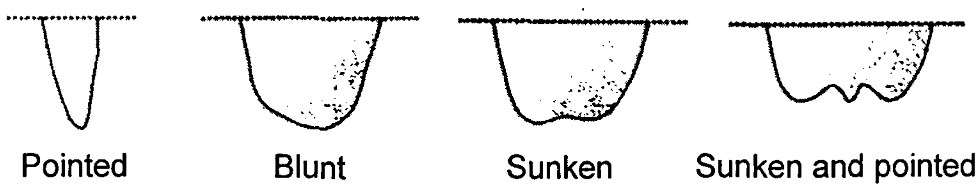

Fig. 3.4 Fruit shape at blossom end

Bacterial wilt (%)	Reaction category
0-10	Resistant (R)
10-20	Moderately resistant (MR)
20-30	Moderately susceptible (MS)
30-70	Susceptible (S)
70-100	Highly susceptible (HS)

(2) Fruit rot incidence (%)

The number of fruits infested per plant was used to record fruit rot incidence.

$$\text{Fruit rot incidence (\%)} = \frac{\text{Total number of fruits} - \text{Number of marketable fruits}}{\text{Total number of fruits}} \times 100$$

The degree of fruit rot incidence was grouped into following categories of disease rating.

Fruit rot incidence (%)	Reaction category
0-5	Highly resistant (HR)
5-10	Resistant (R)
10-25	Moderately susceptible (MS)
25-40	Susceptible (S)
above 40	Highly susceptible (HS)

3.4 Statistical analysis

The data over two years were subjected to Bartlett's test of homogeneity (Panse and Sukhatme, 1984) to reveal the differences if any between the years. The Bartlett's test of Homogeneity was tested by using the following formula:

$$\chi^2 = \frac{K\,(n \log \bar{S}^2 - \Sigma \operatorname{Log} S_r^2)}{C}$$

Where,

$$C = 1 + \frac{n+1}{3nk}$$

n	=	number of years
S^2	=	Pooled error = $1/n\ \Sigma S_r^2$
S_r	=	Error mean sum of squares with respect to each year,
k	=	degree of freedom with respect to error
K	=	$\log_e^{10} = 2.3026$

In case of non-significance of test, average values for each genotype in each replication for the traits studied were used for further statistical analysis. A brief outline of the procedure adopted for the estimation of different statistical parameters is given below:

3.4.2 Analysis of variance

The data were analyzed as per the following model given by Panse and Sukhatme (1984):

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

where,

Y_{ij}	=	Phenotypic observation of i^{th} genotype grown in j^{th} replication
m	=	General population mean
g_i	=	Effect of i^{th} genotype

r_j = Effect of j^{th} replication

e_{ij} = Error associated with i^{th} genotype in the j^{th} replication

On the basis of this model the analysis of variance was done as follows:

Analysis of variance for experimental design

Source of variation	df	Sum of squares	Mean sum of squares (M)	F. cal.	Expected M.S.
Replication (r)	(r-1)	Sr	Sr/(r-1)=Mr	Mr/Me	$\sigma^2e+g\sigma^2r$
Genotype (g)	(g-1)	Sg	Sg/(g-1)=Mg	Mg/Me	$\sigma^2e+r\sigma^2g$
Error (e)	(r-1) (g-1)	Se	Se/(r-1) (g-1)=Me	-	σ^2e

where,

r = number of replications

g = number of genotypes

σ^2e = error variance = Me

σ^2g = variance due to genotypes = Mg–Me/r

σ^2p = variance due to replications = Mr–Me/g

The standard error of mean (SEm) and critical difference (CD) for comparing the means of any two genotypes were computed as follows:

$$SE(m) = \pm \sqrt{Me/r}$$

$$SE(d) = \pm \sqrt{2Me/r}$$

Critical difference (CD) = SE(d) x t (5%) value at error degree of freedom.

3.4.2 Estimation of parameters of variability

The genotypic, phenotypic and environmental coefficients of variation were estimated as suggested by Burton and De Vane (1953) as follows:

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

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

$$\text{Environmental coefficient of variation (ECV\%)} = \frac{\sigma e}{\bar{X}} \times 100$$

where,

σg = genotypic standard deviation

σp = phenotypic standard deviation

σe = environmental standard deviation

$\bar{X}$ = population mean

3.4.3 Heritability (h^2_{bs})

Heritability in broad sense (h^2_{bs}) was calculated as per the following formula given by Burton and De Vane (1953) and Johnson *et al.* (1955):

$$\text{Heritability} = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 e} \times 100$$

where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 e$ = environmental variance

$\sigma^2 g + \sigma^2 e$ = phenotypic variance

3.4.4 Genetic advance

The expected genetic advance (GA) resulting from the selection of 5 per cent superior individuals was calculated following Burton and De Vane (1953) and Johnson *et al.* (1955):

$$GA = K.\sigma p.h^2$$

where,

K = 2.06 (selection differential at 5% selection intensity)

σp = phenotypic standard deviation

h^2 = heritability (broad sense)

$$\text{Genetic advance as percentage of mean} = \frac{\text{Expected GA}}{\text{Grand Mean}} \times 100$$

For categorizing the magnitude of different parameters, the following limits were used:

Genetic advance (GA)	> 50%	-	High
	25% - 50%	-	Moderate
	< 25%	-	Low
PCV, GCV and ECV	> 20%	-	High
	10% - 20%	-	Moderate
	< 10%	-	Low
Heritability	> 80%	-	High
	50% - 80%	-	Moderate
	< 50%	-	Low

3.4.5 Correlation coefficients

For computing phenotypic, genotypic and environmental correlation coefficients, analysis of co-variance were carried out in all possible pairs of combinations of the characters.

Analysis of co-variance

Source of variation	df	Mean sum of product	Expected mean sum of product
Replication (r)	(r–1)	Mr_{xy}	$\sigma e_{xy} + g\sigma r_{xy}$
Genotypes (g)	(g–1)	Mg_{xy}	$\sigma e_{xy} + r\sigma g_{xy}$
Error (e)	(r–1)(g–1)	Me_{xy}	σe_{xy}

where,

σe_{xy} = Error co-variance of character x and character y

σg_{xy} = Genotypic co-variance of character x and character y

The genotypic, phenotypic and error co-variance were calculated as follows:

Genotypic co-variance (σg_{xy}) = $Mg_{xy} - Me_{xy} / r$

Phenotypic co-variance (σp_{xy}) = $\sigma g_{xy} + \sigma e_{xy}$

Environmental co-variance (σe_{xy}) = Me_{xy}

The phenotypic, genotypic and environmental coefficients of correlation were computed as suggested by Al-Jibouri *et al.* (1958).

Phenotypic coefficient of correlation (rp_{xy})

$$rp_{xy} = \frac{\sigma p_{xy}}{\sqrt{\sigma^2 p_x \times \sigma^2 p_y}}$$

where,

σp_{xy} = phenotypic co-variance between character x and y

$\sigma^2 p_x$ = phenotypic variance of character x

$\sigma^2 p_y$ = phenotypic variance of character y

Genotypic coefficient of correlation (rg_{xy})

$$rg_{xy} = \frac{\sigma g_{xy}}{\sqrt{\sigma^2 g_x \times \sigma^2 g_y}}$$

where,

σg_{xy} = genotypic co-variance between character x and y

$\sigma^2 g_x$ = genotypic variance of character x

$\sigma^2 g_y$ = genotypic variance of character y

Environmental coefficient of correlation (re_{xy})

$$re_{xy} = \frac{\sigma e_{xy}}{\sqrt{\sigma^2 e_x \times \sigma^2 e_y}}$$

where,

σe_{xy} = environmental co-variance between character x and y

$\sigma^2 e_x$ = environmental variance of character x

$\sigma^2 e_y$ = environmental variance of character y

The significance of phenotypic coefficients of correlation were tested against 'r' values as given by Fisher and Yates (1963) at n-2 degree of freedom, where 'n' is the number of genotypes.

3.4.6 Path-coefficient analysis

Path-coefficient is a standardized partial regression coefficient, which permits the partitioning of the correlation coefficients into direct and indirect effects. The path-coefficient analysis of important horticultural traits as well as quality traits with yield was done following Dewey and Lu (1959) as under:

Py1 + Py2.r12 + Py3.r13 + ... + Pyn.r1n = ry1

Py1.r12 + Py2 + Py3.r23 + ... + Pyn.r2n = ry2

Py1.r13 + Py2.r23 + Py3 + ... + Pyn.r3n = ry3

:

:

:

:

Py1.r1n + Py2.r2n + Py3.r3n + ... + Pyn = ryn

where,

Py1, Py2, Py3 .... Pyn are the direct path effects of 1, 2, 3, ..., n variables on the dependent variable 'y'.

r12, r13, ... r (n-1) n are the possible coefficients of correlation between various independent variables and ry1, ry2, ry3, ... ryn are the correlation coefficients of independent variables with dependent variable 'y'.

The variation in the dependent variables was assumed to be due to variable (s) not included in the present investigation. The degree of determination of such variables was calculated as follows:

Residual effect (P X R) = $\sqrt{1 - R^2}$

where,

R^2 = Py1.ry1 + Py2.ry2 + ... + Pyn.ryn

where,

R^2 is the square multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the yield component characters.

Results

Chapter IV

RESULTS

The results of the present investigation on nature and magnitude of variability and association studies among different horticultural and quality traits of the thirty diverse genotypes are presented under the following main heads:

4.1 Genetic variability studies

4.2 Correlation coefficients

4.3 Path coefficient analysis

4.4 Morphological characterization of the genotypes

4.5 Disease reaction

4.1 Genetic variability studies

4.1.1 Analysis of variance

Data were pooled over the years as Bartlett's test of homogeneity between error variances (Panse and Sukhatme, 1984) was found to be non-significant for all the traits. The analysis of variances for different traits over the years is presented in Table 4.1. The results obtained with respect to different groups of traits for pooled data are presented below:

I. Horticultural traits

(a) Fresh crop

The analysis of variances revealed that mean squares due to genotypes were significant for the traits *viz.,* days to 50% flowering, days to first fruit picking, primary branches per plant, secondary branches per plant, fruit

Plate 1. Chilli crop in the experimental field

Table 4.1 Analysis of variance for horticultural and quality traits over the years

Traits	2005			2006			Pooled over years			χ^2 (Bartlett's test)
	Replication	Genotypes	Error	Replication	Genotypes	Error	Replication	Genotypes	Error	
df	2	29	58	2	29	58	2	29	116	
I. Horticultural traits										
(a) Fresh crop										
Days to 50% flowering	0.32	75.99*	0.61	0.44	78.95*	0.53	0.17	154.74*	0.57	0.32
Days to first picking	0.56	78.16*	0.44	0.03	73.79*	0.46	0.25	151.02*	0.45	0.02
Primary branches per plant	0.00	4.35*	0.00	0.00	4.36*	0.00	0.00	8.71*	0.00	0.20
Secondary branches per plant	0.00	2.29*	0.00	0.00	2.28*	0.00	0.00	4.57*	0.00	0.09
Fruit length (cm)	0.00	9.16*	0.00	0.00	9.14*	0.00	0.00	18.29*	0.00	0.84
Fruit girth (cm)	0.00	0.23*	0.00	0.00	0.23*	0.00	0.00	0.46*	0.00	0.61
Average fruit weight (g)	0.00	3.88*	0.00	0.00	4.06*	0.00	0.01	7.94*	0.01	0.00
Number of marketable fruits per plant	2.25	313.79*	2.22	2.74	316.68*	1.62	4.70	630.21*	1.91	1.45
Total number of fruits per plant	0.21	320.73*	1.31	0.36	321.19*	1.27	0.50	642.66*	1.29	0.01
Plant height (cm)	0.78	274.91*	2.29	3.11	269.74*	1.98	0.50	544.47*	2.14	0.30
Marketable yield per plant (g)	2.13	6753.16*	2.80	0.13	6718.81*	2.56	1.50	13471.73*	2.68	0.11
Harvest duration (days)	0.10	112.35*	0.58	0.04	113.63*	0.55	0.11	225.83*	0.57	0.04

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Traits	2005			2006			Pooled over years			χ^2 (Bartlett's test)
	Replication	Genotypes	Error	Replication	Genotypes	Error	Replication	Genotypes	Error	
df	2	29	58	2	29	58	2	29	116	
(b) Seed crop										
Days to ripe fruit picking	0.25	68.90*	0.58	0.69	64.74*	0.47	0.94	133.44*	0.52	0.60
Average dry fruit weight (g)	0.00	0.07*	0.00	0.00	0.07*	0.00	0.00	0.15*	0.00	1.08
Dry fruit yield per plant (g)	5.16	126.77*	1.95	4.84	126.64*	2.08	5.91	250.87*	2.02	0.06
Number of seeds per fruit	2.91	413.43*	2.00	0.50	411.62*	1.63	2.88	824.43*	1.82	0.59
Seed weight per fruit (g)	0.00	0.02*	0.00	0.00	0.02*	0.00	0.00	0.04*	0.00	0.05
100-seed weight (g)	0.00	0.02*	0.00	0.00	0.02*	0.00	0.00	0.03*	0.00	0.00
Peel:seed ratio	0.00	5.15*	0.00	0.00	5.15*	0.00	0.00	10.30*	0.00	0.72
II. Quality traits										
Ascorbic acid (mg/100 g)	0.22	394.59*	2.19	1.53	396.59*	2.05	1.31	790.79*	2.13	0.06
Oleoresin (ASTA Units)	1.63	609.52*	1.44	1.11	609.52*	1.46	2.63	1219.05*	1.45	0.00
Capsanthin (ASTA Units)	1.09	613.99*	1.11	1.09	613.99*	1.11	2.25	1227.98*	1.12	0.00
Capsaicin content (%)	0.00	0.08*	0.00	0.00	0.08*	0.00	0.00	0.16*	0.00	0.03
TSS (%) (Green)	0.00	0.41*	0.00	0.00	0.41*	0.00	0.00	0.82*	0.00	0.00
TSS (%) (Red)	0.00	0.50*	0.00	0.00	0.50*	0.00	0.00	1.01*	0.00	0.00
Moisture content (%)	0.09	11.27*	0.10	0.09	11.27*	0.10	0.13	22.54*	0.11	0.00

* Significant at P=0.05 χ^2 Non-significant

length, fruit girth, average fruit weight, number of marketable fruits per plant, total number of fruits per plant, plant height, marketable green yield per plant and harvest duration.

(b) Seed crop

The mean sum of squares showed that genotypes were significant for all the traits *viz.,* days to ripe fruit picking, average dry fruit weight, dry fruit yield per plant, number of seeds per fruit, seed weight per fruit, 100-seed weight and peel:seed ratio.

II. Quality traits

The analysis of variances indicated that mean squares due to genotypes were significant for all the quality traits under study *viz.,* ascorbic acid, oleoresin, capsanthin, capsaicin content, TSS (at green and red stage) and moisture content.

4.1.2 Mean performance

Mean performance of different genotypes for various traits have been presented in Table 4.2 and described as under:

I. Horticultural traits

(a) Fresh crop

Days to 50 per cent flowering

Observations recorded on different genotypes for this trait revealed that G-4 took minimum days to flower (42.67 days) followed by SKAU-SC-578-1 (43.00 days), SKAU-SC-101 (43.17 days), Arka Lohit (43.83 days) and Kadyavallur Local (43.83 days). However, maximum days to 50 per cent flowering were taken by LCA-357 (59.67 days) and Pant C-1 (59.17 days).

Table 4.2 Mean performance of chilli genotypes in relation to different horticultural and quality traits

Genotypes	Horticultural Traits											
	Fresh crop											
	Days to 50% flowering	Days to first fruit picking	Primary branches per plant	Secondary branches per plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	No. of marketable fruits per plant	Total number of fruits per plant	Plant height (cm)	Marketable yield per plant (g)	Harvest duration (days)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
G-4	**42.67**	73.50	5.84	6.65	8.42	0.99	4.45	57.45	68.90	61.40	219.52	63.00
HCH-9639	50.17	81.50	4.99	5.48	**11.57**	0.89	**6.58**	43.75	55.41	68.30	261.71	52.67
Anugraha	47.17	75.00	5.98	6.07	8.08	0.89	3.16	54.90	64.20	48.32	196.76	62.67
CO-3	50.33	77.50	6.12	7.08	8.76	0.94	3.73	47.37	59.28	63.48	175.29	53.67
P. Yellow	45.50	74.17	6.93	**7.48**	8.39	1.14	6.41	43.58	54.51	70.31	**268.22**	52.33
PKM-1	54.17	81.50	6.18	7.06	8.80	1.00	4.07	43.59	54.79	67.63	140.78	51.83
DPCH-1	50.50	78.50	**3.00**	**3.80**	8.40	1.95	5.78	**11.31**	**19.48**	**32.22**	**63.65**	**37.17**
LCA-357	**59.67**	86.50	4.08	5.59	10.48	1.01	4.40	36.40	48.24	59.17	161.30	53.83
SKAU-SC-304-1	49.50	77.50	3.44	5.93	6.88	1.49	3.38	32.90	43.86	58.30	108.26	50.50
NCH-162	47.33	74.50	6.58	7.06	8.82	0.99	4.44	45.97	55.23	59.48	183.13	52.50
DCL-352	55.50	84.50	6.58	6.15	5.06	1.01	3.12	32.74	41.90	47.27	98.53	40.83
ACH-201	58.83	86.50	7.03	6.55	11.06	0.97	4.18	31.74	43.43	56.77	141.11	51.83
Kadyavallur Local	58.50	90.17	5.98	5.52	8.52	1.08	3.18	42.62	53.10	73.12	131.04	53.83
Arka Lohit	43.83	**72.50**	5.03	6.14	8.32	0.91	3.13	42.93	53.58	64.87	120.30	52.30

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
BC-25	51.50	82.83	5.48	5.87	8.08	1.00	3.93	32.09	44.33	53.41	107.41	52.50
KCA-190	52.00	83.83	5.80	5.96	8.23	0.99	3.24	40.36	50.83	58.06	126.79	51.50
Kashmir local	43.83	75.50	4.02	5.54	8.33	1.29	3.17	42.96	53.79	61.52	142.86	50.50
KCA-171	54.50	82.50	4.74	4.94	8.72	0.93	3.97	46.40	55.56	50.21	161.46	51.50
K-1	54.50	85.50	6.02	6.21	5.88	1.00	3.98	45.00	54.81	65.10	170.32	50.50
DCL-520	50.50	82.00	4.97	5.47	5.82	**2.00**	3.32	34.58	44.17	48.41	104.16	52.50
SKAU-SC-23-1	48.50	77.50	4.33	6.14	9.89	1.18	4.28	38.10	47.43	70.25	174.15	50.50
ACS-2000-2	50.50	79.17	3.13	5.83	10.97	1.01	6.40	24.39	34.42	64.03	157.36	51.50
SKAU-SC-578-1	43.00	76.83	4.97	4.83	7.82	1.10	4.55	35.49	45.58	66.56	152.91	52.50
SKAU-SC-101	43.17	72.50	5.13	6.90	8.25	0.99	4.57	45.40	55.33	**73.27**	210.47	52.50
DCL-524	49.50	78.50	5.09	6.81	7.83	0.98	4.86	39.18	49.30	60.21	154.10	53.50
Ujwala	53.33	84.83	7.17	4.98	**5.04**	**0.81**	2.38	42.17	51.78	53.62	120.21	63.50
Pusa Sada Bahar	58.50	*87.83*	*6.11*	7.23	5.85	*1.01*	2.49	*52.13*	*61.93*	*42.01*	*142.93*	62.83
Surajmukhi	49.50	81.50	**7.93**	7.18	5.84	1.19	3.32	**63.96**	**74.07**	67.29	223.10	**63.67**
Ajeet-1	51.50	79.50	4.84	5.00	6.46	1.00	4.39	33.74	45.14	52.67	135.60	46.50
Pant C-1	59.17	**88.83**	6.21	6.93	5.85	0.86	**1.92**	53.50	62.16	57.09	110.52	63.00
Mean	50.91	80.43	5.46	6.08	8.01	1.09	4.03	41.22	51.55	59.15	155.47	53.27
SE (d)	0.63	0.56	0.02	0.04	0.02	0.01	0.06	1.15	0.95	1.22	1.36	0.63
CD (0.05)	1.03	0.92	0.02	0.06	0.04	0.01	0.10	1.89	1.56	2.00	2.24	1.03
CV (%)	1.48	0.83	0.33	0.77	0.32	0.97	1.84	3.36	2.21	2.47	1.05	1.41

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Genotypes	Horticultural Traits							Quality Traits						
	Seed crop													
	Day to ripe fruit picking	Average dry fruit weight (g)	Dry fruit yield per plant (g)	No. of seeds per fruit	Seed weight per fruit (g)	100-seed weight (g)	Peel: seed ratio	Ascorbic acid (mg/100 g)	Oleoresin (ASTA Units)	Capsanthin (ASTA Units)	Capsaicin content (%)	TSS (%) (Green)	TSS (%) (Red)	Moisture content (%)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**
G-4	**91.50**	0.71	33.22	71.84	0.36	0.50	9.52	99.43	**78.42**	108.63	0.53	5.22	8.24	84.08
HCH-9639	104.00	0.96	31.66	93.89	0.45	0.48	**10.74**	107.02	63.96	103.58	0.54	5.32	8.30	**87.85**
Anugraha	97.50	0.62	28.10	74.58	0.28	0.40	7.51	104.15	66.65	92.31	0.49	5.24	8.27	83.94
CO-3	104.17	0.74	22.47	93.52	0.42	0.44	6.75	97.23	68.07	88.48	0.58	5.08	8.14	83.64
P. Yellow	92.83	1.03	33.65	82.29	0.42	0.49	10.65	**83.81**	62.65	107.49	**0.19**	5.21	8.24	83.65
PKM-1	104.50	0.56	13.10	84.89	0.39	0.47	6.63	107.24	64.12	**71.71**	0.48	5.18	8.22	85.40
DPCH-1	101.83	1.00	**9.79**	64.20	0.33	**0.52**	8.73	88.62	**22.00**	47.56	0.22	5.04	8.06	81.42
LCA-357	104.50	0.71	19.19	66.75	0.33	0.46	8.51	101.27	71.04	107.43	0.51	5.08	8.11	87.38
SKAU-SC-304-1	104.50	0.61	16.62	98.67	0.42	0.42	5.74	100.80	54.53	79.43	0.43	5.32	8.29	83.39
NCH-162	95.50	0.70	27.98	93.61	0.42	0.43	7.66	89.81	44.59	108.37	0.60	**4.98**	**8.01**	84.37
DCL-352	104.50	0.54	11.06	62.65	0.23	0.36	8.06	123.29	33.77	104.76	0.60	6.15	9.05	86.38
ACH-201	107.83	0.81	22.03	82.07	0.34	0.42	9.74	123.05	44.28	108.37	0.37	5.04	8.11	84.32
Kadyavallur Local	108.50	0.58	19.39	72.89	0.27	0.39	7.45	92.81	60.68	94.09	0.48	5.10	8.17	83.97
Arka Lohit	94.33	0.63	20.63	71.38	0.33	0.45	7.06	119.70	63.25	72.61	0.52	5.30	8.24	82.82
BC-25	104.50	0.75	20.22	76.54	0.33	0.43	6.72	104.37	54.15	84.18	0.36	5.23	8.19	81.67

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
KCA-190	107.50	0.62	21.54	81.22	0.34	0.41	6.05	107.71	35.77	**111.46**	0.49	5.16	8.19	**80.46**
Kashmir local	96.17	0.68	22.17	71.81	0.32	0.41	6.76	109.37	49.48	103.57	0.51	5.03	8.07	81.32
KCA-171	102.50	0.70	23.82	76.67	0.33	0.45	8.37	101.67	47.64	96.65	0.59	5.13	8.06	81.28
K-1	105.17	0.76	24.66	74.88	0.32	0.43	8.08	92.31	35.24	78.01	0.35	5.11	8.21	83.49
DCL-520	108.50	0.57	12.95	81.85	0.32	0.42	6.95	93.34	53.75	107.41	0.41	5.21	8.34	86.79
SKAU-SC-23-1	101.67	0.91	27.97	72.62	0.36	0.44	7.93	98.07	77.08	108.75	0.45	5.00	8.03	81.70
ACS-2000-2	103.83	**1.12**	28.69	**102.45**	**0.48**	0.47	8.64	108.03	33.25	101.25	0.39	5.09	8.19	81.87
SKAU-SC-578-1	98.00	0.83	23.44	83.75	0.41	0.44	7.64	112.24	31.19	103.91	0.61	5.24	8.21	83.03
SKAU-SC-101	98.17	0.88	28.87	82.30	0.38	0.44	8.58	119.57	51.20	101.11	0.62	5.48	8.88	83.71
DCL-524	99.50	0.78	22.68	89.17	0.33	0.37	8.65	104.45	49.31	97.18	0.50	5.23	8.43	80.98
Ujwala	103.83	0.59	21.12	64.26	**0.23**	**0.34**	6.10	99.20	40.97	103.32	0.86	6.03	9.14	83.38
Pusa Sada Bahar	**108.83**	0.64	28.81	61.06	**0.23**	0.37	7.14	104.08	65.29	98.80	0.87	**6.21**	**9.41**	81.14
Surajmukhi	100.50	0.65	**34.35**	66.86	0.24	0.37	8.52	107.08	42.00	98.29	**0.90**	6.05	9.25	81.39
Ajeet-1	103.83	0.81	20.45	83.52	0.35	0.42	8.61	117.03	50.53	96.24	0.39	5.68	8.88	83.06
Pant C-1	101.50	**0.48**	22.81	**54.42**	0.24	0.42	**5.71**	**134.59**	50.61	98.07	0.56	5.97	9.05	82.59
Mean	102.00	0.73	23.11	77.81	0.34	0.43	7.84	105.05	52.18	96.10	0.51	5.34	8.40	83.35
SE (d)	0.60	0.01	1.18	1.12	0.01	0.002	0.27	1.21	1.00	0.88	0.01	0.03	0.03	0.27
CD (0.05)	0.99	0.01	1.94	1.84	0.01	0.003	0.45	2.00	1.65	1.45	0.02	0.05	0.05	0.45
CV (%)	0.71	1.27	6.14	1.73	1.99	0.47	0.42	1.39	2.31	1.10	2.45	0.64	0.43	0.39

Days to first fruit picking

Arka Lohit (72.50 days) and SKAU-SC-101 (72.50 days) were the earliest to produce mature green fruits followed by G-4 (73.50 days), whereas Pant C-1 took maximum days (88.83 days) for first fruit picking.

Primary branches per plant

Primary branches per plant ranged from 3.00 to 7.93 (Table 4.2). Minimum number of branches was observed in DPCH-1, whereas maximum number of primary branches per plant was observed in Surajmukhi.

Secondary branches per plant

Number of secondary branches per plant ranged from 3.80 to 7.48. Palampur Yellow had the maximum number of secondary branches per plant (7.48), whereas minimum number of secondary branches per plant (3.80) were recorded in DPCH-1.

Fruit length (cm)

Ujwala (5.04 cm) had the minimum fruit length followed by DCL-352 (5.06 cm), whereas maximum fruit length was recorded in HCH-9639 (11.57 cm).

Fruit girth (cm)

The mean value of genotypes (Table 4.2) revealed that DCL-520 had the maximum fruit girth (2.00 cm). Minimum fruit girth was observed in Ujwala (0.81 cm).

Average fruit weight (g)

The estimates of mean values in Table 4.2 indicated that Pant C-1 had the lowest average fruit weight (1.92 g), whereas Anugraha (6.58 g) had the highest fruit weight.

Number of marketable fruits per plant

A wide range of variability existed for this trait among genotypes under investigation. Maximum number of marketable fruits were observed in Surajmukhi (63.96). Minimum number of marketable fruits were observed in DPCH-1 (11.31).

Total number of fruits per plant

The observations recorded on this trait showed wide range of variability ranging from 19.48 to 74.07. Surajmukhi (74.07) had the highest total number of fruits, whereas DPCH-1 (19.48) produced the lowest number of total fruits per plant.

Plant height (cm)

SKAU-SC-101 (73.27 cm) and Kadya Vallur Local (73.12 cm) had the maximum plant height, while DPCH-1 (32.22 cm) was the shortest.

Marketable green yield per plant (g)

Among the genotypes studied, wide range of variability was observed for this trait. Palam Yellow (268.22 g) was the highest yielder, while DPCH-1 (63.65 g) was the lowest yielder.

Harvest duration (days)

Data implied that longest harvest duration was recorded in Surajmukhi (63.67 days) followed by Ujwala (63.50 days), G-4 (63.00 days), Pusa Sada Bahar (62.67 days) and Anugraha (62.67 days). DPCH-1 (37.17 days) had the shortest harvest duration.

(b) Seed crop

Days to ripe fruit picking

The perusal of mean values in Table 4.2 revealed that Pusa Sada Bahar (108.83 days), DCL-520 (108.50 days), Kadyavallur Local (108.50 days) and ACH-201 (107.83 days) took maximum days for first picking. G-4 (91.50 days) was the earliest for picking of ripe fruits.

Average dry fruit weight (g)

The estimates of mean value on average dry fruit weight revealed that ACS-2000-2 (1.12 g) had the highest fruit weight whereas, Pant C-1 (0.48 g) had the lowest fruit weight.

Dry fruit yield per plant (g)

Among the genotypes studied, Surajmukhi (34.35 g) was the highest yielder followed by G-4 (33.22 g). On the other hand, DPCH-1 was the lowest yielder (9.79 g).

Number of seeds per fruit

Maximum number of seeds per fruit were observed in ACH-2000-2 (102.45), while minimum number of seeds per fruit were found in Pant C-1 (54.42).

Seed weight per fruit (g)

The perusal of mean values revealed that ACS-2000-2 (0.50 g) had the highest seed weight. On the other hand Ujwala (0.23 g), Pusa Sada Bahar (0.23 g), DCL-352 (0.23 g), Surajmukhi (0.24 g) and Pant C-1 (0.24 g) had the lowest seed weight per fruit, which were statistically comparable.

100-seed weight (g)

Data implied that DPCH-1 had the highest 100-seed weight (0.51 g), whereas Ujwala had the lowest 100-seed weight (0.34 g).

Peel:seed ratio

HCH-9639 (10.74) and Palam Yellow (10.65) had the highest peel:seed ratio. The Lowest peel:seed ratio was observed in Pant C-1 (5.71) followed by SKAU-SC-300-1 (5.74), KCA-190 (6.05) and Ujwala (6.10).

II. Quality traits

Ascorbic acid (mg/100 g)

Pant C-1 (134.59 mg/100 g) had the maximum ascorbic acid while Palam Yellow had the minimum ascorbic acid (83.81 mg/100 g).

Oleoresin (ASTA Units)

G-4 (78.42 ASTA Units) had the highest ASTA Units for oleoresin, whereas DPCH-1 had the lowest ASTA Units for oleoresin (22.00).

Capsanthin (ASTA Units)

The perusal of mean values showed that KCA-190 had the maximum colouring matter (111.46 ASTA Units). Minimum colouring matter was observed in PKM-1 (71.71 ASTA Units) and Kadyavallur Local (72.61 ASTA Units).

Capsaicin content (%)

The genotype Surajmukhi recorded highest percentage of capsaicin content (0.90%) while Palam Yellow (0.19%) recorded the lowest percentage of the capsaicin content.

TSS at green stage (%)

Pusa Sada Bahar (6.21%) recorded the maximum TSS at mature green stage. Minimum TSS was observed in NCH-162 (4.98%), SKAU-SC-23-1 (5.00%) and Kashmir Local (5.03%) which were statistically at par (Table 4.2).

TSS at red stage (%)

Data implied that Pusa Sada Bahar had the maximum TSS at red ripe stage (9.41%). NCH-162 had the minimum TSS (8.01%).

Moisture content (%)

The estimates of mean values on moisture content revealed that HCH-9639 (87.85%) had the highest moisture content, while KCA-190 (80.46%) followed by DCL-524 (80.98%) had the lowest moisture content.

4.1.3 Parameters of variability

Different parameters of variability have been calculated from the research data *viz.,* range, general mean, phenotypic variance, genotypic variance, environmental variance, coefficients of variation at phenotypic (PCV), genotypic (GCV) and environmental (ECV) levels, heritability in broad sense, genetic advance and genetic advance (as per cent of mean) (Table 4.3) to

Plate 2. Variation for fruit colour at mature green and red ripe stage

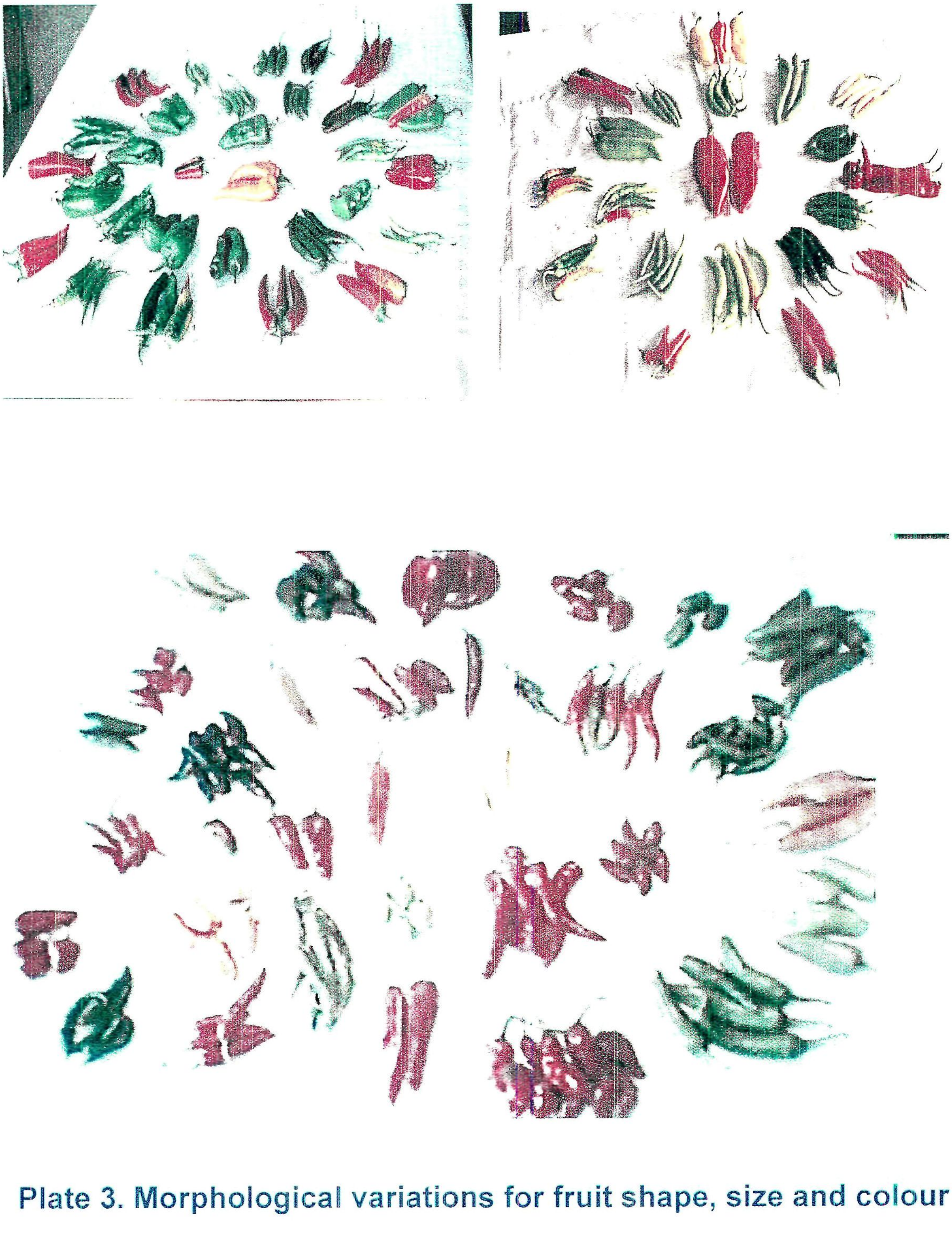


Plate 3. Morphological variations for fruit shape, size and colour

Table 4.3 Estimates of variability parameters for horticultural and quality traits in chili

Traits	Range	General mean ± SE (m)	Variance			Coefficient of variation			Heritability (h^2) (%)	Genetic advance (K=2.06)	Genetic advance (% of mean)
			Phenotypic	Genotypic	Environmental	Phenotypic (PCV)	Genotypic (GCV)	Environmental (ECV)			
1. Horticultural traits											
a) Fresh crop											
Days to 50% flowering	42.67-59.67	50.91±0.44	26.34	25.76	0.57	10.08	9.97	1.48	89.80	10.34	20.31
Days to first fruit picking	72.50-88.83	80.43±0.39	25.76	21.39	0.45	6.31	5.75	0.83	90.30	10.27	12.77
Primary branches per plant	3.00-7.93	5.46±0.01	1.45	1.37	0.00	22.08	21.47	0.33	91.20	2.48	45.45
Secondary branches per plant	3.80-7.48	6.08±0.03	0.76	0.66	0.002	14.38	13.36	0.77	93.70	1.79	29.45
Fruit length (cm)	5.04-11.57	8.01±0.02	3.05	2.77	0.00	21.79	20.78	0.32	90.00	3.60	44.92
Fruit girth (cm)	0.81-2.00	1.08±0.01	0.07	0.06	0.00	25.47	23.45	0.97	91.90	0.57	52.54
Average fruit weight (g)	1.92-6.58	4.03±0.04	1.33	1.18	0.005	28.61	27.00	1.84	88.60	2.36	58.60
Number of marketable fruits/plant	11.31-63.96	41.22±0.80	106.87	105.01	1.92	25.08	24.86	3.36	90.20	20.92	50.75
Total number of fruits per plant	19.48-74.07	51.55±0.66	108.43	98.78	1.29	20.20	19.28	2.21	87.80	21.19	41.10
Plant height (cm)	32.22-73.27	59.15±0.84	92.84	79.79	2.14	16.29	15.10	2.47	89.70	19.39	32.78
Marketable yield per plant (g)	63.65-268.22	155.47±0.95	2248.50	2100.62	2.68	30.50	29.48	1.05	91.00	97.55	62.75
Harvest duration (days)	37.17-63.67	53.27±0.44	38.18	37.59	0.57	11.60	11.51	1.41	87.50	12.54	23.54

Contd../-

	Traits	Range	General mean ± SE (m)	Variance			Coefficient of variation			Heritability (h^2) (%)	Genetic advance (K=2.06)	Genetic advance (% of mean)
				Phenotypic	Genotypic	Environmental	Phenotypic (PCV)	Genotypic (GCV)	Environment (ECV)			
b)	**Seed crop**											
	Days to ripe fruit picking	91.50-108.83	102.00±0.42	22.69	22.11	0.52	4.67	4.61	1.71	89.78	9.60	9.41
	Average dry fruit weight (g)	0.48-1.12	0.73±0.01	0.03	0.02	0.00	21.54	20.51	1.27	89.70	0.32	43.69
	Dry fruit yield per plant (g)	9.79-34.35	23.11±0.82	43.38	41.36	2.02	28.50	27.83	6.14	88.48	12.94	55.98
	Number of seeds per fruit	54.40-102.45	77.89±0.78	139.06	114.27	1.82	15.14	13.11	1.73	85.70	23.98	30.79
	Seed weight per fruit (g)	0.23-0.48	0.34±0.004	0.01	0.00	0.00	23.34	22.25	1.99	89.30	0.17	48.75
	100-seed weight (g)	0.34-0.52	0.43±0.001	0.00	0.00	0.00	16.29	15.28	0.47	90.90	0.15	33.63
	Peel:seed ratio	5.71-10.74	7.84±0.19	1.72	1.33	0.00	16.72	14.71	0.42	91.00	2.70	34.44
ii)	**Quality traits**											
	Ascorbic acid (mg/100 g)	83.81-134.59	105.05±0.84	133.77	119.13	2.13	11.01	10.39	1.39	88.40	23.46	22.33
	Oleoresin (ASTA Units)	22.00-78.42	52.18±0.70	204.51	196.29	1.45	27.41	26.85	2.31	90.30	29.26	56.07
	Capsanthin (ASTA Units)	71.71-111.46	96.10±0.61	205.86	178.18	1.12	14.93	13.89	1.10	89.40	29.39	30.58
	Capsaicin content (%)	0.19-0.90	0.51±0.01	0.03	0.02	0.00	31.73	30.64	2.45	87.45	0.33	64.28
	TSS (%) (Green)	4.98-6.21	5.34±0.02	0.14	0.08	0.00	6.95	5.39	0.64	88.40	0.76	14.24
	TSS (%) (Red)	8.01-9.41	8.40±0.02	0.17	0.11	0.00	4.90	3.88	0.43	87.59	0.84	10.00
	Moisture content (%)	80.46-87.85	83.35±0.19	3.87	3.74	0.11	2.36	2.32	0.39	90.20	3.94	4.73

facilitate selection for various traits. A wide range of variability was observed for all the traits studied. The results pertaining to these parameters are briefly presented below:

I. Horticultural traits

(a) Fresh crop

Days to 50 per cent flowering

The data (Table 4.3) revealed that phenotypic variance (26.34) for the trait was higher in magnitude than corresponding genotypic variance (25.76). The estimates of GCV and ECV were low with values of 9.97 and 1.48, respectively. However, the value of PCV was found to be moderate (10.08). Heritability was high (89.80%) with low genetic advance (20.31).

Days to first picking

The magnitudes of phenotypic and genotypic variances were 25.76 and 21.39, respectively. The values of PCV (6.31), GCV (5.75) and ECV (0.83) were low in magnitudes. Heritability was high (90.30%) with low genetic advance (12.77).

Primary branches per plant

This trait displayed low phenotypic (1.45) and genotypic (1.37) variances. The values of PCV and GCV were high in magnitudes i.e. 22.08 and 21.47, respectively, while ECV was low (0.33). High heritability (91.20%) coupled with moderate genetic advance (45.42) were recorded for this trait.

Secondary branches per plant

Phenotypic and genotypic variances with their respective values of 0.76 and 0.66 were recorded for this trait. The values of PCV (14.38) and GCV (13.36) were moderate. High heritability (93.70%) was associated with moderate genetic advance (29.45) for this trait.

Fruit length (cm)

The phenotypic and genotypic variances recorded for this trait were 3.05 and 2.77, respectively. The values of PCV (21.79) and GCV (20.78) were found to be high. This character exhibited high heritability (90.00%) coupled with moderate genetic advance (44.91).

Fruit girth (cm)

The values of phenotypic and genotypic variances were 0.07 and 0.06, respectively. The estimates of PCV (25.47) and GCV (23.45) were high in magnitudes, whereas ECV (0.97) was low. High heritability (91.90%) alongwith high genetic advance (52.78) were noticed for this trait.

Average fruit weight (g)

The phenotypic and genotypic variances were found to be 1.33 and 1.18, respectively. The PCV and GCV were high with values 28.61 and 27.00, respectively, while ECV was low (1.84). High heritability (88.60%) associated with high genetic advance (58.56) were recorded for this trait.

Plate 4. Variability in fruit length at mature green and red ripe stage

Plate 5. Variability in length and girth of chilli

Number of marketable fruits per plant

Phenotypic and genotypic variances were found to be 106.87 and 105.01, respectively. PCV and GCV were high in magnitudes i.e. 25.08 and 24.86, respectively, while ECV was low (3.36). Heritability was high (90.20%) with high genetic advance (50.75).

Total number of fruits per plant

The values of phenotypic and genotypic variances were 108.43 and 98.78, respectively. The estimates of PCV were high (20.20) while for GCV were moderate with values of 19.28. However, value of ECV was low (2.21). High heritability (87.80%) associated with moderate genetic advance (41.11) were recorded for this trait.

Plant height (cm)

The magnitudes of phenotypic and genotypic variances for this trait were 92.84 and 79.79, respectively. The phenotypic and genotypic coefficients of variation were moderate in magnitudes with values of 16.29 and 15.10, respectively, while it was low at environmental level (2.47). Heritability estimate (89.70%) was high with moderate genetic advance (32.78).

Marketable green yield per plant (g)

This trait exhibited the phenotypic and genotypic variances of 2248.50 and 2100.62, respectively. The magnitudes of PCV (30.50) and GCV (29.485) were high. The estimates of heritability were high (91.00%) alongwith high genetic advance (62.95).

Plate 6. Freshly harvested produce of chilli at mature green stage

Harvest duration (days)

Phenotypic and genotypic variances were found to be 38.18 and 37.59, respectively. The PCV (11.60) and GCV (11.57) were moderate, whereas ECV was low (1.41) in magnitude. Heritability estimates (87.50%) were high with low genetic advance (23.55).

(b) Seed crop

Days to ripe fruit picking

The magnitudes of phenotypic and genotypic variances were found to be 22.69 and 22.11, respectively. The values of PCV (4.67), GCV (4.61) and ECV (0.71) were low in magnitudes. Heritability was high (89.78%) with low genetic advance (9.41).

Average fruit weight (g)

The phenotypic and genotypic variances were found to be 0.03 and 0.02, respectively. The PCV and GCV estimates were high with values of 21.54 and 20.51, respectively. High heritability (89.70%) associated with moderate genetic advance (43.83) were recorded for this trait.

Dry fruit yield per plant (g)

This trait exhibited phenotypic and genotypic variances of 43.38 and 41.36, respectively. The magnitude of PCV and GCV were high with values of 28.50 and 27.83, respectively. The estimates of heritability were high (88.48%) associated with high genetic advance (55.99).

Number of seeds per fruit

This trait showed the phenotypic and genotypic variances of 139.06 and 114.27, respectively. The coefficients of variation at phenotypic (15.14) and genotypic (13.11) levels were moderate. The trait exhibited high heritability (85.70%) with moderate genetic advance (30.79).

Seed weight per fruit (g)

The estimates of PCV (19.96) and GCV (17.25) were moderate in magnitude, whereas ECV (1.99) was low. High heritability (89.30%) alongwith moderate genetic advance (50.00) were noticed for this trait.

100-seed weight (g)

The PCV (9.83) and GCV (8.28) were low in magnitude. High heritability estimates (90.90%) associated with moderate genetic advance (34.88) were observed for this trait.

Peel:seed ratio

The phenotypic and genotypic variances recorded for this trait were 1.72 and 1.33, respectively. The moderate values of PCV (16.7) and GCV (14.71) were observed for this trait. This character exhibited high heritability (91.00%) coupled with moderate genetic advance (34.44)

II. Quality traits

Ascorbic acid (mg/100 g)

Phenotypic and genotypic variances with their respective values of 133.77 and 119.13 were recorded for this trait. The values of PCV (11.01) and GCV (10.39) were moderate, whereas ECV was low (1.39). High heritability (88.40%) associated with low genetic advance (22.33) was observed for this trait.

Oleoresin (ASTA Units)

High phenotypic (204.51) and genotypic (196.29) variances were displayed by this trait. The values of PCV and GCV were high in magnitude i.e. 27.41 and 26.85, respectively. High heritability (90.30%) coupled with high genetic advance (56.08) were recorded for this trait.

Capsanthin (ASTA Units)

The magnitudes of phenotypic and genotypic variances were found to be 205.86 and 178.18, respectively. The values of PCV (14.33) and GCV (13.89) were moderate, whereas that of ECV (1.10) was low in magnitude. Heritability was high (89.40%) with moderate genetic advance (30.58).

Capsaicin content (%)

This character showed respective values of 0.03 and 0.02 for phenotypic and genotypic variances. The PCV (31.73) and GCV (30.64) were high in magnitude, but ECV (2.45) was low. Heritability estimates (87.45%) were high associated with high genetic advance (64.71).

TSS at green stage (%)

The phenotypic and genotypic variances were found to be 0.14 and 0.08. The PCV (6.45), GCV (5.39) and ECV (0.64) were low in magnitudes with high heritability (88.40%) but low genetic advance (14.24).

TSS at red stage (%)

The values of phenotypic and genotypic variances for this trait were 0.17 and 0.11, respectively. The magnitudes of PCV (4.90), GCV (3.88) and ECV (0.43) were low. The estimates of heritability were high (87.59%) alongwith low genetic advance (10.00).

Moisture content (%)

The magnitudes of phenotypic and genotypic variances of this trait were 3.87 and 3.74, respectively. The values of PCV (2.36), GCV (2.32) and ECV (0.39) were low in magnitude. Heritability was high (90.20%) with low genetic advance (4.73).

4.2 Correlation coefficients

The correlation coefficients among different horticultural and quality traits were worked out in all possible combinations at phenotypic (P) and genotypic (G) levels for marketable green yield per plant as well as for dry yield per plant from the pooled data over two years i.e. 2005 and 2006. The results obtained are given in Table 4.4 and 4.5. For most of the traits, genotypic correlation values were higher than those at phenotypic levels.

Correlation coefficients for marketable green yield at phenotypic (P) level

The results pertaining to correlation coefficients for marketable green yield at phenotypic level are presented in Table 4.4 and are briefly discussed below:

I. Horticultural traits

Marketable green yield per plant (g)

A perusal of data revealed that marketable green yield per plant was found to be significantly and positively correlated with total number of fruits per plant (0.585), plant height (0.575), number of marketable fruits per plant (0.562), average fruit weight (0.465), secondary branches per plant (0.461) and

Table 4.4 Estimates of phenotypic (P) and genotypic (G) correlation coefficients for different pair of horticultural and quality traits in green chilli

		Marketable green yield per plant (g)	Days to 50% flowering	Days to first fruit picking	Primary branches/ plant	Secondary branches/ plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Number of marketable fruits per plant	Total number of fruits per plant	Plant height (cm)	Harvest duration (days)	Moisture content (%)	Ascorbic acid (mg/100 g)	TSS (%) (green)
Marketable green yield per plant (g)	P		**-0.379***	**-0.371***	0.300	**0.461***	0.354	**-0.364***	**0.465***	**0.562***	**0.585***	**0.575***	**0.368***	0.196	-0.206	-0.107
	G		-0.383	-0.374	0.300	0.462	0.354	-0.364	0.466	0.567	0.589	0.580	0.372	0.199	-0.208	-0.107
Days to 50% flowering	P			**0.915***	0.188	-0.022	-0.096	-0.140	-0.313	-0.100	-0.103	-0.293	0.027	0.151	0.133	0.262
	G			0.934	0.190	-0.023	-0.097	-0.142	-0.316	-0.099	-0.102	-0.298	0.027	0.157	0.137	0.267
Days to first fruit picking	P				0.247	-0.103	-0.207	-0.113	**-0.380***	-0.035	-0.040	-0.216	0.117	0.102	0.144	0.335
	G				0.250	-0.103	-0.208	-0.115	-0.383	-0.036	-0.040	-0.221	0.117	0.105	0.145	0.338
Primary branches/ plant	P					**0.573***	-0.358	**-0.437***	**-0.364***	**0.614***	**0.615***	0.157	**0.496***	0.112	0.079	**0.441***
	G					0.574	-0.358	-0.437	-0.365	0.620	0.618	0.159	0.500	0.114	0.080	0.443
Secondary branches/plant	P						-0.046	**-0.375***	-0.119	**0.603***	**0.617***	**0.398***	**0.442***	0.008	0.104	0.184
	G						-0.046	-0.375	-0.119	0.609	0.622	0.404	0.446	0.008	0.105	0.186
Fruit length (cm)	P							-0.148	**0.639***	-0.234	-0.192	0.341	-0.186	0.160	-0.083	**-0.701***
	G							-0.148	0.640	-0.236	-0.193	0.345	-0.188	0.162	-0.084	-0.704
Fruit girth (cm)	P								0.124	**-0.479***	**-0.503***	**-0.364***	**-0.428***	0.012	**-0.394***	-0.211
	G								0.125	0.484	-0.507	-0.368	-0.432	0.013	-0.398	-0.211
Average fruit weight (g)	P									**-0.405***	**-0.382***	0.223	**-0.417***	0.155	-0.319	**-0.480***
	G									-0.410	-0.385	0.226	-0.421	0.156	-0.323	-0.483
Number of marketable fruits per plant	P										**0.984***	0.339	**0.783***	-0.013	0.083	0.325
	G										0.995	0.343	0.794	-0.017	0.083	0.329
Total number of fruits per plant	P											**0.371***	**0.784***	0.011	0.086	0.298
	G											0.378	0.794	0.010	0.085	0.301
Plant height (cm)	P												0.185	0.124	0.021	-0.252
	G												0.191	0.128	0.022	-0.257
Harvest duration (days)	P													-0.074	0.075	0.357
	G													-0.077	0.075	0.360
Moisture content (%)	P														-0.011	-0.038
	G														-0.013	-0.037
Ascorbic acid (mg/100 g)	P															**0.437***
	G															0.442
TSS (%) (green)	P															
	G															

* significant at P=0.05

harvest duration (0.368), however, it exhibited negative significant correlation with days to 50 per cent flowering (-0.379), days to first fruit picking (-0.371) and fruit girth (-0.364).

Days to 50 per cent flowering

It is evident from Table 4.4 that days to 50 per cent flowering had significant positive correlation with days to first fruit picking (0.915).

Days to first fruit picking

Days to first fruit picking exhibited significant negative correlation with average fruit weight (-0.380).

Primary branches per plant

The inter-relationships of primary branches per plant with total number of fruits per plant (0.615), number of marketable fruits per plant (0.614), secondary branches per plant (0.573), harvest duration (0.496) and TSS (0.441) were positive and significant, while significant negative associations were recorded with fruit girth (-0.437) and average fruit weight (-0.364).

Secondary branches per plant

At phenotypic level, secondary branches per plant showed positive and significant correlation with total number of fruits (0.617), number of marketable fruits per plant (0.603), harvest duration (0.442) and plant height (0.398). Negative significant correlation was observed with fruit girth (-0.375).

Fruit length (cm)

Fruit length recorded positive correlation with average fruit weight (0.639), whereas it was negatively correlated with TSS (-0.701).

Fruit girth (cm)

The estimates of correlation coefficients at phenotypic level showed that fruit girth had significant negative association with total number of fruits (-0.503), number of marketable fruits per plant (-0.479), harvest duration (-0.428), ascorbic acid (-0.394) and plant height (-0.364).

Average fruit weight (g)

At phenotypic level, it was observed that average fruit weight had negative association with TSS (-0.480), harvest duration (-0.417), number of marketable fruits per plant (-0.405) and total number of fruits per plant (-0.382).

Number of marketable fruits per plant

This trait exhibited positive association with total number of fruits per plant (0.984) and harvest duration (0.783).

Total number of fruits per plant

It showed positive and significant correlation with harvest duration (0.784) and plant height (0.371).

II. Quality traits

Ascorbic Acid (mg/100g)

At phenotypic level, Ascorbic Acid exhibited significant positive correlation with T.S.S. at green stage (0.437).

Correlation coefficients for dry yield per plant at phenotypic (P) level (Table 4.5)

I. Horticultural traits

Dry yield per plant (g)

Dry yield per plant was found significantly and positively correlated with total number of fruits per plant (0 615), number of marketable fruits per plant (0.606), harvest duration (0.564), secondary branches per plant (0.463), capsanthin (0.461), plant height (0.459) and peel:seed ratio (0.441), while it was significantly and negatively correlated with days to ripe fruit picking (-0.440) and fruit girth (-0.437).

Days to 50 per cent flowering

Days to 50 per cent flowering had significant positive correlation with days to ripe fruit picking (0.766), whereas it had significant negative association with seed weight per fruit (-0.415).

Primary branches per plant

This trait showed significant and positive correlation with total number of fruits per plant (0.615), number of marketable fruits per plant (0.614), secondary branches per plant (0.573), harvest duration (0.496), TSS at red stage (0.434) and capsaicin (0.430), however it had significant negative correlation with seed weight per fruit (-0.489), 100-seed weight (-0.472), fruit girth (-0.437) and average fruit weight (-0.400).

Table 4.5 Estimates of phenotypic (P) and genotypic(G) correlation coefficients for different pair of horticultural and quality traits in dry chilli

Traits		Dry yield per plant (g)	Days to 50% flowering	Days to ripe fruit picking	Primary branches per plant	Secondary branches per plant	Fruit length (cm)	Fruit girth (cm)	Average dry fruit weight (g)	No. of seeds per fruit	Seed weight per fruit (g)	100-seed weight (g)	Peel:seed ratio	No. of marketable fruit per plant	Total No. of fruits per plant	Plant height (cm)	Harvest duration (days)	Oleoresin (ASTA Units)	Capsanthin (ASTA Units)	Capsaicin (%)	TSS (%) (Red)
Dry yield per plant (g)	P		-0.344	**-0.440***	0.287	**0.463***	0.229	**-0.437***	0.354	0.132	0.157	0.026	**0.441***	**0.606***	**0.615***	**0.459***	**0.564***	0.304	**0.461***	0.264	0.112
	G		-0.356	-0.457	0.295	0.474	0.234	-0.448	0.364	0.137	0.163	0.026	0.453	0.626	0.632	0.471	0.586	0.314	0.474	0.270	0.116
Days to 50% flowering	P			**0.766***	0.188	-0.022	-0.096	-0.140	-0.330	-0.326	**-0.415***	-0.283	-0.158	-0.100	-0.103	-0.293	0.027	-0.068	-0.019	0.083	0.233
	G			0.780	0.190	-0.023	-0.097	-0.142	-0.334	-0.328	-0.424	-0.286	-0.160	-0.099	-0.102	-0.298	0.027	-0.068	-0.018	0.086	0.236
Days to ripe fruit picking	P				-0.020	-0.207	-0.095	0.129	-0.210	-0.004	-0.228	-0.316	-0.272	-0.301	-0.293	-0.252	-0.148	-0.173	-0.050	0.050	0.156
	G				-0.020	-0.209	-0.096	0.132	-0.213	-0.005	-0.232	-0.319	-0.275	-0.307	-0.298	-0.266	-0.147	-0.177	-0.051	0.049	0.161
Primary branches per plant	P					**0.573***	-0.358	**-0.437***	**-0.400***	-0.268	**-0.489***	**-0.472***	0.018	**0.614***	**0.615***	0.157	**0.496***	0.062	0.298	**0.430***	**0.434***
	G					0.574	-0.358	-0.437	-0.401	-0.270	-0.491	-0.472	0.018	0.620	0.618	0.159	0.500	0.062	0.299	0.431	0.435
Secondary branches per plant	P						-0.046	**-0.375***	-0.151	0.085	-0.086	-0.267	0.037	**0.603***	**0.617***	**0.398***	**0.442***	**0.396***	0.257	0.216	0.244
	G						-0.046	-0.375	-0.152	0.086	-0.086	-0.267	0.037	0.609	0.622	0.404	0.446	0.398	0.257	0.216	0.245
Fruit length (cm)	P							-0.148	**0.572***	**0.471***	**0.627***	**0.486***	**0.474***	-0.234	-0.192	0.341	-0.186	0.271	0.101	**-0.376***	**-0.684***
	G							-0.148	0.573	0.475	0.629	0.487	0.474	-0.236	-0.193	0.345	-0.188	0.272	0.102	-0.377	-0.687
Fruit girth (cm)	P								0.110	0.008	0.164	0.347	-0.048	**-0.479***	**-0.503***	**-0.364***	**-0.428***	-0.229	-0.314	**-0.368***	-0.191
	G								0.110	0.008	0.165	0.347	-0.048	-0.484	-0.507	-0.368	-0.432	-0.230	-0.314	-0.370	-0.192
Average dry fruit weight (g)	P									**0.429***	**0.756***	**0.695***	**0.688***	**-0.435***	**-0.422***	0.181	**-0.363***	-0.133	-0.018	**-0.456***	-0.326
	G									0.432	0.760	0.697	0.689	-0.440	-0.426	0.185	-0.366	-0.133	-0.019	-0.459	-0.329
No. of seeds per fruit	P										**0.762***	0.189	0.178	-0.226	-0.186	0.356	-0.224	-0.007	0.068	-0.302	**0.455***
	G										0.771	0.189	0.179	-0.230	-0.190	0.361	-0.227	-0.008	0.068	-0.303	-0.460
Seed weight per fruit (g)	P											**0.742***	**0.372***	**-0.427***	**-0.401***	0.286	**-0.379***	-0.083	-0.092	**-0.517***	**-0.571***
	G											0.745	0.374	-0.432	-0.406	0.291	-0.383	-0.084	-0.093	-0.520	-0.574
100-seed weight (g)	P												**0.457***	**-0.451***	**-0.448***	-0.018	**-0.393***	-0.102	-0.314	**-0.587***	**-0.489***
	G												0.457	-0.456	-0.451	-0.017	-0.396	-0.102	-0.315	-0.589	-0.491
Peel:seed ratio	P													-0.065	-0.046	0.175	-0.179	0.070	0.202	-0.277	-0.145
	G													-0.065	-0.047	0.177	-0.181	0.071	0.202	-0.278	-0.145
No. of marketable fruit per plant	P														**0.984***	0.339	**0.783***	0.457	0.319	**0.584***	0.349
	G														0.995	0.343	0.794	0.466	0.324	0.591	0.353
Total No. of fruits per plant	P															**0.371***	**0.784***	**0.502***	0.332	**0.566***	0.321
	G															0.378	0.794	0.507	0.334	0.569	0.325
Plant height (cm)	P																0.185	0.307	0.275	0.017	-0.188
	G																0.191	0.312	0.282	0.018	-0.192
Harvest duration (days)	P																	**0.415***	0.353	**0.594***	**0.393***
	G																	0.421	0.357	0.601	0.396
Oleoresin (ASTA Units)	P																		0.183	0.041	-0.114
	G																		0.183	0.040	-0.115
Capsanthin (ASTA Units)	P																			0.298	0.146
	G																			0.299	0.147
Capsaicin (%)	P																				**0.653***
	G																				0.658
TSS (%) (Red)	P																				
	G																				

* significant at P=0.05

Secondary branches per plant

It exhibited significant positive correlation with total number of fruits per plant (0.617), marketable number of fruits (0.603), harvest duration (0.442), plant height (0.398) and oleoresin (0.396) but was negatively associated with fruit girth (-0.375).

Fruit length (cm)

Fruit length indicated significant positive correlation with seed weight per fruit (0.627), average fruit weight (0.573), 100-seed weight (0.486), peel:seed ratio (0.474) and number of seeds per fruit (0.471), however, it showed significant negative correlation with TSS at red stge (-0.684) and capsaicin (-0.376).

Fruit girth (cm)

It showed significant negative correlation with total number of fruits per plant (-0.503), number of marketable fruits per plant (-0.479), harvest duration (-0.428), capsaicin (-0.368) and plant height (-0.364).

Average fruit weight (g)

The estimates of correlation coefficients indicated that average fruit weight had significant positive correlation with seed weight per fruit (0.756), 100 seed weight (0.695), peel:seed ratio (0.683) and number of seeds per fruit (0.429). It exhibited negative correlation with capsaicin content (-0.456), number of marketable fruits per plant (-0.435), total number of fruits per plant (-0.422) and harvest duration (-0.363).

Number of seeds per fruit

The inter-relationships of number of seeds per fruit at phenotypic level with seed weight per fruit (0.762) was significantly positive, whereas it was negative and significant with TSS at red stage (-0.455).

Seed weight per fruit (g)

The estimates of correlation coefficients revealed that seed weight per fruit had significant positive correlation with 100-seed weight (0.742) and peel:seed ratio (0.372) whereas, it had negative correlation with TSS at red stage (-0.571), capsaicin content (-0.517), number of marketable fruits per plant (-0.427), total number of fruits per plant (-0.401) and harvest duration (-0.379).

100-seed weight (g)

100-seed weight had significant positive association with peel:seed ratio (0.457) however, it showed significant negative correlation with capsaicin content (-0.587), TSS at red stage (-0.489), number of marketable fruits per plant (-0.451), total number of fruits per plant (-0.448) and harvest duration (-0.393).

Number of marketable fruits per plant

This trait exhibited significant positive correlation with total number of fruits per plant (0.984), harvest duration (0.783), capsaicin content (0.584) and oleoresin (0.457).

Total number of fruits per plant

It showed significant positive correlation with harvest duration (0.784), capsaicin content (0.566), oleoresin (0.502) and plant height (0.371).

Harvest duration

This trait exhibited significant and positive correlation with capsaicin content (0.594), oleoresin (0.415) and TSS at red stage (0.393).

II. *Quality traits*

Capsaicin content

Capsaicin content was found significantly and positively correlated with TSS at red stage (0.653).

4.3 Path coefficient analysis

The correlation coefficients provide information regarding the association of different characters among themselves and better insight into the cause of the association is provided by the path coefficient analysis. It allows to partition the correlation coefficients into direct and indirect effects of the traits contributing toward the dependent variable. In the present investigation, marketable green yield and dry yield were taken as resultant variable with other traits as causal variables. The results obtained at the phenotypic and genotypic levels for marketable green yield and dry yield are presented in Table 4.6 and 4.7, respectively.

4.3.1 Estimates of direct and indirect effects at phenotypic and genotypic level for marketable green yield

At phenotypic level, the direct positive effects of various traits on marketable green yield per plant could be arranged in the following descending order : average fruit weight, total number of fruits per plant, number of marketable fruits per plant, TSS at green stage, fruit length, plant height,

Table 4.6 Estimates of direct and indirect effects of different horticultural and quality traits on marketable green yield of chilli at phenotypic (P) and genotypic (G) levels

		Days to 50% flowering	Days to first fruit picking	Primary branches/ plant	Secondary branches/ plant	Fruit length (cm)	Fruit girth (cm)	Average fruit weight (g)	Number of marketable fruits per plant	Total number of fruits per plant	Plant height (cm)	Harvest duration (days)	Moisture content (%)	Ascorbic acid (mg/100 g)	TSS (%) (Green)	Correlation with marketable green yield/ plant
Days to 50% flowering	P	**-0.050**	-0.064	0.017	0.001	-0.018	0.002	-0.199	-0.034	-0.042	-0.034	0.000	0.010	-0.017	0.049	-0.379*
	G	**-0.097**	-0.019	0.015	0.001	-0.019	0.003	-0.203	-0.067	-0.009	-0.032	-0.001	0.012	-0.017	0.050	-0.383
Days to first fruit picking	P	-0.046	**-0.070**	0.023	0.004	-0.038	0.001	-0.242	-0.012	-0.016	-0.025	-0.002	0.006	-0.018	0.063	-0.371*
	G	-0.090	**-0.020**	0.020	0.003	-0.041	0.002	-0.246	-0.025	-0.003	-0.024	-0.003	0.008	-0.018	0.063	-0.374
Primary branches/ plant	P	-0.009	-0.017	**0.091**	-0.020	-0.065	0.006	-0.232	0.207	0.249	0.018	-0.007	0.007	-0.010	0.083	0.300
	G	-0.018	-0.005	**0.079**	-0.015	-0.070	0.009	-0.234	0.417	0.053	0.017	-0.014	0.009	-0.010	0.083	0.300
Secondary branches/plant	P	0.001	0.007	0.052	**-0.035**	-0.008	0.005	-0.076	0.203	0.250	0.046	-0.006	0.001	-0.013	0.034	0.461*
	G	0.002	0.002	0.046	**-0.026**	-0.009	0.007	-0.077	0.410	0.053	0.044	-0.012	0.001	-0.013	0.035	0.462
Fruit length (cm)	P	0.005	0.015	-0.033	0.002	**0.182**	0.002	0.407	-0.079	-0.078	0.040	0.002	0.010	0.010	-0.131	0.354
	G	0.009	0.004	-0.028	0.001	**0.196**	0.003	0.410	-0.159	-0.016	0.037	0.005	0.012	0.010	-0.131	0.354
Fruit girth (cm)	P	0.007	0.008	-0.040	0.013	-0.027	**-0.013**	0.079	-0.161	-0.204	-0.042	0.006	0.001	0.049	-0.039	-0.364*
	G	0.014	0.002	-0.035	0.010	-0.029	**-0.020**	0.080	-0.326	-0.043	-0.040	0.012	0.001	0.049	-0.039	-0.364
Average fruit weight (g)	P	0.016	0.027	-0.033	0.004	0.116	-0.002	**0.637**	-0.136	-0.155	0.026	0.006	0.010	0.040	-0.090	0.465*
	G	0.031	0.008	-0.029	0.003	0.125	-0.002	**0.641**	-0.275	-0.033	0.025	0.011	0.012	0.040	-0.090	0.466
Number of marketable fruits per plant	P	0.005	0.002	0.046	-0.021	-0.043	0.006	-0.258	**0.367**	0.378	0.039	-0.010	-0.001	-0.010	0.061	0.562*
	G	0.010	0.001	0.049	-0.016	-0.046	0.010	-0.263	**0.672**	0.085	0.037	-0.022	-0.001	-0.010	0.061	0.567
Total number of fruits per plant	P	0.005	0.003	0.056	-0.022	-0.035	0.006	-0.243	0.331	**0.405**	0.043	-0.010	0.001	-0.011	0.056	0.585*
	G	0.010	0.001	0.049	-0.016	-0.038	0.010	-0.247	0.669	**0.085**	0.041	-0.022	0.001	-0.011	0.056	0.589
Plant height (cm)	P	0.015	0.015	0.014	-0.014	0.062	0.005	0.142	0.114	0.150	**0.116**	-0.002	-0.008	-0.003	-0.047	0.575*
	G	0.029	0.004	0.013	-0.010	0.068	0.007	0.145	0.230	0.032	**0.109**	-0.005	0.010	-0.003	-0.048	0.580
Harvest duration (days)	P	-0.001	-0.008	0.045	-0.016	-0.034	0.005	-0.265	0.264	0.317	0.022	**-0.013**	-0.005	-0.009	0.067	0.368*
	G	-0.003	-0.002	0.040	-0.012	-0.037	0.009	-0.270	0.534	0.068	0.021	**-0.027**	-0.006	-0.009	0.067	0.372
Moisture content(%)	P	-0.008	-0.007	0.010	0.000	0.029	0.000	0.099	-0.004	0.005	0.014	0.001	**0.064**	0.001	-0.007	0.196
	G	-0.015	-0.002	0.009	0.000	0.032	0.000	0.100	-0.011	0.001	0.014	0.002	**0.076**	0.002	-0.007	0.199
Ascorbic acid (mg/100 g)	P	-0.007	-0.010	0.007	-0.004	-0.015	0.005	-0.203	0.028	0.035	0.002	-0.001	-0.001	**-0.125**	0.082	-0.206
	G	-0.013	-0.003	0.006	-0.003	-0.016	0.008	-0.207	0.056	0.007	0.002	-0.002	-0.001	**-0.124**	0.082	-0.208
TSS (%) (green)	P	-0.013	-0.023	0.040	-0.006	-0.128	0.003	-0.305	0.109	0.121	-0.029	-0.005	-0.002	-0.055	**0.188**	-0.107
	G	-0.026	-0.007	0.035	-0.005	-0.138	0.004	-0.310	0.221	0.026	-0.028	-0.010	-0.003	-0.055	**0.187**	-0.107

* significant at P=0.05, Residual effect: P = 0.0724, G = 0.0632; Bold values indicates direct effects

primary branches per plant and moisture content. However, ascorbic acid, days to first fruit picking, days to 50 per cent flowering, secondary branches per plant, fruit girth and harvest duration had direct negative effects on marketable green yield per plant.

At genotypic level, the estimates of direct effects indicated that number of marketable fruits per plant, average fruit weight, fruit length, TSS at green stage, plant height, total number of fruits per plant, primary branches per plant and moisture content had positive direct effects on marketable green yield per plant, while ascorbic acid, days to 50 per cent flowering, harvest duration, secondary branches per plant, days to first fruit picking and fruit girth had negative direct effects on marketable green yield per plant.

Days to 50 per cent flowering

This character showed negative association with marketable green yield. Break-up of this association revealed that indirect effects via TSS (0.049), primary branches per plant (0.017) and moisture content (0.010) were positive. Negative indirect effects via days to first fruit picking (-0.064), total number of fruits per plant (-0.042), number of marketable fruits per plant (-0.034), plant height (-0.034) and fruit length (-0.018) contributed for the negative direct effect (-0.050) at phenotypic level.

At genotypic level, indirect effects via TSS (0.050), primary branches per plant (0.015) and moisture content (0.012) constituted the major portion of positive indirect effects. These effects were however, counteracted by the negative indirect effects via average fruit weight (-0.203), number of marketable fruits per plant (-0.067) and plant height (-0.032) which resulted in negative direct effect (-0.097).

Days to first fruit picking

Days to first fruit picking showed negative direct effect (-0.076) on marketable green yield at phenotypic level. It had positive indirect effects via TSS (0.063) and primary branches per plant (0.023) and negative indirect effects via average fruit weight (-0.242), days to 50 per cent flowering (-0.046), fruit length (-0.038) and plant height (-0.025).

At genotypic level, this character showed negligible negative direct effect (-0.020). It had positive indirect contributions through TSS (0.063), primary branches per plant (0.020) and moisture content (0.008). Negative contributions through average fruit weight (-0.246), days to 50 per cent flowering (-0.090), fruit length (-0.041), number of marketable fruits per plant (-0.025) and plant height (-0.024) resulted in negative association.

Primary branches per plant

This character had positive association with marketable green yield. The further break up of the correlation showed that indirect effects via total number of fruits per plant (0.249) and number of marketable fruits per plant (0.207) mainly contributed to this association alongwith its direct positive effect (0.091). These effects were however, counteracted by the negative indirect effects via average fruit weight (-0.232) and fruit length (-0.065) at phenotypic level.

At genotypic level, indirect effects via number of marketable fruits per plant (0.417), TSS (0.083), and total number of fruits per plant (0.053) constituted the major portion of positive indirect effects and added to the total association alongwith its direct positive effect (0.079). These effects were however, counteracted by the negative indirect effects via average fruit weight (-0.234) and fruit length (-0.070).

Secondary branches per plant

Secondary branches per plant had negative direct effect (-0.035) at phenotypic level while, its association with marketable green yield per plant was positive and significant. In this case, partitioning of total association showed that indirect positive effects via total number of fruits (0.250) and number of marketable fruits per plant (0.203) constituted the major portion followed by primary branches per plant (0.052), plant height (0.046) and TSS (0.034). The indirect negative effects via other traits were of low magnitude except average fruit weight (-0.076).

At genotypic level, indirect effects via number of marketable fruits per plant (0.410) and total number of fruits per plant (0.053) contributed mainly to the association along with plant height (0.044), whereas, negative indirect effect was observed mainly via average fruit weight (-0.077).

Fruit length (cm)

The association of this character was found to be positive with marketable green yield per plant at phenotypic level. Major portion of this association was due to indirect effect via average fruit weight (0.407) and its

Average fruit weight (g)

The association of this character was found to be positive with marketable green yield. Major portion of this association was due to direct effect (0.637), while indirect effect via fruit length (0.116) had some addition at phenotypic level. Negative indirect effects were observed via total number of fruits (-0.155), number of marketable fruits per plant (-0.136) and TSS (-0.090).

The positive direct effect (0.641) and indirect effect via fruit length (0.125) were found to be the major constituent of the total association at genotypic level. The traits *viz.* marketable fruits per plant (-0.275), TSS (-0.090) and total number of fruits per plant (-0.033) exhibited negative indirect effects.

Number of marketable fruits per plant

This character revealed positive association with marketable green yield. The major portion of this association was due to indirect effect via total number of fruits per plant (0.378) and direct effect (0.367), while indirect effects via TSS at green stage (0.061), primary branches per plant (0.046) and plant height (0.039) had some addition to the total association at phenotypic level. The negative indirect effects via average fruit weight (-0.258) and fruit length (-0.043) counteracted the positive effect.

The positive direct effect (0.672) and indirect effects via total number of fruits per plant (0.085), TSS (0.061), primary branches per plant (0.049) and plant height (0.039) were found to be the major constituent of the total association at genotypic level. The negative indirect effects via average fruit weight (-0.263), fruit length (-0.046) and harvest duration (-0.022) affected the total association to some extent.

Total number of fruits per plant

This character showed positive association with marketable green yield per plant. Partitioning of the total association at phenotypic level indicated that direct effect (0.405) and indirect via number of marketable fruits per plant (0.331) were positive and mainly contributed to the association. These effects *were however, counteracted by negative indirect effects via average fruit weight* (-0.243) and fruit length (-0.035).

At genotypic level, indirect effects via number of marketable fruits per plant (0.669) and direct effect (0.085) were the major constituents of the association. However, negative indirect effects were observed via average fruit weight (-0.247) and fruit length (-0.038).

Plant height (cm)

Plant height exhibited positive indirect effects via total number of fruits per plant (0.150), average fruit weight (0.142), number of marketable fruits per plant (0.114) which alongwith positive direct effect (0.116) contributed mainly to the positive association with marketable green yield per plant. Negative indirect effects via TSS (-0.047) and secondary branches per plant (-0.014) though counteracted these effects at phenotypic level.

It showed positive direct (0.109) and indirect effects via number of marketable fruits per plant (0.230), average fruit weight (0.145), fruit length (0.068), and total number of fruits (0.038), whereas, negative indirect effects were observed via TSS (-0.048) and secondary branches per plant (-0.010) at genotypic level.

Harvest duration (days)

At phenotypic level, beside negligible direct effect (-0.013), this trait revealed positive indirect effects via total number of fruits per plant (0.317), number of marketable fruits per plant (0.264), TSS (0.067) and primary branches per plant (0.045). Negative indirect effects via average fruit weight (-0.265), fruit length (-0.034) and secondary branches per plant (-0.016) affected the total association with marketable green yield.

At genotypic level, indirect effects via number of marketable fruits per plant (0.534), total number of fruits per plant (0.068) and TSS (0.067) constituted the major portion of positive indirect effects. These effects were however, counteracted by the negative indirect effects via average fruit weight (-0.270) and fruit length (-0.037) which resulted in negative direct effect (-0.027).

Moisture content (%)

This trait showed low association with marketable green yield. Indirect effects via average fruit weight (0.099) and fruit length (0.029) alongwith direct effect (0.064) partly contributed to the association at phenotypic level.

At genotypic level, indirect effects via average fruit weight (0.100), fruit length (0.032) and direct effect (0.076) constituted the major portion of association while, negative indirect effects via days to 50 per cent flowering (-0.015) and number of marketable fruits per plant (-0.011) affected the total association.

Ascorbic acid (mg/100 g)

Ascorbic Acid had negative direct effect (-0.125) at phenotypic level. The breaking up of the association showed that the major portion of the association was through indirect effects via TSS (0.082), total number of fruits per plant (0.035) and number of marketable fruits per plant (0.028). The negative indirect effects via average fruit weight (-0.203) and fruit length (-0.015) restricted the total association at phenotypic level.

It also exhibited negative direct effect (-0.124) at genotypic level. Indirect effects via TSS (0.082) and number of marketable fruits per plant (0.056) were positive. The negative indirect effects through average fruit weight (-0.207), fruit length (-0.016) and days to 50 per cent flowering (-0.013) affected the total association to some extent.

TSS (%)

TSS showed direct positive association (0.188) at phenotypic level. The indirect effect via total number of fruits per plant (0.121) and number of marketable fruits per plant (0.109) were positive and partly contributed to the total association. The indirect effects via average fruit weight (-0.305), fruit length (-0.128), ascorbic acid (-0.055) and days to first fruit picking (-0.023) were found to be negative.

At genotypic level, this character showed direct positive effect (0.187). The indirect effects through number of marketable fruits per plant (0.221), primary branches per plant (0.035) and total number of fruits per plant (0.026) were positive, whereas, indirect effects through average fruit weight (-0.310), fruit length (-0.138) and ascorbic acid (-0.055) were negative and affected the total association to greater extent.

The residual effects recorded at phenotypic and genotypic levels were 0.0724 and 0.0632, respectively.

Path coefficient analysis for dry yield

The direct and indirect effects of various traits on dry yield at phenotypic and genotypic levels are presented in Table 4.7 and are discussed below:

Estimates of direct and indirect effects at the phenotypic and genotypic levels

At the phenotypic level, the direct positive effects of various traits on dry yield per plant could be arranged in the following descending order : average fruit weight, total number of fruits per plant, number of marketable fruits per plant, harvest duration, seed weight per fruit, capsanthin, secondary branches per plant and peel:seed ratio. However, 100-seed weight, number of seeds per fruit, oleoresin, primary branches per plant, TSS, days to 50 per cent flowering, plant height, fruit girth, capsaicin, days to ripe fruit picking and fruit length had direct negative effects on dry yield per plant.

At genotypic level, the estimates of direct effects indicated that seed weight per fruit, average fruit weight, number of marketable fruits per plant, harvest duration, total number of fruits per plant, peel:seed ratio, capsanthin and secondary branches per plant had positive direct effects on dry yield per plant, while 100-seed weight, number of seeds per fruit, oleoresin, plant height, TSS,

Table 4.7 Estimates of direct and indirect effects of different horticultural and quality traits on dry yield of chilli at phenotypic (P) and genotypic (G) levels

Traits		Days to 50% flowering	Days to ripe fruit picking	Primary branches per plant	Secondary branches per plant	Fruit length (cm)	Fruit girth (cm)	Average dry fruit weight (g)	No. of seeds per fruit	Seed weight per fruit (g)	100-seed weight (g)	Peel:seed ratio	No. of marketable fruits per plant	Total No. of fruits per plant	Plant height (cm)	Harvest duration (days)	Oleoresin (ASTA Units)	Capsanthin (ASTA Units)	Capsaicin content (%)	TSS (%) (Red)	Correlation with dry yield/plant
Days to 50% flowering	P	**-0.043**	-0.015	-0.016	-0.001	0.001	0.004	-0.247	0.044	-0.060	0.059	-0.005	-0.032	-0.039	0.012	0.006	0.001	-0.003	-0.002	-0.014	-0.344
	G	**-0.065**	0.017	-0.012	-0.001	0.001	0.002	-0.226	0.174	-0.349	0.186	-0.023	-0.052	-0.024	0.029	0.009	0.008	-0.002	-0.007	-0.021	-0.356
Days to ripe fruit picking	P	-0.033	**-0.020**	0.002	-0.014	0.001	-0.005	-0.158	0.001	-0.033	0.064	-0.009	-0.097	-0.112	0.010	-0.040	0.020	-0.007	-0.001	-0.010	-0.440*
	G	-0.050	**0.022**	0.001	-0.008	0.001	-0.002	-0.144	0.003	-0.192	0.207	-0.039	-0.160	-0.069	0.026	-0.048	0.020	-0.005	-0.004	-0.014	-0.457
Primary branches per plant	P	-0.008	0.001	**-0.083**	0.039	0.001	0.016	-0.299	0.036	-0.071	0.098	0.001	0.198	0.236	-0.006	0.134	-0.007	0.043	-0.010	-0.027	0.287
	G	-0.012	0.001	**-0.062**	0.021	0.002	0.006	-0.271	0.143	-0.405	0.306	0.003	0.324	0.144	-0.015	0.163	-0.007	0.027	-0.034	-0.039	0.295
Secondary branches per plant	P	0.001	0.004	-0.049	**0.067**	0.001	0.014	-0.113	-0.011	-0.012	0.055	0.001	0.194	0.237	-0.016	0.119	-0.047	0.037	-0.005	-0.015	0.463*
	G	0.001	-0.005	-0.035	**0.036**	0.001	0.005	-0.103	-0.045	-0.071	0.173	0.005	0.318	0.145	-0.039	0.146	-0.045	0.024	-0.017	-0.022	0.474
Fruit length (cm)	P	0.004	0.002	0.030	-0.003	**-0.001**	0.006	0.428	-0.063	0.091	-0.101	0.016	-0.076	-0.074	-0.014	-0.050	-0.032	0.015	0.008	0.042	0.229
	G	0.006	-0.002	0.022	-0.002	**-0.006**	0.002	0.388	-0.251	0.518	-0.316	0.068	-0.123	-0.045	-0.034	-0.061	-0.031	0.009	0.029	0.062	0.234
Fruit girth (cm)	P	0.006	-0.003	0.037	-0.025	0.001	**-0.038**	0.081	-0.001	0.024	-0.072	-0.002	-0.155	-0.193	0.015	-0.116	0.027	-0.045	0.008	0.012	-0.437*
	G	0.009	0.003	0.027	-0.014	0.001	**-0.015**	0.074	-0.004	0.136	-0.225	-0.007	-0.253	-0.118	0.036	-0.141	0.026	-0.029	0.029	0.017	-0.448
Average dry fruit weight (g)	P	0.014	0.004	0.034	-0.010	-0.001	-0.004	**0.748**	-0.058	0.110	-0.144	0.024	-0.140	-0.162	-0.007	-0.098	0.016	-0.003	0.010	0.020	0.354
	G	0.022	-0.005	0.024	-0.006	-0.004	-0.002	**0.677**	-0.229	0.626	-0.452	0.099	-0.230	-0.099	-0.018	-0.120	0.015	-0.002	0.036	0.030	0.364
No. of seeds per fruit	P	0.014	0.001	0.020	0.006	0.001	0.001	0.321	**-0.134**	0.111	-0.039	0.006	-0.073	-0.071	-0.014	-0.061	0.001	0.010	0.007	0.028	0.132
	G	0.021	0.001	0.015	0.003	-0.003	0.001	0.291	**-0.529**	0.635	-0.123	0.026	-0.120	-0.044	-0.035	-0.074	0.001	0.006	0.024	0.042	0.137
Seed weight per fruit (g)	P	0.018	0.004	0.042	-0.006	-0.001	-0.006	0.366	-0.102	**0.145**	-0.154	0.013	-0.138	-0.154	-0.011	-0.102	0.010	-0.013	0.012	0.035	0.157
	G	0.027	-0.005	0.030	-0.003	-0.004	-0.002	0.514	-0.408	**0.824**	-0.483	0.053	-0.226	-0.094	-0.028	-0.125	0.009	-0.008	0.041	0.005	0.163
100-seed weight (g)	P	0.012	0.005	0.040	-0.018	0.001	-0.013	0.520	-0.025	0.108	**-0.207**	0.016	-0.146	-0.172	0.001	-0.106	0.012	-0.045	0.013	0.030	0.026
	G	0.019	-0.007	0.029	-0.010	-0.003	-0.005	0.471	-0.100	0.614	**-0.649**	0.065	-0.238	-0.105	0.002	-0.129	0.011	-0.029	0.046	0.044	0.026
Peel:seed ratio	P	0.007	0.005	-0.002	0.002	0.001	0.002	0.514	-0.024	0.054	-0.095	**0.034**	-0.021	-0.018	-0.007	-0.048	-0.008	0.029	0.006	0.009	0.441*
	G	0.010	-0.006	-0.001	0.001	-0.003	0.001	0.467	-0.095	0.308	-0.296	**0.143**	-0.034	-0.011	-0.017	-0.059	-0.008	0.019	0.022	0.013	0.453
No. of marketable fruits per plant	P	0.004	0.006	-0.052	0.031	0.001	0.017	-0.326	0.030	-0.062	0.070	-0.002	**0.366**	0.367	-0.014	0.211	-0.054	0.046	-0.013	-0.021	0.606*
	G	0.006	-0.007	-0.038	0.022	0.001	0.007	-0.298	0.122	-0.356	0.296	-0.009	**0.522**	0.232	-0.033	0.260	-0.052	0.030	-0.046	-0.032	0.626
Total No. of fruits per plant	P	0.004	0.006	-0.052	0.042	0.001	0.018	-0.315	0.025	-0.058	0.093	-0.002	0.317	**0.383**	-0.015	0.212	-0.059	0.048	-0.013	-0.020	0.615*
	G	0.007	-0.006	-0.038	0.023	0.001	0.007	-0.288	0.100	-0.334	0.293	-0.007	0.519	**0.233**	-0.037	0.259	-0.057	0.031	-0.044	-0.029	0.632
Plant height (cm)	P	0.013	0.005	-0.013	0.027	0.001	0.013	0.136	-0.048	0.042	0.004	0.006	0.109	0.142	**-0.040**	0.050	-0.036	0.038	0.001	0.011	0.459*
	G	0.019	-0.006	-0.010	0.015	-0.002	0.005	0.125	-0.191	0.240	0.011	0.025	0.179	0.088	**-0.097**	0.062	-0.035	0.026	-0.001	0.017	0.471
Harvest duration (days)	P	-0.001	0.003	-0.042	0.030	0.001	0.015	-0.271	0.030	-0.055	0.081	-0.006	0.253	0.300	-0.007	**0.270**	-0.049	0.051	-0.013	-0.024	0.564*
	G	-0.002	-0.003	-0.030	0.016	0.001	0.006	-0.248	0.120	-0.316	0.257	-0.026	0.415	0.185	-0.019	**0.327**	-0.047	0.033	-0.047	-0.036	0.586
Oleoresin (ASTA Units)	P	0.003	0.003	-0.005	0.027	0.001	0.008	-0.099	0.001	-0.012	0.021	0.002	0.147	0.193	-0.012	0.112	**-0.118**	0.026	-0.001	0.007	0.304
	G	0.004	-0.004	-0.004	0.014	-0.002	0.003	-0.090	0.004	-0.070	0.066	0.010	0.243	0.116	-0.030	0.137	**-0.112**	0.017	-0.003	0.010	0.314
Capsanthin (ASTA Units)	P	0.001	0.001	-0.025	0.017	0.001	0.011	-0.014	-0.009	-0.013	0.065	0.007	0.103	0.127	-0.011	0.095	-0.022	**0.143**	-0.007	-0.009	0.461*
	G	0.001	-0.001	-0.018	0.009	-0.001	0.005	-0.013	-0.036	-0.076	0.205	0.029	0.169	0.078	-0.027	0.117	-0.021	**0.092**	-0.023	-0.013	0.474
Capsaicin content (%)	P	-0.004	-0.001	-0.037	0.015	0.001	0.013	-0.342	0.041	-0.075	0.122	-0.010	0.188	0.217	-0.001	0.160	-0.005	0.043	**-0.022**	-0.040	0.264
	G	-0.006	0.001	-0.026	0.008	0.002	0.005	-0.311	0.161	-0.429	0.382	-0.040	0.309	0.132	-0.002	0.197	-0.004	0.027	**-0.078**	-0.059	0.270
TSS (%) (Red)	P	-0.010	-0.003	-0.037	0.017	0.001	0.007	-0.244	0.061	-0.083	0.101	-0.005	0.112	0.123	0.008	0.106	0.013	0.021	-0.015	**-0.061**	0.112
	G	-0.015	0.003	-0.026	0.009	0.004	0.003	-0.222	0.244	-0.473	0.319	0.021	0.184	0.076	0.019	0.129	0.013	0.013	-0.051	**-0.090**	0.116

* significant at P=0.05, Residual effect: P = 0.0914, G = 0.0303; Bold values indicates direct effects

capsaicin, days to 50 per cent flowering, primary branches per plant, days to ripe fruit picking, fruit girth and fruit length had negative direct effects on dry yield per plant.

Days to 50 per cent flowering

Besides direct negative effect (-0.043), days to 50 per cent flowering had indirect positive effects via 100-seed weight (0.059), number of seeds per fruit (0.044) and plant height (0.012). The indirect effects via average fruit weight (-0.247), seed weight per fruit (-0.060), total number of fruits per plant (-0.039) and number of marketable fruits per plant (-0.032) were found to be negative at phenotypic level (Table 4.7).

This character showed direct negative effect (-0.065) for dry yield per plant at genotypic level. The indirect effects through 100-seed weight (0.186), number of seeds per fruit (0.174) and plant height (0.029) were positive. The negative indirect effects via seed weight per fruit (-0.349), average fruit weight (-0.226), number of marketable fruits per plant (-0.052) and total number of fruits per plant (-0.024) affected the total association.

Days to ripe fruit picking

At phenotypic level, it had negative direct effect (-0.020). Break-up association showed that indirect effects through 100-seed weight (0.064) and oleoresin (0.020) were positive. Negative indirect effects via average fruit weight (-0.158), total number of fruits per plant (-0.112), number of marketable fruits per plant (-0.097) and harvest duration (-0.040) contributed major portion of the association.

It exhibited positive direct effect (0.022) at genotypic level. Indirect effects via 100-seed weight (0.207), plant height (0.026) and oleoresin (0.020) were positive. The negative indirect effects via seed weight per fruit (-0.192), number of marketable fruits per plant (-0.160), average fruit weight (-0.144), total number of fruits per plant (-0.069), days to 50 per cent flowering (-0.050), harvest duration (-0.048) and peel:seed ratio (-0.039) affected the total association.

Primary branches per plant

The association of this character was found to be positive with dry yield per plant. Major portion of this association was due to indirect effect via total number of fruits per plant (0.236), number of marketable fruits per plant (0.198), harvest duration (0.134) and 100-seed weight (0.098). Indirect effect via capsanthin (0.043), secondary branches per plant (0.039) and number of seeds per fruit (0.036) had some addition at phenotypic level. Negative indirect effects via average fruit weight (-0.299), seed weight per fruit (-0.071) and TSS (-0.027), alongwith negative direct effect (-0.083) affected the total association to some extent.

At genotypic level, indirect effects via number of marketable fruits per plant (0.324), 100-seed weight (0.306), harvest duration (0.163), total number of fruits per plant (0.144) and number of seeds per fruit (0.143) were found to be the major constituents of the total association. Negative indirect effects via seed weight per fruit (-0.405) and average fruit weight (-0.271), alongwith negative direct effect (-0.062) restricted the total association to some extent.

Secondary branches per plant

This character exhibited positive association with dry yield. On the break-up of the total association it was observed that indirect effects through total number of fruits per plant (0.237), number of marketable fruits per plant (0.194) and harvest duration (0.119) alongwith direct effect (0.067) were the main contributors to the total association at phenotypic level. Negative indirect effects were observed via average fruit weight (-0.113) and oleoresin (-0.047).

At genotypic level, direct effect was positive (0.036). Indirect effects via number of marketable fruits per plant (0.318), 100-seed weight (0.173), harvest duration (0.146) and total number of fruits per plant (0.145) exhibited maximum contribution to total association, while negative indirect effects via average fruit weight (-0.103), seed weight per fruit (-0.071), number of seeds per fruit (-0.045), oleoresin (-0.045) and plant height (-0.039) affected the total association.

Fruit length (cm)

Fruit length had negligible direct effect (-0.001) at phenotypic level. In this case, partitioning of total association indicated that indirect effects via average fruit weight (0.428) and seed weight per fruit (0.091) and primary branches per plant (0.030) were positive and contributed to the total correlation coefficient. The indirect effect via 100-seed weight (-0.101), number of marketable fruits per plant (-0.076), total number of fruits per plant (-0.074), harvest duration (-0.050), and oleoresin (-0.032) were found to be negative.

At genotypic level too, it exhibited negative direct effect (-0.006). Indirect effects via seed weight per fruit (0.518) and average fruit weight (0.388) constituted the major portion of association followed by peel:seed ratio (0.068), TSS (0.062), and capsaicin (0.029). Indirect effects were negative via 100-seed weight (-0.316), number of seeds per fruit (-0.251), number of marketable fruits per plant (-0.123), harvest duration (-0.061), total number of fruits per plant (-0.045) and plant height (-0.034).

Fruit girth (cm)

This character showed significant negative association with dry yield per plant. Break-up of this association revealed that indirect effects via total number of fruits per plant (-0.193), number of marketable fruits per plant (-0.155), harvest duration (-0.116), 100-seed weight (-0.072) and capsanthin (-0.045) alongwith its direct effect (-0.038) were negative at phenotypic level. Average fruit weight (0.081) and primary branches per plant (0.037) exhibited positive indirect effects.

At genotypic level, indirect effects through seed weight per fruit (0.136) and average fruit weight (0.074) constituted the major portion of positive indirect effects. These effects were however, counteracted by the negative indirect effects via number of marketable fruits per plant (-0.253), 100-seed weight (-0.225), harvest duration (-0.141), total number of fruits per plant (-0.118) and capsanthin (-0.029) which resulted in negative direct effect (-0.015).

Average dry fruit weight (g)

This character had positive association with dry yield. Partitioning of the correlation showed that direct effect (0.748) contributed mainly to the total association. The indirect effects via total number of fruits per plant (-0.162), 100-seed weight (-0.144) and harvest duration (-0.098) restricted the association to some extent at phenotypic level.

At genotypic level, the direct effect (0.677) and indirect effect via seed weight per fruit (0.626) constituted the major portion of the total association. The indirect effects via 100-seed weight (-0.452), number of marketable fruits per plant (-0.230), number of seeds per fruit (-0.229), harvest duration (-0.120) and total number of fruits (-0.099) were found to be negative.

Number of seeds per fruit

This trait exhibited low association with dry yield per plant. On the split-up of the total association it was observed that indirect effects via average fruit weight (0.321) and seed weight per fruit (0.111) were the main contributor to the total association at phenotypic level. However, direct effect (-0.134) alongwith indirect effects via number of marketable fruits per plant (-0.073), total number of fruits per plant (-0.071) and harvest duration (-0.061) were negative.

At genotypic level, indirect effects via seed weight per fruit (0.635) and average fruit weight (0.291) exhibited the maximum contribution to the total association while negative indirect effects via 100-seed weight (-0.123), number of marketable fruits per plant (-0.120) and harvest duration (-0.074) alongwith negative direct effect (-0.529) affected the total association.

Seed weight per fruit (g)

Seed weight per fruit showed direct positive association (0.145) at phenotypic level. The indirect effect via average fruit weight (0.366) was positive and contributed mainly to total association alongwith direct effect. The indirect effects via 100-seed weight (-0.154), total number of fruits per plant (-0.154), number of marketable fruits per plant (-0.138), harvest duration (-0.102) and number of seeds per fruit (-0.102) were found to be negative.

At genotypic level, direct positive effect (0.824) and indirect positive effects via average fruit weight (0.514) were the main contributors to the total correlation coefficient. Indirect effects via 100-seed weight (-0.483), number of seeds per fruit (-0.408), number of marketable fruits per plant (-0.226) and harvest duration (-0.125) were negative.

100-seed weight (g)

100-seed weight had negative direct effect (-0.207) at phenotypic level. Its association with dry yield per plant was low. The break-up of the association showed that the major portion of the association was through indirect effects via average fruit weight (0.520) and seed weight per fruit (0.108). However, these effects were counteracted by the negative contributions via total number of fruits per plant (-0.172), number of marketable fruits per plant (-0.146) and harvest duration (-0.106) at phenotypic level.

It also exhibited negative direct effect (-0.649) at genotypic level. Indirect effects via seed weight per fruit (0.614) and average fruit weight (0.471) were positive. The negative indirect effects via number of marketable fruits per plant (-0.238), harvest duration (-0.129), total number of fruits per plant (-0.105) and number of seeds per fruit (-0.100) affected the total association to some extent. The indirect effects via other traits were of low magnitudes.

Peel:seed ratio

This character showed significant positive association with dry yield at phenotypic level. *In this case, partitioning of the total association showed that* indirect effect via average fruit weight (0.514) constituted the major portion followed by direct effect (0.034). Indirect effects via other traits were of low magnitudes.

At genotypic level, indirect effects via average fruit weight (0.467) and seed weight per fruit (0.308) contributed mainly to the positive association alongwith direct effect (0.143). The indirect effect via 100-seed weight (-0.296) was negative.

Number of marketable fruits per plant

The association of this character was found to be significantly positive with dry yield at phenotypic level. Major portion of this association was due to indirect effect via total number of fruits per plant (0.367) and harvest duration (0.211) alongwith its direct effect (0.366). Indirect effect via average fruit weight (-0.326) was negative.

The positive direct effect (0.522) and indirect effects via 100-seed weight (0.296), harvest duration (0.260) and total number of marketable fruits per plant (0.232) were found to be the major constituents of the total association at genotypic level. Negative indirect effects were observed via seed weight per fruit (-0.356) and average fruit weight (-0.298).

Total number of fruits per plant

This character exhibited significant positive association with dry yield per plant. The major portion of this association was due to direct effect (0.383) and indirect effects via number of marketable fruits per plant (0.317) and harvest duration (0.212) at phenotypic level. The negative indirect effect via average fruit weight (-0.315) counteracted the positive effects.

At genotypic level, the indirect effects via number of marketable fruits per plant (0.519), 100-seed weight (0.293), harvest duration (0.259) and direct effect (0.233) were found to be the major constituents of the total association. Indirect effects via seed weight per fruit (-0.334) and average fruit weight (-0.288) were negative.

Plant height (cm)

This character also exhibited significant positive association with dry yield per plant. On the split-up of the total association, negative direct effect of low magnitude (-0.040) was observed. The indirect effects via total number of fruits per plant (0.142), average fruit weight (0.136) and number of marketable fruits per plant (0.109) were the main contributors to the total association at phenotypic level.

At genotypic level, indirect effects via seed weight per fruit (0.240), number of marketable fruits per plant (0.179) and average fruit weight (0.125) contributed positively. However, these effects were counteracted by negative indirect effect via number of seeds per fruit (-0.191) and its direct effect (-0.097).

Harvest duration (days)

Partitioning of the significantly positive association at phenotypic level indicated that indirect effects via total number of fruits (0.300), number of marketable fruits per plant (0.253) alongwith direct effect (0.280) were the main contributors. Average fruit weight (-0.271) exhibited negative indirect effect.

At genotypic level, indirect effects via number of marketable fruits per plant (0.415), 100-seed weight (0.257), total number of fruits per plant (0.185), number of seeds per fruit (0.120) and direct effect (0.327) constituted the major portion of the association while, seed weight per fruit (-0.316) and average fruit weight (-0.248) had negative contributions.

Oleoresin (ASTA Units)

Oleoresin showed direct negative association (-0.118) at phenotypic level. The indirect effects via total number of fruits per plant (0.193), number of marketable fruits per plant (0.147) and harvest duration (0.112) were positive and partly contributed to the total association. The indirect effects via average fruit weight (-0.099) was found to be negative.

The character exhibited direct negative effect (-0.112) for dry yield at genotypic level. The indirect effects via number of marketable fruits per plant (0.243), harvest duration (0.137) and total number of fruits per plant (0.116), were positive and mainly contributed to the total correlation coefficient. Indirect effects were negative via average fruit weight (-0.090) and seed weight per fruit (-0.070).

Capsanthin (ASTA Units)

Significant positive association of capsanthin was observed with dry yield. The further break-up of the correlation showed that direct effect (0.143) and indirect effects via total number of fruits per plant (0.127), number of marketable fruits per plant (0.103) and harvest duration (0.095) contributed positively at phenotypic level.

At genotypic level, the indirect effects via 100-seed weight (0.205), number of marketable fruits per plant (0.169) and harvest duration (0.117) alongwith its direct effect (0.092) contributed mainly to the total association.

Capsaicin content (%)

Capsaicin content had negative direct effect (-0.022) of low magnitude at phenotypic level. Its association with dry yield was positive. The break-up of the association showed that the major portion of the association was through indirect effects via total number of fruits per plant (0.217), number of marketable fruits per plant (0.188), harvest duration (0.160) and 100-seed weight (0.122). However, negative indirect effects via average fruit weight (-0.342) and seed weight per fruit (-0.075) counteracted the positive effects at phenotypic level.

It also exhibited negative direct effect (-0.078) at genotypic level. Indirect effects via 100-seed weight (0.382), number of marketable fruits per plant (0.309), harvest duration (0.197), number of seeds per fruit (0.161) and total number of fruits per plant (0.132) were positive. The negative indirect effects via seed weight per fruit (-0.429) and average fruit weight (-0.311) affected the total association to some extent.

TSS (%)

Partitioning of the correlation coefficient showed that positive indirect effects via total number of fruits per plant (0.123), number of marketable fruits per plant (0.112), harvest duration (0.106) and 100-seed weight (0.101) constituted the major portion of the association. Its direct effect (-0.061) and indirect effects via average fruit weight (-0.244) and seed weight per fruit (-0.083) were negative.

At genotypic level, indirect effects via 100-seed weight (0.319), number of seeds per fruit (0.244), number of marketable fruits per plant (0.184) and harvest duration (0.129) were positive and main contributors to the total association. Indirect effects via seed weight per fruit (-0.473) and average fruit weight (-0.222) were negative alongwith direct effect (-0.090).

The residual effects recorded at phenotypic and genotypic levels were 0.0914 and 0.0303, respectively.

4.4 Morphological characterization of genotypes

Thirty genotypes of chilli *(Capsicum annuum* L.) were critically observed for morphological characterization and the results are presented in Table 4.8.

4.5 Disease reaction

Thirty genotypes of chilli were tested for their reaction to diseases during both the years (2005 and 2006) under natural epiphytotic conditions. The data recorded on bacterial wilt and fruit rot incidence and the response of genotypes to disease reaction is tabulated in Table 4.9.

Table 4.8 Morphological characterization of chilli genotypes

Sr. No.	Category	Class	Genotypes
1.	**Mature fruit colour**	(a) Yellow	DPCH-1, Palam Yellow
		(b) Light green	Anugraha, ACH-201, Arka Lohit, KCA-190, KCA-171, DCL-520, SKAU-SC-578-1, Ajeet-1
		(c) Green	G-4, CO-3, PKM-1, SKAU-SC-304-1, DCL-352, Kadyavallur local, BC-25, Kashmir local, K-1, SKAU-SC-23-1, ACS-2000-2, SKAU-SC-101, DCL-524, Pant C-1
		(d) Dark green	HCH-9639, LCA-357, NCH-162, Ujwala, Pusa Sada Bahar, Surajmukhi
2.	**Ripe fruit colour**	(a) Bright red	DPCH-1, LCA-357, SKAU-SC-304-1, NCH-162, Arka loti, K-1, SKAU-SC-23-1, SKAU-SC-578-1, Pant C-1
		(b) Red	HCH-9639, PKM-1, Kadyavallur local, BC-25, KCA-190, KCA-171, DCL-520, SKAU-SC-101, Pusa Sada Bahar, Ajeet-1, Surajmukhi
		(c) Deep red	G-4, Anugraha, Palam Yellow CO-3, DCL-352, ACH-201, Kashmir local, ACS-2000-2, DCL-524, Ujwala
3.	**Fruit shape at pedicel attachment**	(a) Acute	G-4, Anugraha, ACH-201, Arkalohit, KCA-190, KCA-171, K-1, SKAU-SC-101, DCL-524, KCA-190, KCA-171, K-1, SKAU-SC-101, DCL-524, Ujwala, Pusa Sada Bahar, Surajmukhi, Pant C-1
		(b) Obtuse	DPCH-1, HCH-9639, CO-3, Palam Yellow, DKM-1, LCA-357, SKAU-SC-304-1, NCH-162, DCL-352, Kadyavallur local, BC-25, Kashmir local, SKAU-SC-23-1, ACS-2000-2, SKAU-SC-578-1, Ajeet-1

Contd../-

Sr. No.	Category	Class	Genotypes
		(c) Truncate	DCL-520
		(d) Lobate	-
		(e) Cordate	-
4.	**Fruit shape at blossom end**	(a) Pointed	G-4, HCH-9639, Anugraha, CO-3, Palam Yellow, PKM-1, LCA-357, SKaU-SC-304-1, NCH-162, DCL-352, ACH-201, Kadyavallur local, Arkalohit, BC-25, KCA-190, Kashmir local, KCA-171, K-1, DCL-520, SKAU-SC-23-1, aCS-2000-2, SKAU-SC-578-1, SKAU-SC-101, DCL-524, Ujwala, Pusa Sada Bahar, Surajmukhi, Ajeet-1
		(b) Blunt	DPCH-1, Pant C-1
		(c) Sunken	-
		(d) Sunken & pointed	-
5.	**Fruit position**	(a) Erect	DPCH-1, Ujwala, Pusa Sada Bahar, Surajmukhi, Pant C-1
		(b) Semi-pedent	Palam Yellow, SKAU-SC-304-1, DCL-352, SKAU-SC-23-1, SKAU-SC-578-1, SKAU-SC-101
		(c) Pendent	G-4, Anugraha, HCH-9639, CO-3, PKM-1, LCA-357, NCH-162, ACH-201, kadyavallur local, Arka loti, BC-25, KCA-190, KCA-171, Kashmir local, K-1, DCL-520, ACS-2000-2, DCL-524, Ajeet-1
6.	**Fruit bearing habit**	(a) Solitary	G-4, HCH-9639, Anugraha, CO-3, Palam Yellow, PKM-1, LCA-357, SKAU-SC-304-1, NCH-162, DCL-352, ACH-201, Kadyavallur local, Arka loti, BC-25, KCA-190, KCA-171, Kashmir local, K-1, DCL-520, SKAU-SC-23-1, ACS-2000-2, SKAU-SC-578-1, SKAU-SC-101, DCL-524, Ajeet-1, Pant C-1
		(b) Cluster	DPCH-1, Ujwala, Pusa Sada Bahar and Surajmukhi

Plate 7. Morphological variation at mature green and ripe fruit stage

Plate 8. Variability in fruit orientation and bearing habit

Table 4.9 Reaction of chilli genotypes to bacterial wilt and fruit rot incidence

Genotypes	Bacterial wilt (%)		Reaction category		Fruit rot (%)		Reaction category	
	2005	2006	2005	2006	2005	2006	2005	2006
G-4	17.57	18.01	MR	MR	16.59	16.66	MS	MS
HCH-9639	28.78	30.00	S	S	20.48	21.60	MS	MS
CO-3	79.92	74.69	HS	HS	19.70	20.42	MS	MS
P. yellow	26.55	26.19	MS	MS	19.63	20.53	MS	MS
PKM-1	53.19	52.34	S	S	20.04	20.87	MS	MS
DPCH-1	82.00	83.76	HS	HS	41.24	42.50	HS	HS
Anugraha	10.00	9.52	R	R	14.56	14.41	MS	MS
LCA-357	54.86	57.88	S	S	24.29	24.82	MS	MS
SKAU-SC-304-1	60.23	62.49	S	S	25.06	25.08	S	S
NCH-162	21.14	22.97	MS	MS	17.62	15.90	MS	MS
DCL-352	65.38	69.11	S	S	22.29	21.42	MS	MS
ACH-201	69.00	67.67	S	S	26.03	27.71	S	S
Kadya vallur local	57.10	60.36	S	S	20.73	18.70	MS	MS
Arkalohit	60.88	59.65	S	S	19.41	20.36	MS	MS
BC-25	71.60	70.38	HS	HS	28.31	26.75	S	S
KCA-190	67.72	63.27	S	S	20.59	20.58	MS	MS
Pusa Sada Bahar	4.73	5.00	R	R	16.15	15.46	MS	MS
Kashmir local	57.38	51.48	S	S	20.60	19.59	MS	MS
KCA-171	59.22	57.67	S	S	16.65	16.33	MS	MS
K-1	66.16	63.44	S	S	18.22	17.53	MS	MS
DCL-520	63.39	64.55	S	S	21.89	21.47	MS	MS
Surajmukhi	3.97	3.89	R	R	13.50	13.80	MS	MS
SKAU-SC-23-1	31.76	33.55	S	S	19.56	19.74	MS	MS
ACS-2000-2	75.39	71.83	HS	HS	29.07	29.18	S	S
SKAU-SC-578-1	31.99	38.65	S	S	21.95	22.37	MS	MS
SKAU-SC-101	29.15	29.34	MS	MS	18.08	17.78	MS	MS
DCL-524	66.33	61.43	S	S	20.29	20.78	MS	MS
Ujwala	4.69	4.74	R	R	18.37	18.73	MS	MS
Ajeet-1	63.39	68.16	S	S	25.06	25.29	S	S
Pant C-1	16.67	20.00	MR	MR	13.90	13.93	MS	MS

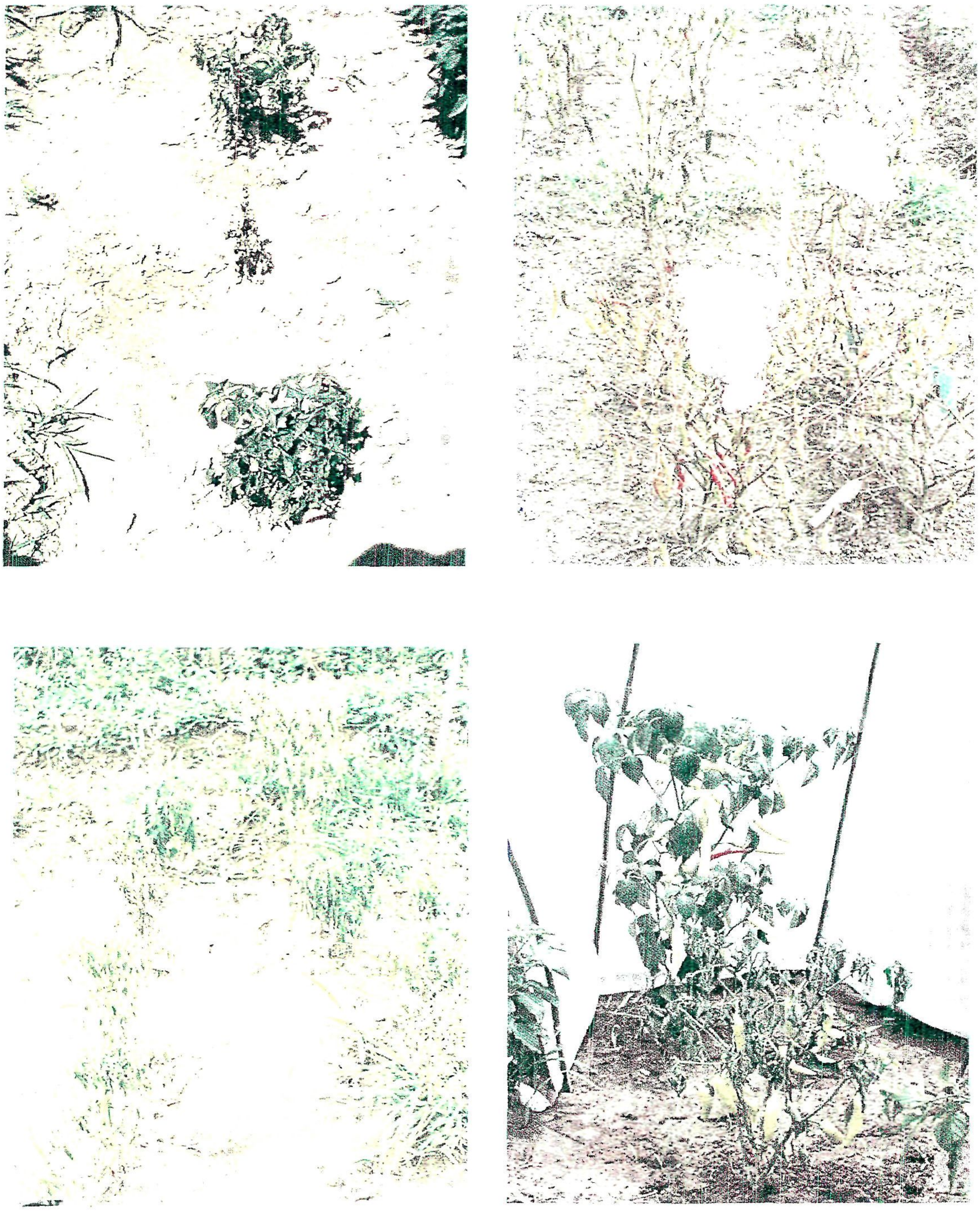


Plate 9. Bacterial wilt in chilli

G-4

Ujwala

Surajmukhi

Anugraha

Plate 10. Bacterial wilt resistant genotypes

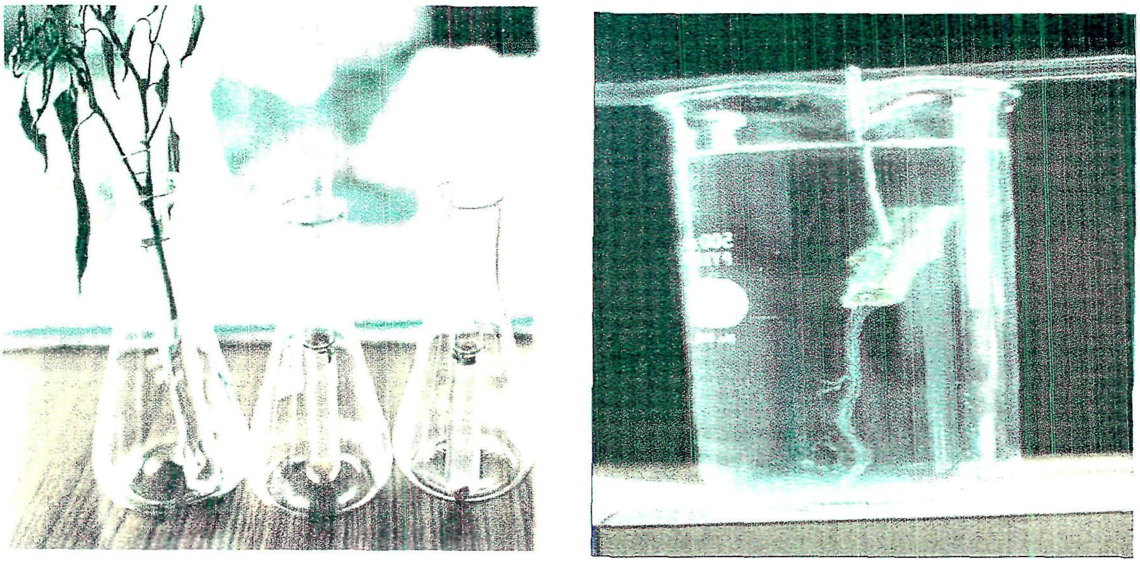


Plate 11. Ooze test for bacterial wilt

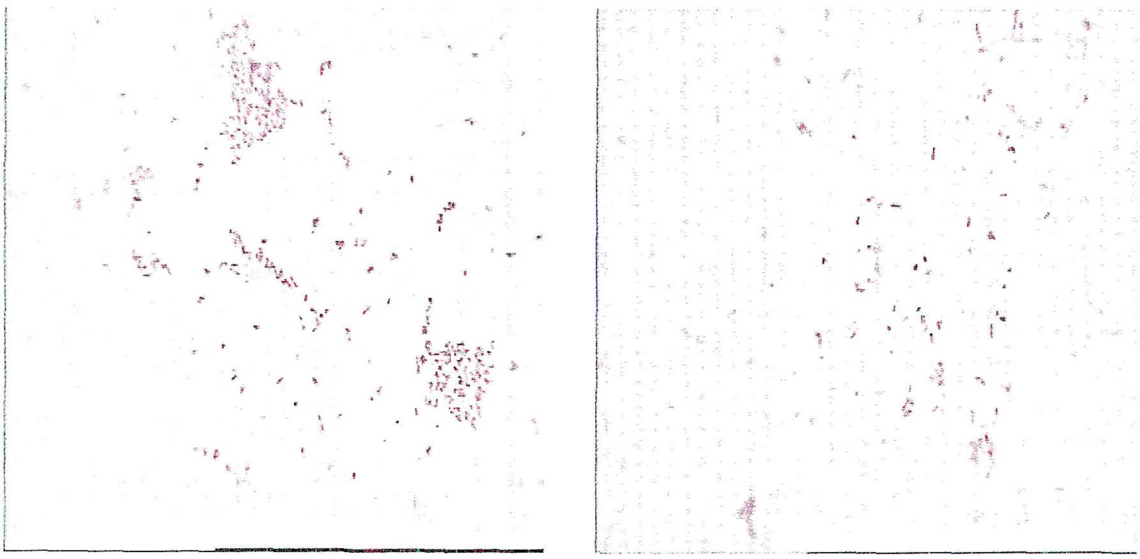


Plate 12. *Ralstonia solanacearum*, the wilt causing bacteria

Plate 13. Fruit rot incidence in chilli

Discussion

Chapter-V

DISCUSSION

Although chillies were introduced to India quite late after they were discovered yet the delay could not lessen India's fascination for chilli- the so popular flavouring agent. It has become an integral part of the Indian culture. Till today many superstitions are related with chillies like it is hanged up at the entrance door with a few lemons to guard the house from the evil, the dry chillies are rotated over children's head and burnt for safety of child from evil effect of devils etc.

At present chillies are produced throughout the length and breadth of the country making it the most dominating player in the world market. India contributes the maximum share of chillies in the world figuring up to around 11 lakh tonnes and is also the leading country in context of area covered. India is also the largest consumer and exporter of this crop. It consumes around 6.2 million tonnes of chillies i.e. about 90% of the total produce of the country. The demand from the chilli powder-producing sector constitute to 30% of the total production in the country. Inspite of increase in area and production of chilli annually, its average yield remains low. The average productivity of dry chilli in the country is around 1,112 kg/ha, while Andhra Pradesh tops with the maximum productivity of 1,948 kg/ha followed by Punjab (1,607 kg/ha). The lowest productivity is in Himachal Pradesh (270 kg/ha).

About 1.4 lakh tonnes of chillies worth Rs 500 crores are exported from the country which makes 33% of the total spice export. Chilli powder, dried chillies, pickled chillies and chilli oleoresins are some of the forms in which this crop is exported. Though the Indian exports are showing satisfactory trends, nowadays India is facing a very tough competition in the international export market as other competitive countries are providing quality chilli at very cheaper rates. Considering its importance for home consumption and export, there is a need to develop varieties/hybrids having high yield potential alongwith good quality traits.

The genetic improvement for yield and other traits in any crop can be brought about in two ways; first by manipulating the genetic make up of the plant through a number of desirable, often mutually compatible genes or characters in a single genotype and secondly by getting rid of the undesirable genes which inhibit or retard certain pathways leading to higher productivity. The first step in this direction is the basic understanding of genetic make up of attributes, variability available in these and genetic association among various traits. Thus, the present study entitled "Studies on genetic variation and association among various morphological and quality traits in chilli (*Capsicum annuum* L.)" was taken up as a first step with long-term objective of tailoring superior chilli varieties. In the present investigation, a total of thirty genotypes were critically evaluated for yield and other horticultural and biochemical traits to select superior genotypes.

Variability is the basic ground for evolution of any genotype. A wide range of variability always provide better chances for the selection of desirable types, whereas parameters of variability *viz.,* coefficient of variation, heritability and genetic gain and correlation serve as a beacon to plant breeder in finding desirable genotypes for improving different traits.

The salient findings of the present investigation have been discussed aspect-wise as under:

5.1 Variability studies

Selection, basic to every breeding programme, is effective only on genetic variation and its success would mainly depend upon the scientific management of the variability (Johannsen, 1909). A large amount of variability always provides the better chance of selecting desired types (Vavilov, 1951). Most of the economic traits, which are of the interest to plant breeders, are quantitative in nature and highly influenced by environment for their expression. According to Fisher (1918), these quantitative traits exhibiting continuous variation are under the control of both heritable and non-heritable factors. Response to selection would depend upon the relative proportion of heritable portion of the continuous variation. The heritable component is due to consequences of genotypes, while the non-heritable portion is mainly due to unknown environmental factors. Though, it is very difficult to assess the genotypes directly, but it is possible through the assessment of phenotypic expression (which is the result of genotype and the environmental interaction) in the existing material. Thus, the study of phenotypic variability for yield and other horticultural traits under investigation is of immense importance.

a) Analysis of variance

The results were discussed for pooled data over two years as the Bartlett's test of homogeneity between error variances was found to be non-significant for all the traits. The analysis of variance for pooled data (Table 4.1) revealed significant differences among the genotypes for all the horticultural and quality traits studied. These differences indicated the presence of good amount of variability and considerable scope for improvement. Sufficient genetic variability for many of the traits studied had also been reported by earlier workers with their genetic material under their environmental conditions (Das and Chaudhary, 1999a; Munshi and Behera,2000; Mishra *et al.,* 2001; Dipendra and Gautam, 2002; Rathod *et al.,* 2002a; Sreelathakumary and Rajamony, 2002; Nehru *et al.,* 2003; Buso *et al.,* 2003; Mini and Khader, 2004; Sheela *et al.*,2004; Verma *et al.,* 2004 and Wasule *et al.,* 2004).

b) Mean performance of genotypes

On the basis of estimates of mean values with respect to characters of horticultural importance (Table 4.2), Palam Yellow (268.22g) gave the highest marketable green yield per plant followed by HCH-9639 (261.71g), Surajmukhi (223.10g), G-4 (219.52g), SKAU-SC-101 (210.47g) and Anugraha (196.76g). In respect to dry yield, genotypes Surajmukhi gave the highest dry yield per plant (34.35g) followed by Palam Yellow (33.65g), G-4 (33.22g), HCH-9639 (31.66g), SKAU-SC-101(28.87g) and Pusa Sada Bahar(28.81g) This might be attributed to better manifestation of various yield contributing characters such as plant height, fruits per plant, harvest duration, fruit length and average green and dry fruit weight.

Since, chilli is grown in the low and mid hills of Himachal Pradesh during rainy season, taller plants are preferred to prevent diseases, besides, ensuring fruiting over a longer period of time. The plant height was maximum in SKAU-SC-101 (73.27 cm) followed by Kadyavallur local (73.12 cm). The number of branches per plant is a direct component contributing towards fruit yield. The number of primary branches per plant was maximum in Surajmukhi (7.93) followed by Ujwala (7.17), while maximum secondary branches per plant was noticed in Palam Yellow (7.48) followed by Pusa Sada Bahar (7.23).

Long harvest duration is desirable to have continuous supply to the market for longer period. Harvest duration was maximum in Surajmukhi (63.67 days) followed by Ujwala (63.50 days), Pant C-1 (63.00 days), G-4 (63.00 days), Pusa Sada Bahar (62.83 days) and Anugraha (62.67 days). Number of fruits per plant is the most important component of yield. Genotype Surajmukhi (63.96) followed by G-4 (57.45), Anugraha (54.90), Pant C-1 (53.50) and Pusa Sada Bahar (52.13) gave maximum number of marketable fruits per plant. Maximum number of total fruits per plant were also observed in these genotypes *viz.,* Surajmukhi (74.07) followed by G-4 (68.90), Anugraha (64.20), Pant C-1 (62.16) and Pusa Sada Bahar (61.93).

Among the quality traits, genotype Pant C-1 (134.59 mg/100g) had the maximum ascorbic acid, while moisture content was maximum in HCH-9639 (87.85%) followed by LCA-357 (87.38%). Pusa Sada Bahar had maximum TSS at green stage (6.21%), which are important constituents of nutrition in green chilli. Surajmukhi was most pungent with highest capsaicin content (0.90%) followed by Pusa Sada Bahar (0.87%) and Ujwala (0.86%). Capsanthin was maximum in KCA-190 (111.46 ASTA Units), whereas oleoresin was maximum in G-4 (78.42 ASTA Units).

Genotypic differences for quantitative traits in fresh and seed crop *viz.,* **yield** (Nawalagatti *et al.,* 1999; Munshi and Behera, 2000 and Sreelathakumary and Rajamony, 2002), **days to 50 per cent flowering** and **days to first fruit picking** (Nayeema *et al.,* 1998; Kumar *et al.,* 1999a; Munshi and Behera, 2000; Mishra *et al.,* 2001; Buso *et al.,* 2003; Sheela *et al.,* 2004 and Verma *et al.,* 2004), **plant height** (Das and Choudhary, 1999a; Kumar *et al.,* 1999a; Mohammed *et al.,* 2001; Sreelathakumary and Rajamony, 2002 and Sheela *et al.,* 2004), **branches per plant** (Das and Choudhary, 1999a; Kumar *et al.,* 1999a; Mohammed *et al.,* 2001; Nehru *et al.,* 2003; Sheela *et al.,* 2004 and Verma *et al.,* 2004), **harvest duration** (Kumar *et al.,* 1999a; Nandadevi and Hosamani, 2003 and Sheela *et al.,* 2004), **fruits per plant** (Munshi and Behera, 2000; Mohammed *et al.,* 2001; Sreelathakumary and Rajamony, 2002 and Nandadevi and Hosamani, 2003), **number of marketable fruits per plant** (Xu *et al.,* 1992; Mishra *et al.,* 2001 and Dipendra and Gautam, 2003), **fruit length** (Munshi and Behera, 2000; Mishra *et al.,* 2001; Mohammed *et al.,* 2001; Sreelathakumary and Rajamony, 2002; Sheela *et al.*, 2004 and Verma *et al.,* 2004), **average fruit weight** (Munshi and Behera, 2000; Sreelathakumary and Rajamony, 2002; Gupta and Tambe, 2003 and Sheela *et al.,* 2004), **fruit girth**

(Munshi and Behera, 2000; Mohammed *et al.,* 2001; Sreelathakumary and Rajamony, 2002 and Sheela *et al.,* 2004), **number of seeds per fruit** (Bhagyalakshmi *et al.,* 1990; Rani, 1996; Kumar *et al.,* 1999a and Gupta and Tambe, 2003), **seed weight per fruit** (Sahoo *et al.,* 1989), **100-seed weight** (Sahoo *et al.,* 1989; Rani, 1996 and Kumar *et al.,* 1999a) have been reported by earlier workers.

c) Parameters of variability

To understand the nature of observed variability in the germplasm, the variability was partitioned into genotypic and environmental components (Table 4.3). A perusal of results revealed that genotypic variances were of higher magnitude than the corresponding environmental variances for all the characters under study indicating higher genetic variability and little influence of environment on these traits.

Among horticultural traits *viz.,* marketable green yield per plant, dry yield per plant, number of marketable fruits per plant, total number of fruits per plant, plant height, harvest duration, number of seeds per fruit and quality traits *viz.,* ascorbic acid, oleoresin and capsanthin exhibited high values of phenotypic and genotypic variances, indicating high variability. The wide range of variability for the traits under study was apparently due to the presence of extreme types. The differences between phenotypic and genotypic variances for most of the traits were relatively low but for marketable green yield per plant capsanthin, number of seeds per fruit and ascorbic acid, the wider differences indicated that these traits may not perform consistently in fluctuating environmental conditions. Since, phenotypic and genotypic variances do not have clear cut limits and categorization of genetic variances as high or low is difficult, therefore, unsuitable for comparing the population when expressed in absolute values. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are independent from the units of measurement, can thus precisely be utilized for making comparison between populations for different metric traits.

A perusal of the results (Table 4.3) revealed that the values of PCV were higher than GCV for all the traits. The estimates of PCV and GCV were high for capsaicin content, marketable green yield per plant, average green fruit weight, dry fruit yield per plant, oleoresin, fruit girth, number of marketable fruits per plant, primary branches per plant, fruit length and average dry fruit weight. Higher magnitude of PCV and GCV indicated the presence of substantial variability ensuring ample scope for improvement through selection for these traits. PCV and GCV were moderate for seed weight per fruit, peel:seed ratio, plant height, number of seeds per fruit, capsanthin, secondary branches per plant, harvest duration and ascorbic acid suggesting that these traits have less potential for direct selection. Estimates of PCV and GCV were low for 100-seed weight, days to first fruit picking, days to ripe fruit picking, moisture content, TSS at green stage and red stage. High PCV and moderate GCV for total number of fruits per plant indicate that genotypes possessed comparatively low genetic variation for this trait. Days to 50 per cent flowering on other hand exhibited moderate PCV and low GCV.

These results further substantiate the findings of earlier workers for **fruit yield** (Munshi and Behera, 2000; Mishra *et al.,* 2001; Dipendra and Gautam, 2002; Sreelathakumary and Rajamony, 2002; Nandadevi and Hosamani, 2003; Mini and Khader, 2004 and Sreelathakumary and Rajamony, 2004a), **fruits per plant** (Munshi and Behera, 2000; Rathod *et al.,* 2002; Sreelathakumary and Rajamony, 2002; Mini and Khader, 2004; Sreelathakumary and Rajamony, 2004a and Verma *et al.,* 2004), **average fruit weight** (Sreelathakumary and Rajamony, 2002; Mini and Khader, 2004 and Sreelathakumary and Rajamony, 2004a), **primary branches per plant** (Nandadevi and Hosamani, 2003 and Verma *et al.,* 2004), **fruit length** (Munshi and Behera, 2000; Sreelathakumary and Rajamony, 2002; Nandadevi and Hosamani, 2003; Sreelathakumary and Rajamony, 2004a and Verma *et al.,* 2004), **fruit girth** (Sreelathakumary and Rajamony, 2002; Sreelathakumary and Rajamony, 2004a and Verma *et al.,* 2004), **secondary branches per plant** (Mohammed *et al.,* 2001), **100-seed weight** (Kumar *et al.,* 1999a), **capsaicin** (Ramanujam and Tirumalachar, 1967; Manju and Sreelathakumary, 2002) and for **oleoresin** (Manju and Sreelathakumary, 2002).

Most of the traits showed relatively low level of environmental coefficient of variation indicating that the traits under investigation were less influenced by the environment. Higher estimates of PCV than GCV further confirmed close association between phenotype and genotype.

d) Heritability and genetic advance

Heritability in broad sense is of tremendous significance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression (Lush, 1940). According to Burton and De Vane (1953), heritability is a measure of heritable variation, and it is helpful in predicting the expected amount of improvement to be achieved through selection together with the genotypic coefficient of variation.

All horticultural traits *viz.,* days to 50 per cent flowering, days to first green fruit picking, primary branches per plant, secondary branches per plant, fruit length, fruit girth, average green fruit weight, number of marketable fruits per plant, total number of fruits per plant, plant height, marketable green yield per plant, harvest duration, days to ripe fruit picking, average dry fruit weight, dry fruit yield per plant, number of seeds per fruit, seed weight per fruit, 100-seed weight, peel:seed ratio, and quality traits *viz.,* moisture content, ascorbic acid, oleoresin, capsanthin, capsaicin, and TSS at green and red stage exhibited high heritability (Table 4.3), indicating that these traits were less influenced by the environment. This suggested that large proportion of phenotypic variance has been attributed to genotypic variance and hence, reliable selection could be made for these traits on the basis of phenotypic variation. Johnson *et al.* (1955) stressed that for estimating the real effects of selection, heritability alone is not sufficient and genetic advance alongwith heritability is more useful. High heritability alongwith high genetic advance was recorded for marketable green yield per plant, dry fruit yield per plant, number of marketable fruits per plant, average green fruit weight, fruit girth, seed weight per fruit, oleoresin and capsaicin content, whereas high heritability coupled with moderate genetic advance was recorded for total number of fruits per plant, average dry fruit weight, primary branches per plant, secondary branches per plant, fruit length, plant height, number of seeds per fruit, 100-seed weight, peel:seed ratio and capsanthin. The results revealed that the inheritance of these characters is under the control of additive gene action (Panse, 1957). So, selection will be more effective for the improvement of these traits.

High heritability for harvest duration, days to 50 per cent flowering, days to first green and ripe fruit picking, ascorbic acid, TSS at green and red stage and moisture content were found to be associated with low genetic advance. The association of high heritability with low genetic advance reveals that inheritance of these characters is under the control of non-additive gene effects. Improvement of these traits through simple selection might not give desirable results and need to be improved through hybridization (Panse, 1957). Similar results have been reported earlier for **fruit yield per plant** (Munshi and Behera, 2000; Mohammed *et al.,* 2001; Dipendra and Gautam, 2002; Rathod *et al.,* 2002a; Sreelathakumary and Rajamony, 2002; Nandadevi and Hosamani, 2003; Nehru *et al.,* 2003; Das and Maurya, 2004; Mini and Khader, 2004; Mishra *et al.,* 2004 and Sreelathakumary and Rajamony, 2004a), **fruits per plant** (Munshi and Behera, 2000; Dipendra and Gautam, 2002; Rathod *et al.,* 2002a;

Sreelathakumary and Rajamony, 2002; Das and Maurya, 2004; Mini and Khader, 2004; Mishra *et al.,* 2004; Sreelathakumary and Rajamony, 2004a; Verma *et al.,* 2004 and Wasule *et al.,*2004), **fruit weight** (Kataria *et al.,* 1997; Singh and Singh, 1998; Sreelathakumary and Rajamony, 2002; Das and Maurya, 2004; Mini and Khader, 2004 and Sreelathakumary and Rajamony, 2004a), **plant height** (Bhagyalakshmi *et al.*, 1990 and Mohammed *et al.,* 2001), **fruit length** (Mohammed *et al.,* 2001), **fruit girth** (Mohammed *et al.,* 2001; Sreelathakumary and Rajamony, 2002 and Sreelathakumary and Rajamony, 2004a), **number of branches per plant** (Bhagyalakshmi *et al.,* 1990), **seeds per fruit** (Bhagyalakshmi *et al.,* 1990 and Kumar *et al.,* 1999a), **100-seed weight** (Bhagyalakshmi *et al.,* 1990), **capsaicin content** (Rani and Singh, 1996 and Manju and Sreelathakumary, 2002), **oleoresin** (Manju and Sreelathakumary, 2002), **capsanthin** (Khurana *et al.,* 2003), **days to 50 per cent flowering** (Gopalakrishnan *et al.,* 1987; Nayeema *et al.*, 1998; Khurana *et al.,* 2003 and Verma *et al.,* 2004), **days to first picking** (Mohammed *et al.,* 2001; Khurana *et al.,* 2003 and Verma *et al.,* 2004) and **ascorbic acid** (Bhagyalakshmi *et al.,* 1990 and Kumar *et al.,* 1999a).

5.2 Correlation studies

Knowledge of inter-relationship serves two main purposes from the breeder's point of view. Firstly, these are highly useful in selecting for characters, which are not easily observed or genotypic values of which are modified by the environmental effects. There is ample evidence to show that direct selection for fruit yield in plants is not easy. Thus, any morphological character that is associated with higher yield or which makes a significant contribution to yielding ability would be useful in the improvement of fruit yield. Secondly, inter-relationships between characters make available to the breeder about the sources of information as the nature, extent and direction of selection pressure among characters.

In the present study, in general the genotypic correlation coefficients were of higher magnitude than the corresponding phenotypic ones (Table 4.4 and 4.5), which indicated that though there is a strong inherent association between various characters studied, the phenotypic expression of the correlation gets reduced under the influence of the environment.

Marketable green yield per plant and dry yield had positive and highly significant correlations with total number of fruits per plant, number of marketable fruits per plant, plant height, secondary branches per plant and harvest duration both at phenotypic and genotypic levels. Besides these characters, average green fruit weight with marketable green yield and peel:seed ratio and capsanthin with dry yield had significant positive association. Thus selection on the basis of these traits might lead to higher yield.

Significant positive correlations of yield with **fruits per plant** (Leaya and Khader, 2002; Sreelathakumary and Rajamony, 2002; Khurana *et al.,* 2003; Kumar *et al.,* 2003a; Nandadevi and Hosamani, 2003; Nehru *et al.,* 2003; Dipendra and Gautam, 2003; Sujata *et al.,* 2003; Singh and Singh, 2004;

Sreelathakumary and Rajamony, 2004b and Raikar *et al.,* 2005), **fruit weight** (Munshi *et al.*, 2000; Leaya and Khader, 2002; Sreelathakumary and Rajamony, 2002; Dipendra and Gautam, 2003; Sreelathakumary and Rajamony, 2004b and Raikar *et al.,* 2005), **plant height** (Aliyu *et al.,* 2000; Mohammed *et al.,* 2001; Leaya and Khader, 2002; Dipendra and Gautam, 2003; Khurana *et al.,* 2003; Singh and Singh, 2004 and Raikar *et al.,* 2005), **number of branches per plant** (Mohammed *et al.,* 2001; Kumar *et al.,* 2003a and Raikar *et al.,* 2005), **fruit girth** (Aliyu *et al.,* 2000 and Sreelathakumary and Rajamony, 2002 and 2004b), **peel:seed ratio** (Khurana *et al.,* 2003) and **capsanthin** (Khurana *et al.,* 2003) are in agreement with the present findings.

As observed in the present study, Mohammed *et al.* (2001), Dipendra and Gautam (2003) and Nandadevi and Hosamani (2003) reported positive association of fruits per plant with plant height, branches per plant and harvest duration, while Sreelathakumary and Rajamony (2002) reported positive interrelationship of days to first fruit picking with days to 50 per cent flowering. A positive association of days to 50 per cent flowering with days to first green as well as ripe fruit picking suggested that early flowering genotypes would be an appropriate selection criterion to get early yield. The occurrence of positive correlation of fruits per plant with plant height, primary and secondary branches per plant and harvest duration revealed that the improvement in the former is brought about by selecting the related traits. Similarly, by increasing the plant height and harvest duration, marketable fruits can be increased as these are positively correlated.

Fruit length had positive relationships with average fruit weight (green as well as dry), number of seeds per fruit, seed weight per fruit, 100 seed weight and peel:seed ratio, while it showed significant negative correlation with number of marketable and total fruits per plant, capsaicin content and TSS at green and red stage. These results are supported by the findings of Warade *et al.,* 1997a; Mohammed *et al.,* 2001; Dipendra and Gautam, 2003 and Mathew *et al.,* 2004). The correlation of fruit girth was negative with number of marketable fruits per plant, total number of fruits per plant, plant height, harvest duration, ascorbic acid and capsaicin content.

Average green fruit weight had significant negative relationship with number of marketable fruits per plant, total number of fruits per plant, harvest duration and TSS at green stage (Table 4.4). These results corroborate the findings of Depestre *et al.* (1981). Average dry fruit weight however, showed positive association with number of seeds per fruit, seed weight per fruit, 100-seed weight and peel:seed ratio whereas, had negative association with number of marketable fruits per plant, total number of fruits per plant, harvest duration and capsaicin content. Results of Hwang and Lee, 1978; Rani, 1995; Rani and Singh, 1996; Kumar *et al.,* 1999b; Dipendra and Gautam, 2003 and Kumar *et al.,* 2003a were in consonance with the present findings.

The positive association of number of seeds per fruit with seed weight per fruit; seed weight per fruit with 100-seed weight and peel:seed ratio and 100-seed weight with peel:seed ratio were observed (Table 4.5). Similar results have been obtained by earlier workers (Rao and Chhonkar, 1981; Bhagyalakshmi, 1990 and Rani and Singh, 1996). However, all the seed characters showed negative association with total number of fruits per plant, number of marketable fruits per plant, harvest duration, capsaicin content and TSS at red stage.

Among quality traits oleoresin was significantly and positively associated with secondary branches per plant, total number of fruits per plant and harvest duration. Similar results were obtained by Mini and Vahab (2002). Capsaicin content too showed positive association with primary branches per plant, number of marketable fruits per plant, total number of fruits per plant, harvest duration and TSS at red stage.

The negative correlation of capsaicin content with fruit length and positive association with number of marketable and total fruits per plant showed that high capsaicin content cultivars had small fruits with profuse bearing. Thus, indicated possibilities to combine high yield with high capsaicin content. These results are in agreement with Ramiah and Rayappapillai, 1935; Kamalam and Rajamani, 1966; Gill *et al.,* 1973; Arya and Saini, 1977; Sharma *et al.,* 1981 and Rani, 1995.

Hence, on the basis of correlation studies, it can be concluded that selection for total number of fruits per plant, marketable fruits per plant, average fruit weight, branches per plant and harvest duration will be effective for isolating plants with higher fruit yield in chilli.

5.3 Path coefficient studies

It is now realized that the association between the characters, whose degree is being measured does not exist by itself but a complicated interaction pathway is involved in which various other attributes may also take part. Therefore it would be interesting to study the direct and indirect contribution of each trait towards fruit yield.

The present study revealed that the direct and indirect effects obtained at genotypic level were different from those at phenotypic level (Tables 4.6 and 4.7), which might be due to varying degree of influence of environment on various traits studied. This fact was also revealed from the results of component variance analysis and correlation at the environmental level. Therefore, the path analysis at the phenotypic level may not provide true picture of direct and indirect causes and it would be advisable to understand the contribution of different traits towards the yield per plant at genotypic level. For path analysis at genotypic level, marketable green yield per plant (Tables 4.6) and dry yield per plant (Table 4.7) were taken as dependent variable and all other traits used for correlation were considered as causal variables.

It is evident from the present study (Table 4.6) that average fruit weight had the maximum direct positive contribution towards the marketable green yield per plant followed by total number of fruits per plant, and number of marketable fruits per plant at phenotypic level. At genotypic level, number of marketable fruits per plant had the highest positive direct effect on marketable green yield per plant followed by average fruit weight, fruit length, TSS at green stage, plant height, total number of fruits per plant and primary branches per plant, while negative direct effect was observed for ascorbic acid, days to 50 per cent flowering, secondary branches per plant, harvest duration and fruit girth.

Similarly path analysis for dry yield per plant at phenotypic level revealed that average dry fruit weight had the maximum positive direct effect followed by total number of fruits per plant, number of marketable fruits per plant and harvest duration. At genotypic level, seed weight per fruit had the highest positive direct effect. Other major direct positively contributing traits were average dry fruit weight, number of marketable fruits per plant, harvest duration and total number of fruits per plant.

Direct and positive effect for yield were also observed by earlier workers for **number of fruits per plant** (Munshi *et al.*, 2000; Rangaiah *et al.*, 2001; Leaya and Khader, 2002; Dipendra and Gautam, 2003; Kumar *et al.*, 2003a; Sujata *et al.*, 2003; Mathew *et al.*, 2004; Singh and Singh, 2004; Sreelathakumary and Rajamony, 2004 and Verma *et al.*, 2004), **fruit weight** (Munshi *et al.*, 2000; Leaya and Khader, 2002; Singh and Singh, 2004 and Sreelathakumary and Rajamony, 2004b), **fruit length** (Rangaiah *et al.*, 2001; Dipendra and Gautam, 2003; Kumar *et al.*, 2003a and Sujata *et al.*, 2003), **branches per plant** (Kaul and Sharma, 1989; Das and Choudhary, 1999b; Rangaiah *et al.*, 2001 and Rathod *et al.*, 2002b), **harvest duration** (Nair *et al.*, 1984 and Rangaiah *et al.*, 2001) and **TSS** (Kaul and Sharma, 1989). Therefore, attention should be given to improve these traits, while making selection of high yielding genotypes.

Days to 50 per cent flowering, days to first fruit picking and days to ripe fruit picking had negative direct effects which were further increased by indirect negative effect via average fruit weight at both levels. The negative indirect effect of secondary branches per plant (Table 4.6) was counterbalanced by positive indirect effect via number of marketable fruits per plant and total number of fruits per plant. Number of seeds per fruit and 100 seed weight had negative direct effects (Table 4.7) which were counterbalanced by strong indirect positive effect via average dry fruit weight and seed weight per fruit while positive indirect effect via average dry fruit weight added to the direct positive effect of peel:seed ratio.

Marketable fruits per plant had positive and strong direct effect which was further strengthened by positive indirect effect via total number of fruits per plant which negated the negative indirect effect of average fruit weight (green as well as dry).

The low magnitude of residual effect at phenotypic and genotypic level (Table 4.6 and 4.7) indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variables i.e. marketable green yield and dry yield per plant. In view of direct and indirect contribution of component traits towards marketable green yield per plant, selection on the basis of average fruit weight, number of total and marketable fruits per plant, fruit length, plant height, number of primary branches per plant and TSS at green stage would be beneficial, however, for dry yield, average dry fruit weight alongwith number of total and marketable fruits per plant, harvest duration, seed weight per fruit, number of secondary branches per plant, peel:seed ratio and capsanthin would prove fruitful. While considering green as well as dry yield, selection on the basis of horticultural traits *viz.,* average green and dry fruit weight, number of total and marketable fruits per plant would be worthwhile.

5.4 Morphological characterization of genotypes

Systematic description of germplasm is an important aspect leading to more efficient and desirable use in crop improvement. Moreover, information regarding morphological characters is helpful for the breeders in further research and leading to development of new improved types.

In the present study, Palam Yellow, G-4, Surajmukhi, Anugraha, Pusa Sada Bahar, Ujwala were found promising for high yield potential and other traits. These genotypes had certain morphological features suitable for Indian markets. Palam Yellow had Yellow fruit colour, Anugraha had light green fruit colour, G-4 had green colour, while all other had dark green colour but all of them on ripening had deep red ripe fruit colour. These genotypes possessed acute fruit shape at pedicel attachment and pointed fruit shape at blossom end.

Surajmukhi, Ujwala and Pusa Sada Bahar had erect fruit orientation whereas G-4 and Anugraha had pendent fruit position. Palam Yellow had semi-pendent fruit position.

The fruit bearing habit of G-4, Anugraha and Palam Yellow was solitary whereas Surajmukhi, Ujwala and Pusa Sada Bahar bear fruits in cluster.

5.5 Disease reaction

The major constraints faced by farmers in chilli crop production are bacterial wilt and fruit rot. Genotypes Surajmukhi, Ujwala, Pusa Sada Bahar, Pant C-1 and Anugraha were found resistant, while G-4 was moderately resistant to bacterial wilt. None of the genotype was found to be resistant to fruit rot.

Summary

Chapter-VI

SUMMARY

The present investigation entitled, "Studies on genetic variation and association among various morphological and quality traits in chilli (*Capsicum annuum* L.) was carried out at the Experimental Farm, Department of Vegetable Science and Floriculture, CSKHPKV, Palampur for two consecutive years i.e. *Kharif* 2005 and *Kharif* 2006.

The study material comprised of 30 diverse chilli genotypes, which were evaluated in a randomized block design with three replications to assess the nature and magnitude of genetic variability, to understand the association among various horticultural and quality traits, to work out their direct and indirect contributions to the yield, and to identify the promising genotypes.

Observations were recorded on nineteen horticultural traits, *viz.,* days to 50 per cent flowering, days to first green fruit picking, days to ripe fruit picking, primary branches per plant, secondary branches per plant, fruit length, fruit girth, average green fruit weight, average dry fruit weight, number of marketable fruits per plant, total number of fruits per plant, harvest duration, marketable green yield per plant, dry yield per plant, number of seeds per fruit, seed weight per fruit, 100-seed weight, peel:seed ratio and plant height and seven quality traits *viz.,* ascorbic acid, oleoresin, capsanthin, capsaicin, TSS of fruit at mature green stage and at red ripe stage and moisture content. Along with these traits, genotypes were also assessed for bacterial wilt and fruit rot incidence. Morphological characterization of genotypes was done by using standard descriptors and on visual observations. Five competitive plants were chosen at random in each entry for recording observations on various traits for fresh and seed crop. In bacterial wilt susceptible genotypes observations were recorded only on surviving plants. The data were subjected to statistical analysis as per the standard statistical procedures.

Pooling of data over the years was done, as the Bartlett's test of homogeneity proved non-significant. Analysis of variance revealed significant differences among the genotypes for all the traits. On the basis of mean performance, Palam Yellow, HCH-9639, Surajmukhi, G-4, SKAU-SC-101, Anugraha were found to be superior for marketable green yield, while for dry yield, Surajmukhi, Palam Yellow, G-4, HCH-9639, SKAU-SC-101, Pusa Sada Bahar, ACS-2000-2 and Anugraha were found to be superior. SKAU-SC-101, G-4 and Palam Yellow were the earliest in flowering, first green and ripe fruit picking.

Among horticultural traits, the estimates of PCV and GCV were high to moderate for marketable green yield, dry yield, primary and secondary branches, fruit length and girth, average green and dry fruit weight, number of total and marketable fruits, harvest duration, plant height, number of seeds and seed weight per fruit and peel:seed ratio and for quality traits *viz.*, capsaicin, oleoresin and capsanthin. The PCV and GCV values for other traits were low.

The estimates of high heritability, alongwith high to moderate genetic advance for marketable green yield, dry yield, average green and dry fruit weight, primary and secondary branches per plant, fruit length and girth, number of total and marketable fruits per plant, plant height, number of seeds per fruit, seed weight per fruit, 100-seed weight, peel:seed ratio, capsaicin content, oleoresin and capsanthin, indicated additive gene control for the inheritance of these traits. Hence, these traits can be improved through selection. On the other hand, high heritability associated with low genetic advance was observed for days to 50 per cent flowering, days to first green and ripe fruit picking, harvest duration, ascorbic acid, TSS at green and red stage and moisture content, revealing that dominance or epistatic effects are of considerable value for the inheritance of these traits and thus, need to be improved through hybridization.

Studies on correlation coefficient indicated that in general genotypic correlations were higher than the corresponding phenotypic ones for most of the horticultural traits indicating the existence of inherent association among these traits. Marketable green and dry yield per plant had significantly positive correlations with number of total and marketable fruits per plant, plant height, secondary branches per plant and harvest duration both at phenotypic and genotypic levels. Besides these characters, average green fruit weight with marketable green yield and peel:seed ratio and capsanthin with dry yield had significant positive association.

At phenotypic level, average fruit weight had the maximum direct effect on the marketable green yield followed by total number of fruits and number of marketable fruits per plant. Likewise, average dry fruit weight had the maximum direct effect on dry yield per plant followed by total number of fruits per plant and number of marketable fruits per plant.

At genotypic level, number of marketable fruits per plant exhibited the highest positive direct effect followed by average fruit weight and fruit length for marketable green yield per plant. For dry yield per plant, seed weight per fruit showed highest positive direct effect followed by average dry fruit weight, number of marketable fruits per plant, harvest duration and total number of fruits per plant.

On the basis of morphology, DPCH-1 and Palam Yellow were yellow fruited, while Anugraha had light green fruits. G-4 was having green fruits while Surajmukhi, Pusa Sada Bahar, HCH-9639 had dark green fruits. On ripening, all of these have red to deep red fruits. Surajmukhi, Ujwala and Pusa Sada Bahar bear acute, erect and pointed fruits in cluster, while G-4, Anugraha and SKAU-SC-101 bear acute, solitary, pointed and pendent fruits. Palam Yellow had obtuse, solitary, pointed and semi-pendent fruits, whereas fruit characteristics of BPCH-1 were obtuse, erect, blunt and in cluster.

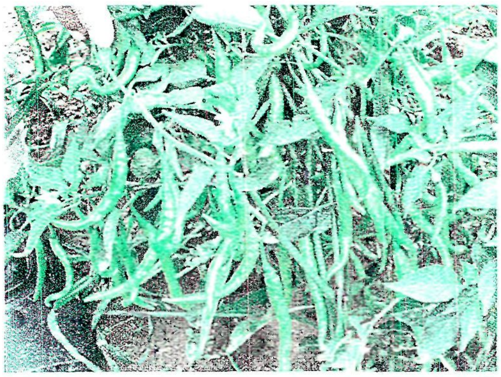
Bacterial wilt and fruit rot are the major bottlenecks in increasing the production. Genotypes Surajmukhi, Ujwala, Pusa Sada Bahar, Pant C-1 and Anugraha were found resistant, while G-4 was moderately resistant to bacterial wilt. None of the genotype showed resistance to fruit rot.

Thus, the present studies revealed that average fruit weight, number of total and marketable fruits per plant, fruit length, plant height, primary branches and TSS were the most contributing traits for marketable green yield, while for dry yield, average dry fruit weight, number of total and marketable fruits per plant, seed weight per fruit, harvest duration, secondary branches, peel:seed ratio and capsanthin would serve as good selection indices for chilli improvement.

CONCLUSION

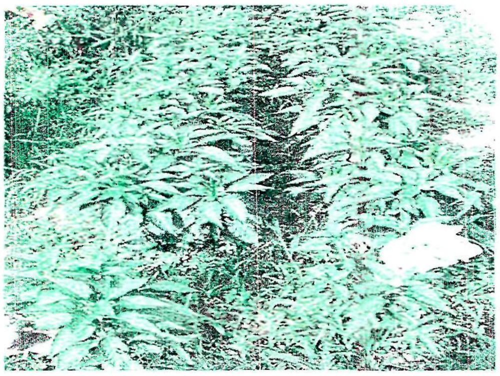
- Sufficient variability existed in the material under study, which could be exploited either through selection or hybridization or both.
- The genotypes Palam Yellow, HCH-9639, Surajmukhi, G-4, SKAU-SC-101 and Anugraha can be directly used for marketable green yield as well as for dry yield after multi-location testing.
- Selection based on average fruit weight, number of marketable fruits per plant, fruit length and total number of fruits per plant would be rewardings for effective improvement of marketable green yield, whereas average dry fruit weight, number of marketable fruits per plant, seed weight per fruit, total number of fruits per plant and harvest duration would be reliable for dry yield.
- Surajmukhi, Pusa Sada Bahar, Ujwala and Anugraha were resistant, while G-4 and Pant C-1 were moderately resistant to bacterial wilt. Moreover, these genotypes exhibited least percentage of fruit rot incidence.

Plate 14. High yielding genotypes



Anugraha

Palam Yellow



Ujwala

SKAU-SC-101

Surajmukhi

Plate 15. Promising genotypes for horticultural and quality traits

Surajmukhi, Ujwala and Pusa Sada Bahar were having the highest capsaicin content, while G-4 had the maximum oleoresin content.

Therefore, due attention should be paid to improve these traits, while initiating improvement programme in chilli.

chili

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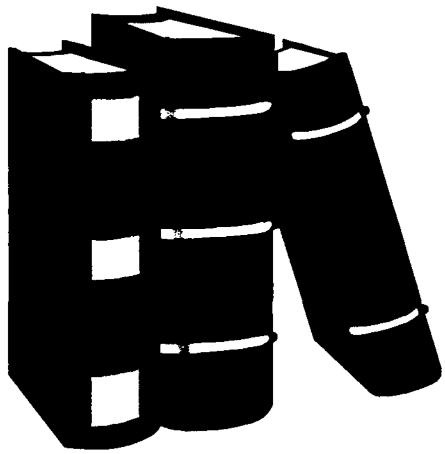

Appendices

Appendix-I

Agro-ecological Zones

Agro-ecological zones	Altitude range (m)	Rainfall (mm)
Zone 1.1	240-1000	< or=1500
Zone 1.2	240-1000	> 1500
Zone 2.1	1001-1500	< or = 1500
Zone 2.2	1001-1500	> 1500
Zone 3.1	1501-2500	< or = 1500
Zone 3.2	1501-3250	> 1500
Zone 4.1	2501-3250	< 700 (Dry)
Zone 4.2	3251-4250	Dry/snow
Zone 4.3	> 4250	Dry/snow

Appendix-II

Weather parameters during the experimental period of 2005

Standard weeks	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Morning	Evening
9	19.00	10.07	7.4	78.29	78.43
10	21.99	10.27	37.0	80.29	74.71
11	22.54	12.19	14.8	78.14	73.71
12	19.79	9.61	89.9	73.14	75.29
13	22.89	9.93	3.6	68.43	67.86
14	26.90	14.79	0.0	60.43	62.00
15	24.56	13.00	0.0	62.29	51.14
16	28.59	15.91	0.0	60.71	54.86
17	28.44	14.90	29.9	57.86	66.43
18	25.39	14.07	29.1	77.43	77.43
19	28.29	16.51	9.0	68.86	65.83
20	29.49	17.26	14.0	68.86	62.71
21	31.31	18.03	3.5	64.57	56.71
22	31.97	19.47	0.0	58.00	51.43
23	32.43	18.36	11.5	55.00	48.00
24	33.01	19.96	13.2	53.29	40.14
25	35.21	22.27	7.2	51.29	46.57
26	29.73	20.49	192.3	86.71	77.00

Contd../-

Standard weeks	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Morning	Evening
27	25.26	18.37	190.8	81.43	85.71
28	26.89	20.40	261.5	96.86	82.71
29	25.99	19.97	151.1	85.14	81.86
30	28.23	20.04	86.6	87.43	83.43
31	27.70	20.06	284.2	89.71	84.00
32	27.57	18.44	105.0	86.86	79.43
33	26.13	20.07	164.8	90.00	88.29
34	27.24	19.07	73.8	76.00	80.57
35	29.70	22.80	76.2	94.00	84.33
36	27.41	20.07	32.1	89.71	80.43
37	24.34	17.33	191.6	88.29	82.71
38	26.41	17.44	322.1	81.86	71.29
39	26.77	16.14	29.6	75.86	70.43

Appendix-III

Weather parameters during the experimental period of 2006

Standard weeks	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Morning	Evening
9	21.34	9.99	8.80	52.86	38.29
10	22.21	11.51	5.60	51.29	38.86
11	18.07	8.76	77.00	61.00	48.86
12	21.29	11.50	4.20	59.57	39.71
13	22.36	11.00	20.60	53.43	44.00
14	27.11	13.91	0.10	39.86	26.57
15	26.11	14.39	11.40	42.86	29.00
16	24.19	13.51	6.90	46.14	40.43
17	30.20	18.07	0.00	38.57	25.57
18	30.26	18.83	1.40	50.86	40.29
19	31.74	20.09	17.60	50.86	40.29
20	29.90	18.83	18.20	58.71	49.00
21	28.49	19.39	27.90	66.71	56.29
22	31.00	19.53	135.40	58.86	46.57
23	29.74	19.30	17.40	63.14	40.86
24	30.43	19.51	16.00	58.71	45.14
25	29.39	19.31	0.00	59.71	42.86
26	27.53	19.03	225.10	84.14	73.71
27	28.39	21.11	75.40	80.14	75.71

Contd../-

Standard weeks	Temperature (°C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Morning	Evening
28	26.11	19.99	183.40	83.29	84.71
29	27.21	20.50	141.20	87.71	83.57
30	24.57	20.26	251.40	92.57	87.29
31	25.81	20.01	198.00	88.71	82.86
32	26.06	19.44	101.40	87.57	80.00
33	28.56	20.33	80.30	84.00	77.14
34	25.79	20.29	264.00	89.43	87.29
35	25.07	18.44	268.60	86.14	85.00
36	26.90	18.96	38.20	83.14	76.14
37	25.4	18.20	142.50	85.00	79.00
38	26.4	17.80	82.40	76.00	68.00
39	27.0	15.20	0.00	62.00	59.00