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Study of the Anther Culture and Comparison of GxE Models for Selection of Stable Genotypes in Chilli (Capsicum annuum L.)

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Study of the Anther Culture and Comparison of G×E Models for Selection of Stable Genotypes in Chilli (*Capsicum annuum* L.)

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BIOMETRICAL GENETICS LABORATORY
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UNIVERSITY OF RAJSHAHI

TO MY

PARENTS

AND
FAMILY MEMBERS

DECLARATION

I hereby declare that the entire work now submitted as a thesis for the Degree of Master of Philosophy at the University of Rajshahi, Bangladesh, is the results of our own investigation. I further certify that the work embodied in this thesis has not been concurrently submitted as candidature for any other degree.

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CERTIFICATE

I hereby certify that the work embodied in this thesis has not already been submitted in substance for any degree, and has not been concurrently submitted in candidature for any degree.

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ABSTRACT

The present investigation consists of the study of anther culture and the study of comparison of G×E models for selection of stable genotypes in chilli (*Capsicum annuum* L.). The materials were seven chilli varieties, *viz., abbreviatum, annumm, acuminatum, nigra, conoides, cerasiformis* and *fasciculatum* which were tested for ten quantitative characters, such as NSBMF, NSBFF, PHMF, NPBFF, NPBFF, LAMF, LAFF, NLMF, NPBMF and NLFF.

Immature anthers of all the seven varieties were used as the main materials in the study of anther culture. MS basal medium supplemented with different combinations of cytokinins and auxins were used. All the seven varieties produced calli supplemented with 0.1 mg/l NAA + 0.1 mg/l 2-1D + 0.2 mg/l BAP. The range of callus induction was from 1.7 to 6.0%. Three varieties, *viz. C. abbreviatum, C. annuum* and *C. fasciculatum* responded well in calli formation in five different media among which *abbreviatum* was the best.

In the study of the comparison of G×E models the range of variation was wide and pronounced for all the characters, indicating that there were genotypic differences among the varieties under study.

For the analysis of stability, under three models, namely Eberhart and Russell's, Perkins' and Jinks' and Freeman and Perkins' were compared to select the stable genotypes. Following all the three models varieties *abbreviatum* for PHMF, *acuminatum* for NPBFF, *abbreviatum, annuum* and *cerasiformis* for PHFF were found to be stable having unit regression co-efficient (b_i), non significant deviation from regression ($\overline{S}^2{}_{d_i}$) and high mean performances.

Following Eberhart and Russell's model, the linear component in the joint regression analysis was found to be important. In Perkins' and Jinks' model both linear and non-linear components were found to be important. But in Freeman and Perkins' model, only non-linear component was significant.

CONTENTS

SECTION TWO (G×E INTERACTION)

GENERAL INTRODUCTION

Chilli, commonly known as pepper, is a recognized spice crop cultivated throughout the world. Improvement of such an important crop through the traditional cultivated method is not accepted in the era of science of biology. Tissue culture technique (one of the techniques of improvement of crop plant) may be adopted for the improvement of this spice crop. In this regard, anther culture is the only process in obtaining haploid plants. As, most of the yield components and yield are quantitative in nature also in case of this crop, they should have to be stable to be grow worldwide.

The commonly chilli, being a member of the Solanaceae or Nightshade family is under the genus *Capsicum.* Solanaceae family has 75 genera and 200 species of herbs, shrubs and small trees. The genus *Capsicum* comprising 20 species distributed throughout the world, except the colder region.

Five species namely, *Capsicum annuum* L.; *C. frutescens* L.; *C. pendulum* Willd.; *C. pubescens* R. and P. and *C.* chinese Jacq. were consolidated as the cultivated capsicums by Smith and Heriser (1951) and Smith *et al.* (1951). However, *C. baccatum* is poorly cultivated outside the parts of South America. According to Eshbaugh (1964) the domesticated forms are classified as *C. baccatum* var. *pendulum* and the wild type as var. *baccatum.* The wild variety is largely confined to Bolivia and surrounding areas. Nevertheless, most of the authors recognised two main species viz. *Capsicum annuum* L. and *C. frutescens* L. Many cultivars were recognised under *Capsicum annuum* L. by several investigators.

Capsicum is not very old extending back to pre-Inca days and native to tropical America and West Indies. It was carried to the old world by the early explorers and introduced into Spain by Columbus (discoverer of America) on his return in 1493 (Boswell, 1949).

Prior to 1885, Portuguese brought *Capsicum* to India from Brazil, and cultivation was reported in China during the late 1700's (Sturtevant, 1885). Most of the cultivars of *Capsicum annuum* L. are widely cultivated in Bangladesh and India. Chilli cultivation spread from the Mediterranean area to England by 1548 and to the central Europe the close of the 16^{th} century (Boswell, 1949).

In the sense of biodiversity, the centre of diversity of the common cultivated pepper *Capsicum annuum* L. is in Mexico and West Indies with a secondary centre in Guatemala. *C. frutescens* is widely distributed throughout the tropical and subtropical Americans, both in the wild and cultivated forms and was domesticated in the central America. The other cultivated and wild species also have their origin in the central and South America and the genus quite clearly has its origin in South America (Bukasovel, 1930; Smith and Heiser, 1951).

All the species under *Capsicum* are disomic in nature having same number of chromosomes of 2n = 24. Chilli plant is annual or biennial herbs or shrubs with simple leaves, axillary cyme type of inflorescence, regular bisexual flower, huypogynous overy. The colour of chilli flower under study is white to purple and flower encircled by the persistent calyx with rotated corolla. The anthers are blue to purple and 5 in number per flower. Seeds of chilli are pale yellow and flat. Fruits are small pod like berries with variable shape size and colour.

In tropical and subtropical region with a warm humid climate *Capsicum* sp. are widely grown. Although the chilli plant can tolerate extreme of climate better than tomato and bringal, but it cannot bear long frost and dies at freezing temperature. Generally, it requires a temperature of 20 – 25^{0}C. Unfavourable temperature and water supply are the basic reasons for bud blossom and fruit drops. Chilli can be grown from the sea level upto an altitude of 6,000 ft. or more in the tropics and also grown as a rain-fed crop with a rainfall of 25"-50" (inch). Heavy rainfall causes poor fruit-set and rotting of the fruits. Water logging even for a short time, causes leaf shedding. Light loamy soil, rich in lime in the best for its cultivation, but it can be grown on a type of soils if it is well drained.

Chilli is widely cultivated in different parts of Bangladesh. The important part of chilli plant is the fruit, which is used as spice and condiment by most of the people in our country. The pungency of chillies is due to the presence of an alkaloid, capsaicin ($C_{18}N_{27}NO_3$, Thresh, 1976; Nelson, 1910), the decylinic acid which is a derivative of vanillylammine present in the placenta. Purseglove (1968) referred that green chillies contain about 83% moisture, 0.6% fat, 1.5 – 3% protein, 6% carbohydrates and 7% fibre. He also reported that chili fruits are rich sources of vitamin-C and *Capsicum annuum* contains 50 – 280mg per 100 gm of ascorbic acid. The green chilli stands third position among all the fruit and vegetables in containing vitamin-C (Anon, 1980). On the average green chilli contains vitamin-C 33.45 mg/100 gm and ripe chilli contains vitamin-C 23.57 mg/100, protein 0.85 mg/100 gm and β-carotene 450.61 mg/100 gm (Khaleque *et al.* 1991). However, *C. frutescens* contain 2-50 mg/100gm of ascorbic acid (cf. Purseglove, 1968). Chilli fruit also contain vitamin B complex and 11.20mg/100 gm calcium (Pushti Barta Sankalan, 1980).

For the normal growth of body to regulate the normal function of the brain and to prevent many diseases, human being has to take protein, vitamin-C, calcium, β-carotene to some extent in their daily diets. In a report, more than 44% people of the country suffering from malnutrition which may be to deficiency in protein, vitamin-C, calcium and β-carotene in their daily diets. Not only people of this country, but also people of other poverty stricken areas like Africa suffer from malnutrition due to protein, vitamin-C, calcium and β-carotene. Non pungent large, green *C. auunnm* L. are rich in those nutrients and may likely add protein, vitamin-C, calcium and β-carotene to their daily diets and consequently suffering people can be relieved to some extent. But non-pungent, large chillies have not yet been developed in Bangladesh and people of the country, therefore, not able to get that type of chillies in their daily diets.

Chillies are used in green and dry form. Though it cannot be classified as food it gives an agreeable flavour and aroma to food and adds greatly pleasure to eating. It stimulates the appetite and increases the flow of the gastric juice. For this reason it is often referred as food accessories or adjuncts.

Sweet peppers have the mildest flavour with little pungency. They are eaten raw in salad and cooked in various ways. But on the other hand *Capsicum frutescens* contains more capsaicin than *Capsicum annuum* L.

Pepper is also used in medicine, particularly used as powerful stimulant and carminative and to prevent fever internally and counter irritant externally. It is not only used in human medicine but also used in veterinary.

Recently, pepper is grown in most of the country throughout the world except the colder region. Chilli as it is a cash crop, it has also a great demand in the international market. Bangladesh could earn foreign exchange out of this crop if it be exported (Ahmed, 1969 and Rashid, 1976). But it is a matter of regret that the production of this crop in Bangladesh is not enough to meet the internal demand of the country, and to meet this shortage, a large quantity of this crop is to be imported every year (Rashid, 1976).

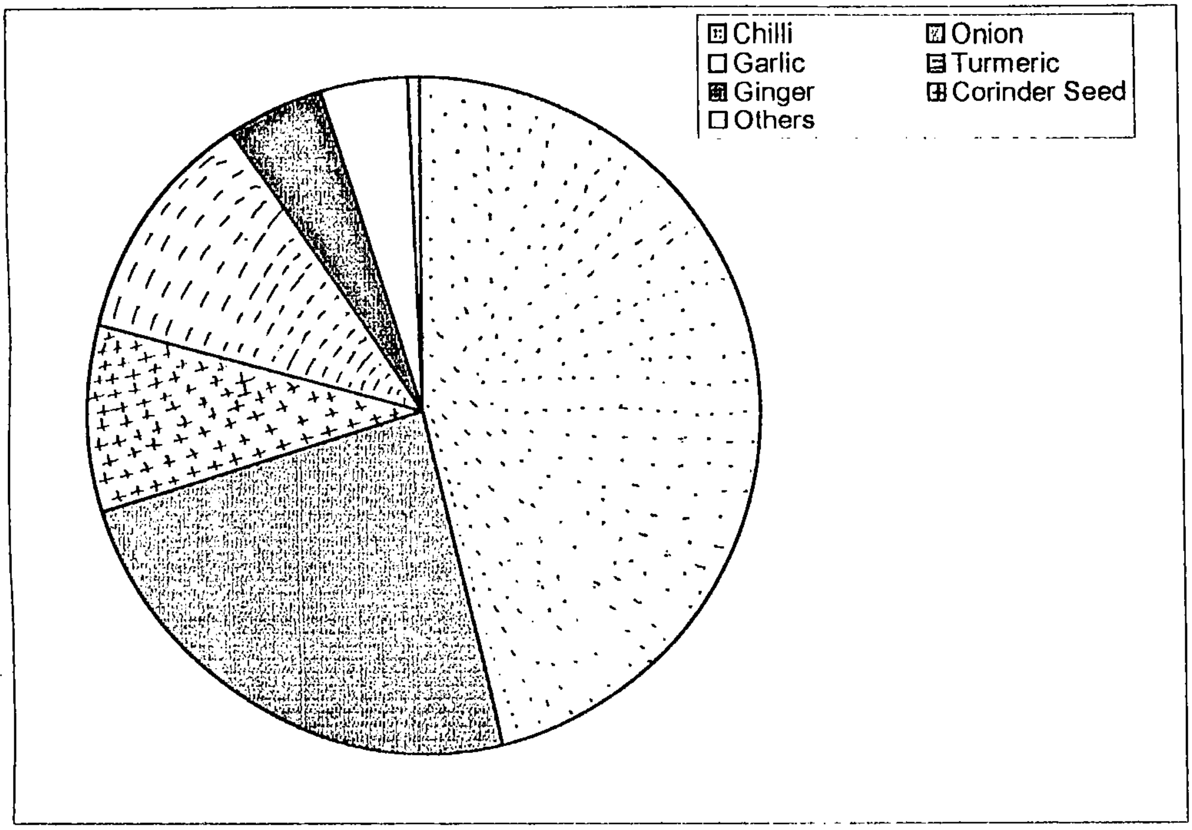
Such an important crop (chilli) is cultivated in very much neglected way and very little works have been done for its improvement in our country. Therefore, per acre yield of this crop is very low. A pie chart showing relative area of chilli cultivation with other spices and a bar diagram showing area in respect of production of chilli by the year 1994 – 2001 are given in the figure 1 and 2, respectively.

In our country this crop is cultivated in a very much-neglected way and per acre yield is as low as 250 lb. only. Many people of our country suffer from malnutrition. So, increase in yield by improving the characters of interest through genetic research will thereby increase in production in chilli crop, which will ultimately increase the total nutrient supply to the people. This to some extent is likely to minimize malnutrition from the people, which is of utmost national need and interest.

That is why, extensive research endeavors should immediately be taken for the improvement of per acre yield of chilli.

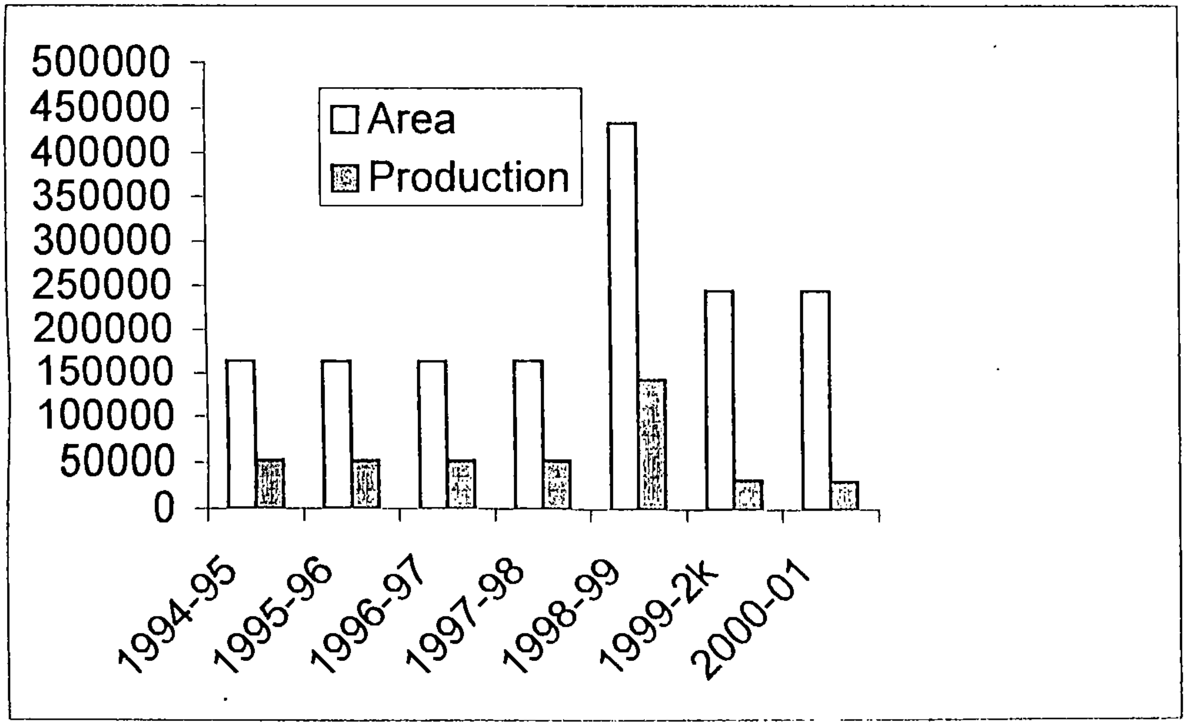
All the varieties under study have the same number of chromosomes (2n = 24). But they differ from one to another due to major and polygenes they possessed. Most of the characters of the chilli plant are quantitative in nature and under polygenic in action. Polygenes are alike in action and small in effects (i.e. non-specific action) than that of major genes. It is affected by the environment where the plants are grown. So the phenotype of a character of plant is contribution of both the genotypic and environmental effects. A gene of small and non-specific effect can be handled by familiar techniques of Mendelian genetics if obscuring effects of segregation of other genes is removed by suitable breeding techniques, non-heritable variation is reduced as far as possible by regorous control of the environment. Technique to detect the effect of small and non-specific genes is demanding and biometrical analysis provides such method. It covers all

Figure 1: Pie chart showing relative area of chilli cultivation with other spices crops.



Source: Statistical Bulletin (Bangladesh Bureau of Bangladesh).

Figure 2: Bar diagram showing area in respect of production of chilli by the year 1994 – 2001



Source: Statistical Bulletin (Bangladesh Bureau of Bangladesh).

the genes contributing to the variation in the chosen character. Several statistical methods have been developed for the study of the inheritance of quantitative characters were not understood until genetical assumptions and biometrical methods developed in the early days of this century were brought together. The genetic studies of continuous variation got their impetus with the advent of pure line theory put forward by Johansen, 1903.

Environment plays a great role on the plant as well as expression of its characters. Now a day, chilli is grown in various parts of the globe. Having the different environmental condition of different region of the world, study of stability (if any) over the different environmental condition of chilli pepper is very logical. World wide recognised as spice crop and rich source of vitamin-C, protein etc the chilli plant under *C. annuum* with seven varieties were under taken to find out its stable quality. And the present investigation was carried out in two sections:

a. Anther culture (Callus induction through anther)
b. Comparison of G×E models for selection of stable genotype of this crop.
    i) Study of Variability
    ii) Study of Stability parameters.

SECTION ONE

Study of the Anther Culture

INTRODUCTION

In genetic and plant breeding research, improvement of crop is very important. In crop improvement, pure line genotypes are important as well. Naturally originated pure line genotypes take much time. Pure line formation is natural tendency for self-fertilizing species and can be obtained with cross-fertilizing species with repeated inbreeding for ten or more generations. Actually it is a time consuming, troublesome and laborious process. Anthers, containing single set of parent chromosome cell, can give the solution of this situation.

Anther culture (androgenesis i.e. the development of haploid plants derived from anther and microspore culture), to generate haploid plants from pollen microspores, is one way to shorten this process. It allows novel allele combinations, particularly ones involving recessive characters, to be assessed in intact plants. Useful individuals can then be developed into homozygous and fertile plants through chromosome doubling techniques, and brought into a breeding programme.

Anthers containing immature pollen (microspores) are the starting materials for androgenesis. Flowers have to be selected at the correct developmental stage, which varies from species to species. In addition, some individual genotypes may not be amenable to anther culture, or require specific pretreatment. Careful microscopy and testing of successful pre-treatments of related species are therefore necessary when dealing with a new species.

Since the development of modern plant breeding techniques during the last two decades, rapid progress has been carried out in haploid production by means of *in vitro* culture of male gametes (Bajaj 1990). The main advantage of using haploids is the rapid homozygosity of the descendants, it is a time saving, procedure for the development of new varieties. Homozygous lines were established through spontaneous chromosome doubling during early stages of *in vitro* culture or through colchicine induced chromosome doubling of haploids. Traditionally, plant breeders can achieve homozygosity by using the self-fertilizition, a time consuming process (Morrison and Evans 1988).

Chilli plant is half self-pollinated and being the genetically complex, anther culture is adopted for the plant. Callus induction through anther culture is under the present study as the 1st step to meet the production of haploid induction of chilli plants.

Haploids may be grouped into two broad categories: i) monoploids i.e. monohaploids- which possess half the number of chromosomes from a diploid species, and ii) polyhaploids (gametophytic set) – which possess half the number of chromosomes from a polyploid species. However, the general term 'haploid' is applied to any plant originating from a sporophyte and containing half the number of chromosome i.e.single set of chromosomes (Islam *et al.* 2001).

The development of haploid plants derived from immature pollen or microspore (anther or microspore culture) is termed as androgenesis (Islam *et al.* 2001). Since the discovery by Guha and Maheshwary (1964, 1966) the immature pollen could be induced to bypass normal developnment within the anther and the production of haploid plants, first realized in *Datura innoxia* Mill. Considerable efforts have been made to extend the technique to other species. In some species it is possible to produce haploids through the culture of isolated microspores (Killer *et al.* 1987).

Through androgenesis new varieties have been developed in a number of agricultural crops such as *Brassica* sp., tobacco, potato, asparagus, wheat, rice, maize, barly etc. (Bajaj 1990).

Being the delicate and sensitive method anther culture is closely related with some factors and they are predominantly determine the success of culture, e.g. i) genotype dependency (Schaeffer *et al.* 1979; Lazar *et al.* 1984; Barnabas *et al.* 1989); ii) donor plants growth conditions (Bajaj 1983; Schmid and Keller 1986); iii) stage of microspore and anther development (Wenzel and Foroughi-Wehr 1984; Dunwell 1986; He and Ouyang 1984); iv) pretreatment of anthers (Schmid 1990; Picard and De Buyser 1975; Pan *et al.* 1975 Hu 1986) and v) culture media (Chuang *et al.* 1978; Chu 1978; Wang and Hu 1984; Fadel and Wenzel 1990). However, under present investigation effort has been performed on the development of methods and protocol establish for production of haploids by anther in chilli.

Anther culture is the process of using anthers to culture haploid plantlets. Guha and Maheshwari discovered the technique in 1964. This technique can be used in over 200 species, including tomato, rice, tobacco, barley, and geranium. Some of the advantages, which make this a valuable method for obtaining haploid plants, are:

- the technique is fairly simple
- it is easy to induce cell division in the immature pollen cells in some species
- a large proportion of the anthers used in culture respond (induction frequency is high)
- haploid can be produced in large numbers very quickly.

A stable pure line plant, genetically homozygous, is defined as a true breeding line. Haploid plant provides beneficial tools for plant breeding and for genetic studies. Haploid production is attractive because it can only provide an opportunity to select at the haploid level *in vitro* for desirable agronomic traits and seed quality characteristic, but also to provide a means of producing genetically stable homozygous lines, fixed by chromosome doubling (Kott and Beversdorf 1990). Having only one set of alleles of parent's genes at each locus, recessive genes or mutants can be detected as they express in absence of dominant genes. The recessive traits are easily expressed at the haploid level, which facilitates the *in vitro* selection of recessive monogenic mutants, and is valuable for mutation breeding (Attanasov *et al.* 1995).

The genetical analysis through conventional method is difficult in chilli, because inheritance pattern in this crop is obscured due to the presence of non-allelic interaction and linkage. To get rid of this situation, therefore, haploid plants need to develop through anther culture. That is why the protocol establishment for callus induction from anthers of chilli plants and further regeneration were done to meet the situation.

REVIEW OF LITERATURE

Literatures in respect of anther culture are scanty. In fact, reports on anther culture in chilli so far are not available. A few number of papers have been published dealing with the problem of anther culture in different crops. A brief review of the anther culture therefore, are made in different crops and are given below.

In an experiment of pollen of Gymnosperm, Talecke (1963) first observed that mature pollen grains of the *Ginkgo biloba* could be induced to form a haploid callus following culture on a suitable medium.

Guha and Maheshwari (1966) reported callus could be induced from pollen grain of Angiosperms. They described that repeated divisions of cultured pollen grains of angiosperms. They were working experiments with cultured pollen grains of *Datura innoxia* Mill. in order to determine the feasibility of this system for the study of factors regulating meiosis. Finally, they stained the plantlets, which were developed through the mature anther culture with acetocarmine and confirmed that each planlet contains only a single set of chromosomes. Actually they were the torchbearers of the anther culture of angiosperm to raise haploid plants.

Tanaka and Nakata (1969) made an experiment with anther culture in tobacco plant. They raised haploid plant and diploid seeds from haploids.

Bhojwani (1987) reported the rules and some valuable suggestion for the technique of anther culture in his experiment of tissue culture methods for haploid production. He cited that different factors affect the androgenesis (anther culture or haploid production). He described the factors affecting the technique of anther culture as donor plant, stage of pollen development, pre-treatment of buds or anthers, genotypic effect, culture medium etc. He also noted some limitations of anther culture in his work.

Karim *et al.* (1991) made an experiment on improved media for callus induction from anther culture of indica rice (*Oriza sativa* L.). In the experiment, they used four improved (Z1, Z2, Z3 and P3) and two original (B5 and P1) media for find out the efficiency of media in callus induction from the anthers of indica rice. They found efficiency of Z2 was higher that that of either B5 or Z1. They also reported that there was a differential response of varieties indicating variable requirment of media ingredients for different cultivars in the experiment. They noticed that liquid media were more efficient ofr callus formation of rice anther than semi-solid medium with same components. They showed liquid Z1 produced a mean of 1.24 calli/anther compared to 0.29 calli/anther in B5 and 0.74 calli/anther in Z3 and they decided on the basis of their result, Z2, Z3 and P3 media could be used for efficient callus induction of indica varieties of rice.

Sandhu *et al.* (1993) conducted an experiment on callus induction and plant regeneration from cultured anthers of indica rice varieties. They used anther-containing pollen at late uninucleate stage, from cold pretreated panicles at 4–5^{0}C for 7 days for the culture. They selected three varieties *viz.* Jaya, IR 54 and Vaigai for culutre. The three varieties were cultured on N_6 medium supplemented with various combinations and concentrations of auxixs, cytokinins ans sucrose by them. They showed that N_6 medium containing 2,4-D (1.75 mg/l), Kn (0.5 mg/l), sucrose (3% w/v) was the best medium, in which best callus was formed ranging from 1.75 % in Jaya to 2.25 % in IR 54. Obtained calli were transferred to N_6 medium supplemented with BAP (0.5 mg/l) and sucrose (4.5% w/v) by them and calli differentiated into shoots ranging from 15% in Jaya to 24% in IR 54.

Karim *et al.* (1993) made an experiment with rice anther culture supplying mannitol and proline. They applied mannitol at the rate of 0.05, 0.1, 0.15 and 0.20M to the medium of anther culture induction. They noticed that with the increase of mannitol concentration decrease the callus induction. In case of mannitol, they also added, at 0.15M treatment green plant regeneration was occurred in increasing number. They apply proline (up to 0.08mM) to post-induction of callus and observed that increased regeneration of green plants.

Das *et al.* (1994) made an experiment with maize (*Zea mays* L.) anther. They described that anthers of 12 different cross varieties of maize were cultured on 6N1 medium supplemented with three levels of TIBA or without TIBA towards the formation of embryoids or callus. Obtained embryoids were then cultured on 6N1 and MS media for their differentiation into plantlets. They also reported that out of twelve crosses, ten crosses responded towards the formation of embryoids and five of them produced differentiated into plantlets. In 0.1 mg/l TIBA, they got the highest frequency of embryoids. They achieved maximum plantlets on 6N1 + 0.1 mg/l TIBA medium from the regeneration of embryoids they studied and they also got plantlets on 6N1 + 1.0 mg/l Kn.

Hossain *et al.* (1995) conducted an experiment on anther culture in *Lolium perenne* L. They reported that more than 400-anther culture developed double haploid progeny. These progenies were derived from eight families and progenies were evaluated for the ploid level, genetic variation at isozime loci and performance at field level. They described that 76% of the total progeny showed diploid form (2n = 14), diploidization were different from family to family. They examined the segregation of the families at eight isozyme loci and level of heterozygosity was low for all. In their experiment, they said, though all plants were grew under controlled conditions not a single survived in the extreme environmental conditions of the winter.

Mandal and Gupta (1995) performed an experiment with anther culture in rice. Anthers were taken from an interspecific hybrid between *Oryza sativa* L. cv. Pankaj×*O. rufipogon* Griff. (both of them having 'AA' genome) by them to obtain submergence tolerant high yielding recombinant type. They used five basal media *viz.* N6, modified N6, R3, He2 and He5, each supplemented with NAA (2 mg/l), Kn (1 mg/l) and sucrose (5%). They got highest callus with the rate of 8.3% in He2 medium. Further, they made regeneration of the callus in medium (MS medium containing 0.5 mg/l NAA; 2 mg/l Kn and sucrose 3 gm/l) and observed 13% (highest) green plant regenerate in He2 medium. They also observed that androgenic double haploid plants made 1:1 segregation of the traits for most of the morphological characters whereas, in F_2 population they got different segregation ratios.

Samad *et al.* (1996) worked on anther culture of some F_1 hybrids of rice. In their experiment they used anthers of F_1's of seven cross combinations between salt tolerant lines and high yielding rice varieties to attempt to induce callus and regeneration of green plants. They used Chaleff's R2 medium supplemented with 2.0 mg/l kinetin for callus induction. In their research, F_1 hybrids of the entire cross combinations produced calli with frequency ranging from 1.78 to 7.71 %. The highest frequency of callus formation was found in Binnatoa × BR9 combination. Plantlet regeneration was taken place in their experiment, when the calli were transferred to MS medium supplemented with 1.0 mg/l IAA + 1.0 mg/l kinetin. They also got the green and albino plants from the calli of Binnatoa × BR9, Pokkali×IR21015, IR5657×BR11 and IR21015×BR11. Maximum yield, in their experiment, of green plantlets was observed in Binnatoa × BR9.

Wijesekera *et al.* (1999) worked on tea (*Camellia sinensis* L.) with anther culture. They studied microsporogenesis in tea anthers to identify the uninucleate stage of microspore development for culture of anthers to induce haploids. They reported that tea flowers produce over 150 anthers depending from on the genotype. They studied the microsporogenesis from the pollen mother cell and correlated the different stages of microspore development with morphological parameters of the anther. They fixed the anthers of clone DG7 and TRI 2025 and stained them with iodine in potassium iodide and observed under a light microscope. They said that the stage of microporogenesis was associated with size and colour of the anther wall and .the uninucleate stage was indentified with anthers that were pale yellow to yellow in colour. Moreover, they cultured the anthers containing uninucleate stage in MS based medium following a heat at 34^0C for 2 to 4 days. After 4 to 6 weeks of incubation in the dark they get callus. They noticed that the tendency of anther filament to callus was high. and they suggested that before culture anther filament should be removed. In addition to this. they also added that root formation was taken place in isolated callus.

Khan *et al.* (1999) made an investigation with anther culture of papaya. They showed different media compositions and bud size has effect on anther culture. They reported that MS medium supplemented with NAA, Kn and other organic components along with different sizes of bud *viz.* 4, 6 and 8mm in length were used to study their effects on anther culture of papaya cv. 'Shahi'. They observed, MS supplemented with 1.0 mg/l NAA + 0.5 mg/l Kn + 400 mg/l glutamin (T_3) was found better in respect of survivability, change in colour and welling tendering for callus formation among different media used. They also reported, maximum swelling and colour change were observed on MS media supplemented with 1.0 mg/l NAA + 0.5 mg/l Kn + 160 mg/l adenine sulfate + 1g/l casein hydrolysate (T_8). From their work, they write down that among the different bud sizes. buds of 6 mm in length performed better and the treatment combination of T_3 ×6 mm bud was found to be the most suitable one.

Huda *et al.* (1999) worked on anther culture of chickpea (*Cicer arietinum* L.). They selected five varieties *viz.* Deshi, Nobin, ICCL-83105, ICCL-85222 AND RBH-228 for embryo induction and plantlet formation. They said anthers containing pollen at mid to late uninucleate stage of flower buds pretreated at 4^0C for 3 – 10 days were cultured on embryo induction medium. They revealed that Nobin and deshi produced embryos in AMS3 medium. Which was supplemented with maltose (90 g/l) instead of sucrose and 2,4-D (2.0 mg/l), Kn (0.5 mg/l), IAA (1.0 mg/l) and higher amount of amino acids: L-proline (500.0 mg/l), L-glutamine (500.0 mg/l), asparagine (100.0 mg/l) and glycin (2.0 mg/l). The induced embryos failed to germinate and deserving further efforts for their germination and plantlet formation.

Ahmed *et al.* (1999) conducted an experiment on anther culture in tomato (*Lycopersicon esculentum* Mill.) They took six genotypes for induction of callus namely, Momotaro, Manik, Dynamo, Epoch, Legend and Ventlsr. They collected anthers containing micropores at late uninucleate stage of flower buds and pretreated at 4^0C for 3 to 10 days and finally cultured them in MS medium. They reported that though variety Manik, Dynamo and Epoch produced callus in MS medium, but out of six genotypes Dynamo and Epoch produced callus most successfully when grown in dark on MS medium supplemented with sucrose (30 g/l), agar (5 g/l) and 2, 4-D (2.0 mg/l) + 6-BA (1.5 mg/l) and Kn (2.0 mg/l) + NAA (1.0 mg/l). They also added, the genotype Dynamo produced highest per cent of callus on MS medium supplemented with 2, 4-D (2.0 mg/l) + 6-BA (1.5 mg/l).

Raj *et al.*(1999) performed a work on anther culture with submergence tolerant lines of rice. To obtain submergence tolerant high yielding recombinant types through anther culture they selected intervarietal F_1 hybrids (*Oryza sativa* var. Pankaj × FR-13A and Mahsuri × FR-13A) in their experiment. They noticed that among the different types of mediua used, N6 medium supplemented with 2.0 mg/l NAA and 0.5 mg/l Kn show better responses for callusing (4.6%). They got green plants from the callus obtained when the calli were transferred to MS supplemented with 0.5 mg/l NAA and 2.0 mg/l Kn.

Rangasmy (1999) conducted an experiment on anther culture and its application in crop improvement. He made a comparative study between anther-derived plants and segregating F_2 population of a cross of *indica* × *japonica* rice varieties (Oozora × Vaigai). He noticed that plant derived from anther showed significant qualitative and quantitative features like, high mean values of yield and yield-related traits, increased grain fertility and fixation of heterosis. He described that A_2 generation's frequency distribution, extent of variability and genetic advance were greater than the F_2's (F_2 plants, which were obtained from hybrid CSH-5). Compared to the F_2's, recessive gene was pronounced in

A_2 generation, indicating that from A_2 generation a greater number of plants can be selected for economic traits. He also performed induction of embryogenic calli and somatic embryoids of n and 2n in a series of indica/ indica and indica/japonica crosses.

Mandal and Maiti (1999) performed an experiment on anther culture response in rice. In their experiment, they used various biological and physico-chemical factors. They showed that two strains *viz.*IRGC 10798 and IRGC 77103, under the same variety SR26-B have differential abilities of callus induction and further regeneration (i.e. plantlet formation). They proved from their results that in anther culture genotype has strong effects. In their another experiment they showed 100-800 mg/l yeast extract as an organic adjuvant, 100 mg/l formed maximum callusing and plant regeneration. They reported 200-mg/l casein hydrolysate (CH) also encouraged callusing in the same variety and they got maximum green plantlet regeneration in control. They also reported that with the increase of CH concentration beyond 100 mg/l exerted negative response when correlated with regeneration percentage. They added that supply of mannitol (as an osmoticum) @ of 100 mg/l induced maximum formation of androgenic calli and regenerants. In comparison of carbon source they noticed that 6% sucrose was found to be better than maltose and sucrose-maltose combinations on morphogenesis of androgenic calli in hybrids of IR8 × CR 644 and BW 311-2 × IR 52713-B-B-8-8-1-2.

Islam *et al.* (2001) conducted in vitro plant regeneration through anther culture of eight wheat varieties. They cultured per-treated anthers containing uninucleate microspores of eight varieties of wheat (*Triticum aestivum* L.) in four media for callus induction. On the basis of anther response, embryo induction, embryo regeneration and production of green and albino plants they estimated the regeneration potentials of the eight varieties. They reported that out of eight only three varieties gave embryos on medium in which high levels of specific amino acids. Variety Barkat produced both embryos and green planlets at the highest frequency followed by Kanchan and pavon 76 and all the responding genotypes also produced albino plants with the green ones, they added. They also observed that three to five days pre-treated anthers formed highest frequency of embryos and green plantlets also. They reported, cold pre-treated anthers (responding genotypes) showed better induction than the control and a three days duration of pre-treatment was most effective and significantly different in comparison to the other treatments and control.

MATERIALS AND METHODS

A. *MATERIALS:*

The young or immature flowers were the materials to perform the callus induction through anther culture technique.

1. Explants:

Anthers of the seven varieties of chilli namely, *abbreviatum, annumm, acuminatum, acuminatum, nigra, conoides, cerasiformis* and *fasciculatum*, containing uninucleate stage were the raw materials.

2. Basal Nutrient Media:

In this investigation MS and ½ MS (see appendix) medium were used for callus induction and proliferation, which is followed by plant regeneration. The compositions of the media are listed in Table 1&2. All the media were solidified with agar.

3. Growth Regulators:

The following growth regulators were used in the present investigation.

Auxins such as: 2,4-Dichlorophenoxy acetic acid (2,4-D), Indol-3 butyric acid (IBA), ∝-Napthalene acetic acid (NAA).

Cytokinin such as: 6- Benzylaminopurin (BAP), Kinetin (Kin).

4. Sterilizing Agents:

In the present study 100% alcohol, 0.1% $HgCl_2$, 0.05% $HgCl_2$, 0.025% $HgCl_2$ were used as sterilizing agents.

5. Chemical Compounds:

Macro and micro nutrients, vitamins, sugar, agar and alcohol of 75%, 80%, 95% and 100% were used as chemical compounds in this study.

6. Others:

Macro and micronutrients, sugar, agar and alcohol of 95% 100% etc. were used as chemical compounds. Besides these, culture container such as petridishes (9cm× 1.5cm), callus and regenerating vessels like test tubes, conical flasks (250ml, 500ml, 1000ml), measuring cylinder, separating funnel, parafilm, aluminum foil, pipette, forceps, cotton, fire box, marker pen, sprit lamp, needle, sharp blade, electronic balance, pH meter, autoclave machine, laminar air flow machine etc. were also used in the study.

In tissue culture technique plants are regenerated inside test tubes, conical flask, petridishes and in other glass vessels. Therefore, it is required to create a suitable environment (which may be termed as microenvironment) inside those glass vessels, so that the plants propagated inside may have suitable support to stand erect and get sufficient of O_2 and CO_2 for respiration and photosynthesis, respectively.

B. ***METHODS:***

The *in vitro* regeneration of plant is a specialized skillful job and some special methods are required for this technique. The methods involved in the present tissue culture investigation are described under the following sub-headings:

1. Preparation of Stock Solution:

Different stock solutions were prepared as the first step for the preparation of medium. The various constituents of the medium were prepared as stock solutions to use them during the preparation of the medium. As different constituents were required in different concentrations, separate stock solutions for macronutrients, micronutrients, vitamins, plant growth regulators, etc were prepared.

a). *Stock Solution A (macronutrients):*

This stock solution was made in such a way that its strength become 10 times more than the final strength of the medium in 500ml water. For this purpose, 10 times the weight of different salts required for 1 litre of medium was weighted accurately. Then salts were sequentially dissolved one after another in a 500 ml volumetric flask with 350 ml of distilled water. The final volume of the solution was made up to make it 500 ml by further addition of distilled water. The solution was filtered through Whatman's No. 1 filter paper to remove all the solid contaminants like the dust, cotton etc. and was poured into a clean plastic container. After labeling, the solution was stored in a refrigerator at 4^{0}C for several weeks.

b). Stock Solution B (micronutrients):

For this constituent of the medium two separate stock solutions were prepared:

(i) This part of the stock solution was made with the micronutrients except $FeSo_4.7H_2O$ and Na_2-EDTA. It was made 100 times the final strength of necessary components in 500ml of distilled water as described for the stock solution A. The solution was filtered and stored at 4^o C for several weeks.

(ii) The second solution was also made 100 times the final strength of $FeSo_4$. $7H_2O$ and Na_2-EDTA in 500 ml distilled water in conical flask and heated slowly at low temperature until the salts dissolved completely. Finally the solution was filtered and stored in refrigerator at 4^oC for several weeks.

c). Stock Solution C (vitamins):

Stock solution C was also made 100 times the final strength of the medium in 500 ml of distilled water as described for stock solution A. The solution was also filtered and stored at 4^oC for several weeks.

d). Stock Solutions for Growth Regulators:

The following different growth regulators and supplements were used in the present investigation:

1. AUXINS

2,4-Dichlorophenoxy acetic acid (2,4-D)

α-Naphthalene acetic acid (NAA)

2. CYTOKYNINE

6-Benzale amino purine (BAP)

6-Furfural amino purine (KIN)

The growth regulators and additive were dissolved in appropriate solvent as shown against each of them (following the Sigma Plant Cell Culture Catalogue, 1992).

Growth Regulators (Solutions)	Solvents
HORMONE	
NAA	1N NaOH
2,4-D	70% ethyl alcohol
BAP	1N NaOH
KN	1N NaOH

To prepare any one of the previously mentioned hormonal stock solution 10 mg of the hormone was placed on a clean plastic weighing boat and dissolved in 1 or 2 ml of particular solvent. The mixture was then washed off with distilled water and collected in a 100 ml measuring cylinder. It was then made up to 100 ml with the addition of distilled water. The solution was then filtered, poured into a clean plastic container and stored in a refrigerator at 4°C for up to several weeks.

To prepare 0.1-mg/ml stock solution for BAP, 10 mg BAP was taken in a clean test tube and dissolved with IN NaOH. The mixture was then washed off separately with distilled water and collected separately in a 100 ml-measuring cylinder. It was then made up to 100 ml with the addition of distilled water. The two solutions were then filtered and stored separately in refrigerator at 4°C for up to several weeks.

2. Preparation of one litre medium:

To prepare one litre of medium, the following steps were followed:

i). For the preparation of desired medium (MS) 30g of sucrose was dissolved in 500 ml of distilled water in a 1 litre volumetric flask.

ii). 50 ml of stock solution A, 5 ml of stock solution B and 5 ml of stock solution C were added to this 500 ml distilled water and mixed up well.

iii). 100 mg of inositol was added to this solution and dissolved completely.

iv). Different required concentrations of hormonal supplements were added to this solution either individually or in combinations and were mixed thoroughly with the help of magnetic stirrer. Since each of the hormonal stock solutions contained 20g of the chemicals in 200ml solution, further 10 ml of any hormonal solution was supplemented. Different concentrations of the hormonal supplements were prepared by adding required amount of the stock solution to the medium following the similar procedure described earlier.

v). The whole mixture was then made up to 1 liter with further addition of distilled water.

vii). pH of the medium was adjusted to 5.8 with a digital p^H meter with the help of 1N NaOH or 1N HCI, whichever was necessary.

viii). To prepare solid medium, 8 gm (at 0.8%) of Sigma brand bacto- agar was added to the medium and to dissolve the agar quickly the whole mixture was heated in a microwave oven.

ix). Sterilization: Fixed volume of hot medium was dispensed into culture vessels i.e. test tubes or conical flasks. The culture vessels were plugged with absorbent cotton and marked with the help of a glass marker to indicate specific hormonal supplement. The culture vessels were then autoclaved at 15-lb/(inch)^2 pressure at 121°C for 20 minutes. In case of test tubes, the medium was allowed to cool as slants after sterilization.

3. Formulation of Culture Medium:

Preparation of stock solution is the first step of culture media preparation. The various constituents of media were prepared into stock solution for ready use during the preparation of medium. The compositions of stock solution are presented in Table 2. Besides to the culture medium, the following chemicals were used where necessary.

a). Addition of growth regulators: Stock solution of growth regulators was added in appropriate concentrations and combinations in above solutions and was mixed well.

b). pH of the medium : pH is the another factor of the medium for callus induction of plants and its parts. In all experimental medium, pH was adjusted to 5.8 – 5.9 using pH meter, with the help of 0.1N HCl or 0.1N KOH (where necessary) before addition of sugar.

c). Carbon Sources: Sucrose was used as the source of carbon.

d). Agar: For solidification of medium agar was used at the rate of 6g/l.

e). Sterilization: Finally the culture petridishes containing medium were autoclaved at 15-lb/(inch)^2 pressure at 121^0 C temperature for 20 minutes to ensure sterilization. Then the petridishes with the medium were allowed to cool and then marked with a glass marker pen to indicate specific hormonal supplementations and stored in the culture room for ready use. Another technique was followed such as all petridishes, conical flask (which also contain medium), forceps, tiles, distilled water container (conical flask) and other necessary things were autoclaved at 121^{0}C for 20 minutes. Then petridishes were carefully opened in the laminar airflow machine and medium was poured in the bottom plate from the conical flask. After being cooled, the petridishes were covered with respective lids. Then every petridish was sealed with the parafilm. Finally, every petridish was marked with a marker pen and stored in the growth chamber for ready use.

4. Search for Uninucleate Stage Containing Anthers:

The following method was used to find out the uninucleate stage containing anthers.
At first, glacial acetic acid and 70% alcohol were mixed up in ratio of 1:3 for fixation of collecting buds or immature flowers and cytological study was done to observe the anthers containing uninucleate cells.

Then buds or immature flowers were washed in running water for 5 – 10 minutes and rinsed with distilled water repeatedly.

In the third step, buds or immature flowers were dissected carefully with the help of a needle.

Then, one to two anthers getting from the same bud of a specific variety were forcedly burst in a drop of 0.5% acetocarmin taken on a slide, and the cells (those were in the anthers) came out. After removing the derbies (i.e. anther wall and others) a cover slip was set on the acetocarmin containing the anthers materials.

At last, under a compound microscope the slide was examined and the rest of the anthers removing from the buds were measured with the help of a compound microscope possessing a mm scale.

5. Culture Technique for Callus Induction:

The following culture techniques were adopted for primary establishment of callus formation.

a). *Plant Growing and Raising:*

Seeds of the above mentioned seven varieties of chilli were sown in earthen pots. Then the germinated seedlings were transplanted in the well-ploughed field.

b). *Explants Collection:*

Flower buds or very immature flowers were collected with the twigs from mother plants.

c). Cold Treatment:

For the anther culture, cold treatment is necessary. After collecting the twigs bearing flower buds of different size were fasten with polyethylene bag. All twigs were put in beaker containing water in such a way that the lower portions of twigs are dipped in water.

With the twig, beakers were then placed in refrigerator whose serving temperature was maintained at 7^0 to at 10^0C for a period of 48 hours.

6. Other Steps of Anther Culture Procedure used in the Present Study:

a). *Buds taken into laminar air flow cabinet*	:	i) After completion of 48 hours period of cold treatment twigs containing flower buds were taken out from the refrigerator and flowers buds were detached from their twigs. Buds were then taken in the laminar air flow cabinet ii) Some times fresh buds (just after plucking from the mother plants) were taken into the laminar airflow cabinet.
b) *Sterilization*	:	i) After taking the young buds into the laminar airflow cabinet, buds were treated with 100% alcohol for one to 5 minutes. In another time, 0.1% and 0.05% mercuric chloride solution for 1 – 2 minutes. ii) Buds were washed with 100% alcohol for surface sterilization in the laminar airflow cabinet. After washing the buds, anthers were removed using a fine tweezers (forceps). Fresh anthers were then treated with 0.05% mercuric chloride solution for 30 seconds to one minute and sometimes with 90% alcohol for 1 – 2 minutes. iii) Fresh anthers were also treated with 0.025% mercuric chloride for 1 – 2 minutes and with 70% alcohol for 1 – 3 minutes.

c) *Culture or Inoculation of anthers* : Following the above sterilization methods, treated anthers were inoculated on culture medium.

a) One hundred to two hundred anthers were plated in medium containing petridish.

b) Same numbers of anthers were placed on a paper bridge in the test tubes containing medium (i.e. medium without any agar).

c) 50 – 100 anthers were plated on the semisolid medium in the test tubes.

d) *Incubation of anthers* : Petridishes or test tubes containing inoculated anthers were then incubated at $27^0 - 28^0C$ chamber in a dark box for 3 – 4 weeks for callus induction.

7. Symbols Used for Callus Induction:

Cultured explants, which showed callus formation, were counted after four weeks of culture. The colour, nature, physical conditions and degree of growth of callus were varied. So, different symbols were used to denote their colour, nature and degree of growth as given below:

a). Colour of callus was marked according to the following symbols.

b). Nature of callus was marked by the following symbols.

COLOUR OF CALLUS	SYMBOLS	NATURE OF CALLUS	SYMBOLS
White	W	Friable	Fr.

c.) Degree of callus formation was marked by the following symbols

Description of callus formation	Symbols
Slight growth	+

8. Formula Used for Callus Induction:

Explants were cultured in petridish containing medium with different concentration of growth regulators for callus formation. After required days of culture, frequency of callus induction was calculated using the following formula.

$$\text{Frequency of callus induced (\%)} = \frac{\text{Total Number of Calluses}}{\text{Total Number of Anthers}} \times 100$$

RESULTS

The response of seven varieties, namely *abbreviatum*, *annumm*, *acuminatum*, *nigra*, *conoides*, *cerasiformes* and *fasciculatum* were investigated for callus induction by using immature flower buds. The inoculated anthers were examined at every 2 – 7 intervals from the time of inoculation and after 3 – 4 weeks some responses were observed. Details of the results under this section so far obtained from each of the experiments is being described under the following sub-heads:

A. *CALLUS FORMATION*

After three to four weeks of inoculation, some masses of irregular and unorganized cells appeared on some anthers (Plate 1 & 2).

B. *DETERMINATION OF SUITABLE MEDIUM FOR CALLUS INDUCTION*

The culture medium is an important factor on which anthers as well as different explants are cultured. Macro, micro, organic, inorganic substances, sucrose etc (main elements of basic medium) are equally needed for all types of plants and/or plant parts. To select a suitable basic medium for calli induction MS (Murashige and Skoog 1962) and ½ MS (locally modified medium) media with different supplements and hormonal concentrations with different combinations were used. Experiment was conducted to obtain embryogenic callus in both MS and in ½ MS. Among the media used, MS basal medium was found to be better for callus initiation (Table 1).

C. *EFFECT OF DIFFERENT HORMONAL AND OTHER SUPPLEMENTS ON MS & ½ MS FOR CALLUS INDUCTION*

Different kinds of cytokinins, namely BAP, KN and auxins like NAA, 2,4-D were separately or combinedly used in this experiment as hormonal or growth regulators. The effect of different concentrations of 2,4-D (from 0.2 – 3.5) mg/l, BAP (from 0.1 – 3.0) mg/l, NAA (from 0.1 – 1.5) mg/l and Kn (from 0.1 – 1.0) mg/l on callus induction from anther of seven varieties of chilli, namely *abbreviatum*, *annumm*, *acuminatum*, *nigra*, *conoides*, *cerasiformes* and *fasciculatum* were observed.

The qualitative response of the anthers towards callus was observed in presence of 2,4-D in MS and in ½ MS. Calli were formed and increased their size within 10 – 20 days in 2,4-D, whereas it was noticed that another hormone except 2,4-D were far from the same result. Although calli were also formed in other hormone but their size were remain unchanged. In medium all calli were whitish in colour, watery and soft in nature (Plate 1 & 2).

D. *EFFECT OF DONOR PLANT OR GENOTYPE IN CALLUS INDUCTION*

In the present investigation, it was noticed that all the seven genotypes i.e. donor plants (from where anthers were taken) did not equally respond in the same or different combinations of growth regulators (Figure 1).

The genotype *abbreviatum* responded and formed calli in MS basal medium containing 2,4-D 0.5mg/l + kn 0.1mg/l, NAA 0.3mg/l + BAP 0.1 mg/l, 2,4-D 0.4mg/l + kn 0.1mg/l, NAA 0.1mg/l + Kn o.1 mg/l and NAA 0.1 mg/l + 2,4-D 0.1 mg/l + BAP 0.2 mg/l in combination and in ½ MS basal medium with BAP 0.5 mg/l + NAA 2.5 mg/l + 2,4-D 2.5 mg/l and BAP 0.5 mg/l + kn 0.5 mg/l + NAA 1.0 mg/l + 2,4-D 2.5 mg/l in combination (Table 2).

The genotype *annumm* responded and formed callus in MS medium with 2,4-D 0.5 mg/l + 0.1mg/l Kn; NAA 0.3mg/l + BA P 0.1mg/l; 2,4-D 0.4mg/l + Kn 0.1mg/l; NAA 0.1mg/l +2,4-D 0.1mg/l + BAP 0.2mg/l in combination (Table 3).

The variety *fasciculatum* responded with MS medium containing 2,4-D 0.5 mg/l + 0.1mg/l Kn and NAA 0.1mg/l +2,4-D 0.1mg/l + BAP 0.2mg/l hormones in combinations (Table 4).

Rest of the genotypes under study responded only in MS medium containing NAA 0.1mg/l +2,4-D 0.1mg/l + BAP 0.2mg/l hormones in combination (Table 5).

E. *EFFECT OF PRE-COLD TREATMENT*

In the experiment of callus induction protocol set up, explants or anthers were cultured in two different was to obtain callus. In the first way, fresh anthers (just after collecting from the donor plants) were inoculated and in the second way, low-temperature pretreatment of anthers from a period of 24 – 48 hours at temperatures of 7 – 8^{0}C were inoculated for callus induction. Only low temperature pretreated or cold treated anthers responded and formed callus. It was noticed that the effect of pre cold treatment on callus induction was observed.

F. *EFFECT OF AGE AND STAGES OF ANTHERS*

The effect of age of the plants from which the anthers were taken and the stage of anthers of the seven varieties of chilli under study were observed. The anthers taken from flowers produced during the early stage of the flowering showed better response whereas, anthers taken from the older plants showed less response.

The anther culture is to be done to obtain haploid plants. So, the particular stage of anther is necessary for inoculation. The cells in the anther come from just after 1st meiotic division (uninucleate cell) containing half-number chromosome of spore mother cell is desirable for anther culture. The immature anthers containing the uninucleate cells are taken. The size of anthers of different varieties of chilli under the present study was observed. In the present work, from 1 to 1.5 mm-long anthers of all the seven varieties of chilli contain large number of the uninucleate pollen.

G. *REGENERATION*

All the calli obtained in the present investigation were whitish in colour and friable in nature. These calli were transferred to regeneration medium but no organogenesis did take place.

Table 1: Difference between MS and ½ MS medium regarding callus formation.

Varieties	Callus formed in MS Medium		Callus formed in ½ MS Medium	
	Total number of cultured anthers	% induced callus (Total values)	Total number of cultured anthers	% induced callus (Total values)
abbreviatum	595	14.8	270	3.8
. *annuum*	587	11.7	535	00
acuminatum	176	1.7	454	00
nigra	166	1.8	280	00
conoides	110	2.7	392	00
ceraciformis	165	2.4	503	00
fasciculatum	602	14.9	611	00

Table 2: Effect of growth regulators on callus formation in the variety of *abbreviatum* in MS medium.

Used growth regulators	No. of callus formed	Degree of callus formation	% of callus formed	Colour of callus	Nature of callus
2,4-D 0.5mg/l + kn 0.1mg/l	6	+	6.0	W	Fr.
NAA 0.3mg/l + BAP 0.1 mg/l	3	+	2.5	W	Fr.
2,4-D 0.4mg/l + kn 0.1mg/l	2	+	2.1	W	Fr.
NAA 0.1mg/l + Kn o.1 mg/l	2	+	2.0	W	Fr.
NAA 0.1 mg/l + 2,4-D 0.1 mg/l + BAP 0.2 mg/l	4	+	2.2	W	Fr.

Table 3: Effect of growth regulators on callus formation in the variety of *annuum* in MS medium.

Used growth regulators	No. of callus formed	Degree of callus formation	% of callus formed	Colour of callus	Nature of callus
2,4-D 0.5mg/l + kn 0.1mg/l	5	+	5.4	W	Fr.
NAA 0.3mg/l + BAP 0.1 mg/l	3	+	2.4	W	Fr.
2,4-D 0.4mg/l + kn 0.1mg/l	3	+	1.8	W	Fr.
NAA 0.1mg/l + Kn o.1 mg/l	0	+	00	W	Fr.
NAA 0.1 mg/l + 2,4-D 0.1 mg/l + BAP 0.2 mg/l	2	+	2.1	W	Fr.

Table 4: Effect of growth regulators on callus formation in the variety of *fasciculatum* in MS medium.

Used growth regulators	No. of callus formed	Degree of callus formation	% of callus formed	Colour of callus	Nature of callus
2,4-D 0.5mg/l + kn 0.1mg/l	00	+	00	-	-
NAA 0.3mg/l + BAP 0.1 mg/l	00	+	00	-	-
2,4-D 0.4mg/l + kn 0.1mg/l	00	+	00	-	-
NAA 0.1mg/l + Kn o.1 mg/l	00	+	00	-	-
NAA 0.1 mg/l + 2,4-D 0.1 mg/l + BAP 0.2 mg/l	2	+	1.9	W	Fr.

Table 5: Effect of different combinations of plant growth regulators on callus formation from anthers of chilli on MS medium.

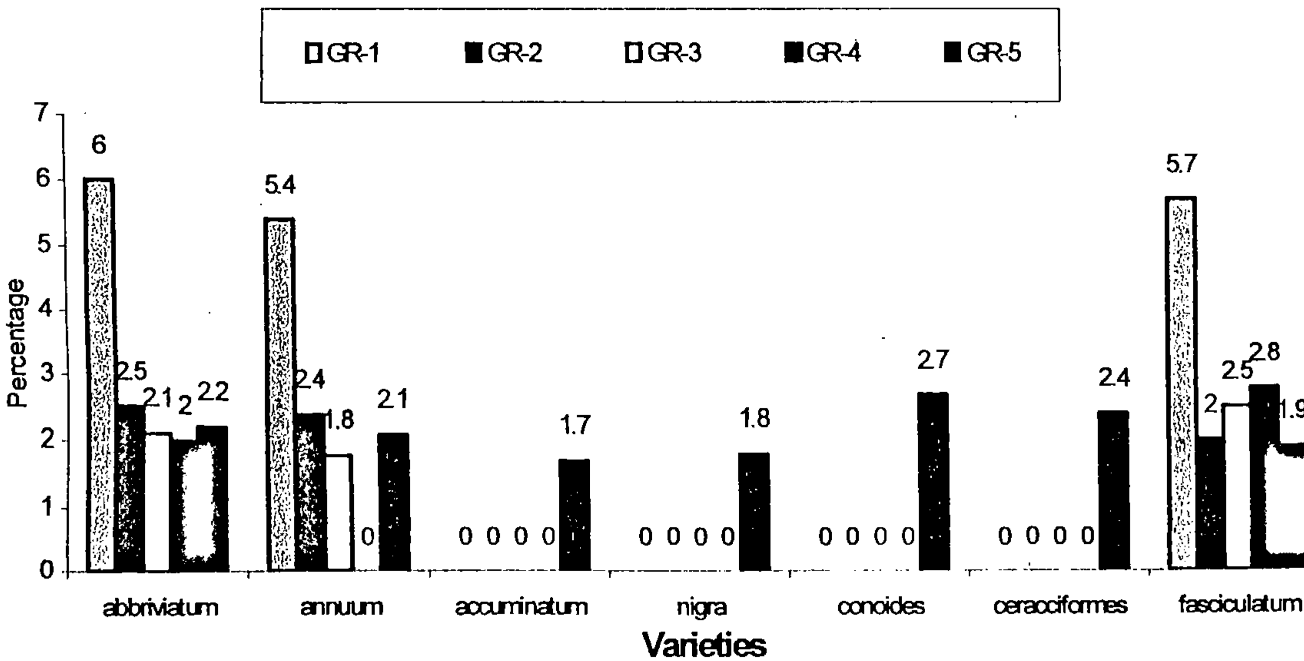
Varieties	Induced callus (%) in different growth regulators				
	GR-1	GR-2	GR-3	GR-4	GR-5
	2,4-.D 0.5mg/l + Kn 0.1mg/l	NAA 0.3mg/l + BAP 0.1mg/l	2,4-D 0.4mg/l + Kn 0.1mg/l	NAA 0.1mg/l + Kn 0.1mg/l	NAA 0.1mg/l + 2,4-.D 0.1mg/l 2 + BAP 0.2mg/l
abbreviatum	6.0	2.5	2.1	2.0	2.2
annuum	5.4	2.4	1.8	00	2.1
accuminatum	00	00	00	00	1.7
nigra	00	00	00	00	1.8
conoides	00	00	00	00	2.7
ceraciformis	00	00	00	00	2.4
fasciculatum	5.7	2.0	2.5	2.8	1.9

GR = Growth Regular

Table 6: Effect of different combinations of plant growth regulators on callus formation from anthers of chilli on ½ MS medium.

Varieties	Induced callus (%) in different combinations of growth regulators				
	BAP 2.5mg/l + 2,4-D 0.5mg/l	BA P 2.5mg/l + NAA 2.5mg/l	BAP 1.0mg/l + NAA 1.0mg/l +2,4-D 0.5mg/l	BAP 0.5mg/l + NAA 2.5mg/l + 2,4-D 2.5mg/l	BAP 0.5mg/l + kn 0.5mg/l + NAA 1.0mg/l + 2,4-D 2.5mg/l
abbriviatum	00	00	00	1.7	2.1
annuum	00	00	00	00	00
acuminatum	00	00	00	00	00
nigra	00	00	00	00	00
conoides	00	00	00	00	00
ceraciformis	00	00	00	00	00
fasciculatum	00	00	00	00	00

Fig.1: Bar diagram due to responses of different varieties on different growth regulators (GR)



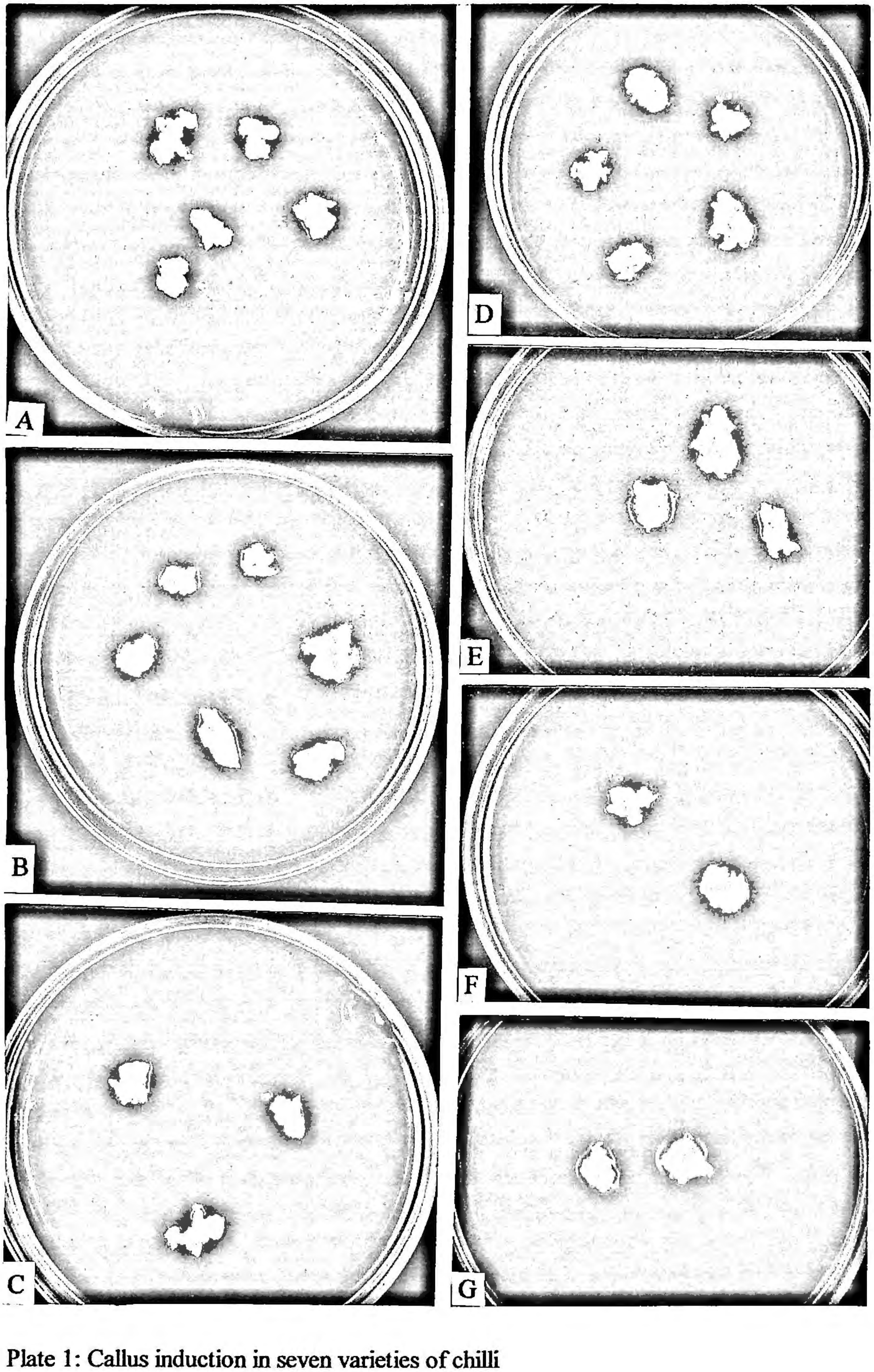


Plate 1: Callus induction in seven varieties of chilli

A) *abbreviatum* B) *annuum* C) *fasciculatum* D) *nigra* E) *conoides* F) *ceraciformis* G) *acuminatum*

DISCUSSION

The haploids obtained through the anther culture are very potential breeding material in crop improvement (Collins and Genovesi, 1981). The anther culture is a technique by which haploidization can be achieved. The haploid plant production through the anther culture was first reported by Guha and Maheswari (1964, 69) in *Datura* plant. Now-a-days the anther culture technique as an efficient method for obtaining haploids is used for creating varieties of different crops. Such as rice (Chen, 1986); wheat (Chuang *et al.* 1978, Islam *et al.*, 2001) barly (De Lafonteyne, 1993); rapeseed (Lobal Mollers, 1991); potato (Pretova, 1993) and others.

The culture of immature anthers is done so as to induce the pollen grains to develop into multicellular forms, particularly into embryos, with half of the normal chromosomes for species. When such haploid embryos are treated with chromosome doubling agents e.g. colchicine, their normal chromosome number is restored (and thus their fertility) and the achieved plants are pure lines. Pure line formation is a natural tendency for self-fertilizing species and can be obtained with cross-fertilizing species with repeated in breeding for 10 or more generations. So far the induction of haploid plant formation from anther cultures has been successful mainly with naturally self-fertilizing species and thus, on chromosome doubling, are in theory very similar if not identical with the parents. However, by first crossing many lines from a self-fertilizing species, new combinations of genes are formed, and haploid plants produced by the anther culture from such crosses can be an extremely valuable and quick way of obtaining the pure lines of these new combinations. If we can find out how to obtain haploid plants from anther culture of cross-fertilizing species, they also could be extremely valuable relative to breeding programmes and the selection of improved strains.

Being genetically complex, as there is linkage and epistatic action between the genes, anther culture must be adopted in chilli plants for production of haploid so as to improve the crop. The present investigation was under taken to meet the first step of haploid production i.e. to establish a protocol of the anther culture of chilli. The varieties induced in this experiment were *abbreviatum, annumm, acuminatum, nigra, conoides, cerasiformes* and *fasciculatum.*

The present investigation on callus induction was conducted with anthers (as explants) collected from the above seven chilli varieties. For embryogenic callus induction, different size of explants was tested in MS and in ½ MS medium with the different supplements. Callus refers to an actively dividing non-organised tissues or undifferencial cells often developing from injury (wounding) or in tissue culture (Pierik, 1987).

The tissue culture technique is recognized as novel means to generate genetic variability (Larkin and Scowcroft, 1981) and has been proposed as an excellent supplementary technique for plant improvement. The technique can accelerate the breeding program through the use of new expanded genetic variability (Nakamura and Meada, 1989; Zapata *et al.*, 1981).

All the varieties studied experienced callusing in the present investigation with a low frequency (Table 5). The frequency of callus formation was low and the range of callus induction was from 1.7 (*acuminatum*) to 6.0% (*abbreviatum*). Many investigators supported low frequency of callus induction. Hakim *et al.* (1991) showed that range of callus induction frequency was from 0.86 to 2.1% in their experiment of *in vitro* plant regeneration in rice through anther culture. Samad *et al.* (1996) also showed low frequency of callus induction. They showed the range of callus induction frequency was from 1.78 to 7.71% in an investigation of plant regeneration from anther culture of some F_1 hybrid rice.

In plant biotechnology, the anther culture is very interesting approach what has been experienced a great deal of limitations. However many other factors like genotypes, composition of the nutrient media, physical growth factors such as light, temperature, moisture etc are important factor for callus induction (Pieric, 1987).

Success in anther culture is predominantly dependent on the genotype of the anther donor plant. Good tissue culture ability is equivalent to a good regeneration capacity under given culture conditions. Probably culture conditions could be optimized for each genotype, as proposed by Dunwell (1981). It is found in the present investigation that different genotypes responded differently in different nutrient media indicating that genotype of the donor plant contributed to the callus formation (Fig.1). Chu (1982) reported that genotype of the pollen plant has the greatest influence on the frequency of pollen callus formation in an investigation of anther culture with rice. Many workers are in agreement with this finding. Jacobsen and Sopory (1987); Brettell *et al.* (1981); Datta and Wenzel (1987) said stringking variation is known to occur in androgenic response between and within species. Mandal and Aparna Maiti (1999) said two strains (*viz.* IRGC 10798 and IRGC 77130) of same variety SR 26-B, in their experiment, showed differential callus formation abilities, indicating that strong involvement of genotypes (even between strains) in governing anther culture response.

Response of donor plant is a common factor in the process of androgenesis in chilli plant. Different types of responses have been usually encountered for different varieties. In the present study, genotypic effect on the anther culture was varied with the culture method (Table 5). Lazar *et al.* (1984) and Barnabas *et al.* (1989) reported that the success of anther culture was strongly genotype dependent and it was under genetic control (Bullock, 1982). Donor plant's physiological state has a great effect on the reproducibility of results and the yield of pollen derivatives in terms of its age and growth conditions. Bhojwani and Razdan (1983) supported that generally, anthers taken during the early age of flowering give better response than those form late plants in the season. In this respect, Dunwell (1958a) suggested that, for the continuous experiments on extended period old flower should be removed without forming fruits. In the present investigation, anthers of early flowering period showed better results. Sunderland (1971) suggested to take anther for culture from flowers produced during the beginning of the flowering period of the plant.

Particular stage of anther can give haploid plants. In the present work, anthers of various types and size were used. Of them, anthers containing uninucleate stage, the cells in anthers having half number of chromosomes of parent plant, showed callus formation. Bhojwani (1987) said selection of the most favourable stage of pollen development at culture is very necessary than the composition of the medium or other factors. Wijesekera *et al.* (1999) supported that uniform stage of anthers are desirable to induce haploids. Generally the anthers around pollen mitosis are most responsive. The anthers containing uninucleate stage the desirable for the haploid production and many investigators in different works (Huda et al. 1999; Islam et al. 2001) supported it.

SECTION TWO

Comparison of G×E Models for Selection of Stable Genotypes in Chilli (*Capsicum annuum* L.)

INTRODUCTION

Changes of environment imply that environmental studies must inevitably become large-scale and complex. Young *et al* (1995) described the environment as 'a complex assemblage of interacting physical, chemical and biological systems with considerable uncertainty about both their nature and their interconnections'. Agricultural research has long generated the need for statistical design and analysis. Such research, by its very nature, can be described as environmental although concern now for the depletion of natural resources perhaps implies a wider role for environmental studies. Riley (1992a) described perceived changes to the source of biometric material and their influence upon biometric requirements and appropriate advice.

All the characters under study are quantitative and under polygenic control. Ploygenes have small and non-specific effect and all are alike in action. Polygenes cumulate their effects to give rise a great action on a phenotype. But the environments, where the plants are grown, also add the non-heritable effect to the genetic action, and finally phenotypes or characters are expressed. Genetically, a character or phenotype is the outcome of genotype×environment interaction. So, quantitative genetic point of view, a character depends on the environment. We have to therefore, measure the environmental or non-heritable effect on genotype. That is why, whole analysis of this part under study was done on the basis of G×E interaction models.

The environment, in which organisms grow and live, has a great role upon living organisms. Quantitative characters are greatly influenced by envioronment with regard to their phenotypic expression. Genotype implies the genetic constitution of an organism and environment refers the sum total physical, chemical and biological factors. A phenotype is the result of interplay between a genotype and its environment.

Environment is aggregate of some factors such as soil, intensity of sun light, wind, air, rainfall, draught, water, storm, fertilizer, insect and pest etc. Comstock and Moll (1963) have classified the environments in two categories like a) micro-environment that includes physical and chemical attributes of soil, climatic variables (temperature and humidity), solar radiation, insect pest and diseases; b) macro-environments, which associated with general locations and period of time and is a collection of micro-environments. Allard and Bradshow (1964) classified the environment as predictable and unpredictable. The predictable environment includes climate, soil type and day light. It also includes controllable variable (Perkins and Jinks, 1971), such as the level of fertilizer application, sowing density and methods of harvesting. The unpredictable environment includes weather fluctuations such as differences between seasons in terms of the amount and distribution of rainfall and prevailing temperatures.

For the self-sufficiency of Bangladesh with respect to condiments and spices, plant breeders are to improve the crops through breeding efforts and modern cultural technology. For successful breeding programmes breeders must have knowledge about the nature and extent of gene actions governing the various quantitative traits and should be able to determine and predict the magnitudes.

Investigation of a quantitative character becomes complicated when more than one environment is included because change in gene expression may occur with the changes of environments. These changes, observable as genotype × environment interaction in a biometrical analysis, have long been recognised as an important source of phenotypic variation (Immer *et al.*, 1934; Yates and Cochran, 1938 and Mather, 1949).

When some of the plant genotypes are grown over an array of environments, the genotypes do not respond in the same relative way in all environments. Quantitative genetic point of view the phenotype is known as genotype ×environment interaction. A population, which can adjust its genotypic and phenotypic state in response to environmental fluctuations in such a way that it gives maximum and stable economic return, can be termed 'well buffered'.

So measurement of environmental effect on the genotype has been subject to the biologists. Most of the economic crop plants are quantitative in nature. These characters can not be studied following Mendelian classical technique of analysis and require special statistical methods. Several statistical methods have been developed for the study of the inheritance of quantitative characters were not understood until genetical assumptions and biometrical methods developed in the early days of last century were brought together. The genetical studies of continuous variation got their impetus with the advent of pure line theory put forward in 1909 by Johannsen, who for the first time clearly distinguished heritable and non-heritable variances. In the same year Nilsson-Ehle stated his multiple factor hypothesis. East (1915) studying the inheritance of quantitative characters of *Nicotiana rustica* L. clearly showed that quantitative characters were inherited with the joint action of genetical and environmental variation and that they were inherited according to Mendel's laws of inheritance. So genetical study of the chilli crop is very much important.

For the study of quantitative genetic analysis with the environmental effect, from the development of quantitative genetics the partitioning of the variation components and the evaluation of these components by application of statistical tools was needed. Fisher (1918) in England and Wright (1923) in the United States first devised statistical methods for the study of the inheritance of quantitative characters. They considered that several genes acted simultaneously on a quantitative character producing the total variation. Fisher developed techniques for the detection and estimation of the average additive and dominance effects of these genes even when the genes were unequal in effect and exhibited incomplete dominance. He pointed out that non-allelic interaction (epistasis) also could be separated.

After this, with the development of first degree of statistics (mean) and second degree of statistics (variance and covariance), two distinct lines of development for the measurement of gene action and interaction involved in the phenomenon of continuous variation.

Mather (1949) developed biometrical techniques based on mathematical models of Fisher *et al.* (1932) and he described how the additive and dominance variation could be estimated in a wide variety of genetical experiments.

Now a day, in the regression analysis, two main approaches have been used for the specifying, estimating and correcting the effects of genotype × environment interaction. One is purely statistical analysis originally proposed by Yates and Cochran (1938) and was latter modified by Finlay and Wilkinson (1963); Eberhart and Russell (1966).

Being an important crop plant home and abroad, chilli peppers are grown worldwide. So, the quality of stability any quantitative character of chilli over a range of environments, undertaken of the present study is logical.

Upto this three G×E models are existed for selection a stable genotype and the models are

i) Eberhart and Russell (1966)

ii) Parkins and Jinks (1968)

iii) Freeman and Perkins (1971)

For the selection of a stable genotype grown in an array of environments, Eberhart and Russell (1966) proposed a model. They used two parameters to describe the performance of a variety over a range of environments. They proposed that the regression of each cultivar on an environmental index and a function of the squared deviations from this regression would provide useful estimates of the cultivar's stability parameters. Stable genotype is one which has a high mean, unit regression co-efficient (b_i = 1.00) and a deviation of zero ($\overline{S}^2{}_{d_i} = 0$) from regression.

Perkins and Jinks (1968) proposed stability model to select the stable genotype. From stability point of view, the variance due to genotype × environmental interaction, being the most important, they proposed that a regression of genotype×environmental interaction on environmental index should be obtained rather than regression of mean performance (Y_{ij}).

Freeman and Perkins (1971) also proposed another model of selection of a stable genotype over a range of environments. They proposed independent estimate of environmental index in the two ways, such as i) Divide the replications into groups, so that the one group may be used for measuring the average performance of varieties in various environments and the other group, averaging over the varieties is used for estimating the environmental index and ii) Use one or more varieties as check and assess the environmental index on the basis of their performance.

To select a stable genotype, that uniformly grows and shows good yield over changing environment, is important. Accordingly to follow the best model to select the stable genotype is also important. That is why the present part of this investigation was under taken to compare the G×E models for selection the stable genotype of chilli plant. Ten quantitative characters of seven chilli varieties were taken to complete the work and plants were grown in five consecutive years as different environments.

REVIEW OF LITERATURE

The relationship between genotype and environment was realized in the last century. Since then many reports, publications and books have been published in this regard. But concerning chilli, literatures with the problem of genotype × environment interactions are scanty. Therefore, literatures also with other crops are briefly reviewed below.

In 1909, Johannsen clearly showed the relationship between heredity and environment. He proposed that the environment play a significant part in determining the life situation. In an investigation with bean (*Phaseolus vulgaris* L.) he showed that the phenotype was the joint product of both heritable and non-heritable effects and the phenotypic variation in any pure life was due to environmental effect.

In 1910, Keeble and Pellow showed that height in peas was affected due to seasonal fluctuations. He also reported that precaution should be taken during the collection of data from plants growing in different seasons for observing the seasonal fluctuations.

East (1915) reported that the continuous variation in the generation for a quantitative character is due to both genetic and environmental effects.

In 1918, Fisher first developed statistical method to partition variance of quantitative character in segregating population into genetic and environmental components.

Fisher *et al.* (1932) described the mathematical method for measuring the inheritance of genotypes over environments.

In a report made by Smith (1944), it was known that the quantitative characters were governed by a large number of genes, which were similar, relatively small, non-dominant and additive in nature.

Mather (1949), Mather and Jones (1958) combinedly developed the techniques to measure the genotype-environment interaction based on the mathematical method of Fisher *et al.* (1932). It involved the partitioning of the variation of quantitative data into genetic and environmental effects and their interactions. Here the degree of interaction was expressed as a linear function of the effect environment.

Kalton *et al.* (1952) and Lebsock and Kalton (1954) estimated environmental variance within several clonal populations. Upon analysis, these estimates exhibited a significant difference for character controlled by gene indicating their presence in genotype-environment interaction. In the latter studies, it was concluded that the environmental variance composed of two components *viz.* a true environmental effect and genotype-environment interaction.

Fijar (1958) stated that the variation of a population was not only by environmental effect but also due to genotype-environment interaction. The presence of large interaction of general combining ability with environment was found by Mutjinger *et al.* (1959) for yield in corn, and Paroda and Joshi (1970) for yield and yield components in wheat.

In 1961, Amir made an investigation to estimate the relative magnitude of genotype-environment interactions for material representing two quite different levels of heterozygosity. It generated scope of the study of measurements of the major agronomic characters such as yield, plant height and ear length of inbreed lines and their top cross progenies to determine the relative importance of line differences environmental factors and interactions.

Finlay and Wilkinson (1963) developed statistical technique to compare yield performance of set cereal varieties grown at several locations for several seasons. The regression of individual yields on the mean yield of all varieties for each sites and season when tested for varieties and sites had a high adaptability at the varietal level. Similar techniques yielding similar result were reported by Yates and Cochran (1938).

Phahler (1965) demonstrated the environmental variability and genetic diversity within population of oat and rye. He found that the performances of the varieties varied with the environments indicating the presence of genotype-environment interactions. He also reported that the variation of the population was due to true environmental effect and a genotype-environment interaction.

Bucio (1966) studied the Genotype-environment interaction in *Nicotiana rustica*. He observed that genotype-environment interaction significantly influenced the phenotypic expression.

Tyson and Brander (1967) made an experiment on interaction of variety×environment, in flax at nine locations in four consecutive years. The significant variety×location×year interaction indicated the need for a thorough test prior to recommendation.

Ramanujam and Thirumalacher (1967) conducted the genetic variability of certain characters in red pepper (*C. annuum* L.). In their experiment they considered several fruit characters in twelve varieties, the weight of placenta per fruit, the capsicin content of the placenta and the capsicin content of the whole fruit showed the high genotypic and phenotypic variability.

Ananda (1968) worked on the relationship between variety and environment in wheat. Analysis of variance of data from trails involving 12 varieties at 4 locations for 3 years showed variety×location×year and variety×location interaction to be significant, indicating that the performance of varieties varied with the environments. The interaction variances were found to decrease with the increase in the number of locations.

Baker (1969) made an experiment on yield of six cultivars of hard red spring wheat grown at each of nine locations in five different years to evaluate genotype×environment interaction. He concluded that all the genotype×environment interactions except genotype×year were significant and important.

Malhotra *et al.* (1974) studied genetic variability and genotype-environment interaction in lentil. Significant differences were recorded in all the six characters studied in 47 lines grown at three regional sites. The number of primary branches, number of clusters and pods per plant, plant height, 100 seed weight and yield per plant were studied. Seed yield gave high co-efficient of genetic variation and estimated genetic advance as a percentage of mean for pod number and 100 seed weight gave high co-efficient of genetic variation and genetic advance and moderate heritability at all three sites.

Zuberi and Gale (1975) made an experiment with the effects of soil nutrients on the expression of eleven traits of *Papaver dabium* and observed significant effect of all nutrients and obtained the greatest effect at Ca. Both linear and non-linear relationships between genotype-environment interaction and environmental mean were found for all the characters.

Khaleque (1975) worked on genotype×environment interactions for eighteen quantitative characters in a 5×5 diallel progenies of rice over two seasons. Joarder and Eunus (1977) also made a study of genotype-environment interaction shown by heading and harvesting time in *Brassica campestres* L. All of them found that genotype-environment interactions were operative in both parental and F_2 generations and that a significant portion of these interactions was accounted for by the linear function of the environmental means. A part of the interaction was independent of this linear component. Both the linear and non-linear components were under the control of different gene systems and subjected to dominance. Interaction between the additive component and the environmental means was greater than that of the dominant component under different environments.

Flower and Roche (1975) observed a large environmental effect when he worked on some agronomic and quality data of spring and winter wheat which was very useful for breeding programmes.

Freeman and Crisp (1979) worked on the use of related varieties in explaining genotype-environment interactions. When genotypes are grown in a range of environments several variables are often recorded on the same genotype. Regression of one character and another may not only gave useful information about the relation between them but also help to explain genotype-environment interactions in the characters of primary interest.

Majid *et al.* (1982) studied forty germplasm of black gram growing in a randomized design. Data on 10 agronomic characters were taken *viz.* days to first flowering, days to maturity, plant height, number of primary branches/plant, number of inflorescence/plant, number of pods/plant, pod length, number of seeds/pod, 500 seed weight and seed yield/plant. The genotypic variance was found to be linear than the genotypic variance for all the characters studied.

In an experiment of yield stability of twenty wheat varieties/lines under four sowing dates, Parh *et al.* (1985) calculated three parameters of stability like, phenotypic index (P) greater than zero, regression co-efficient (b) around unity and least deviation from regression. They reported the line BAW-34 was the most stable genotype over all sowing dates. They showed that the varieties/lines BAW-12, Jupateco-73, Blue Jays' and BAW – 35 were found suitable under favourable environments while Balaka and Baw – 28 were found suitable under unfavourable environments. They concluded saying that above-mentioned varieties be used in a hybridization programmes because they likely to transmit high mean yields with increased stability.

Henry and Daulay (1987) studied G×E interaction on 14 genotypes of *Sesamum* under 4 year rainfed conditions. They showed a significant variation for genotypes and G×E interaction in all the genotypes. They also reported that linear and non-linear components were significant for most of the genotypes for seed yield.

Parth and Khan (1987) worked on G×E interaction of 20 wheat cultivars at four seeding dates. They studied correlation among the stability parameters and reported that significant positive association was found between mean performance and regression co-efficient for days to 50% heading and yield per plant. Non-linear component S^2d of G×E interaction was positively and significantly correlated with days to 50% heading but negatively correlated with days to maturity and plant height. They suggested significant correlation in all the parameters for number of tillers per plant, spike-length and number of grains per spike were controlled by an independent genetic mechanism. So, these traits might be expressed to attain greater stability and ultimately higher yield.

In 1987, Sen *et al* studied yield stability in groundnut involving five genotypes. Combined analysis of variance indicated significant difference of genotypes, environment + (genotype×environment). The linear component was found to be significant but the non-linear component was insignificant. DM-1 showed above average stability with low yield Cox's Bazar and Natal-1 were found below average and stable with high yield. Dhaka-1 was considered unstable. The genotype K-17 exhibited, average stability with high yield.

Chaudhury and Ananda (1988) studied on G×E interaction in Sunflower and reported that significant difference characterized the varieties in all seasons except in the dry matter of seedlings in the rainy season. The seasonal effect was also significant for all the characters except oil content. The G×E interaction had shown significant effects for days to heading, plant height of flowering and maturity, oil and protein content. The interaction (σ^2_{ge}) component was less than the genotype (σ^2_{ge}) component of variance. The magnitude of σ^2_{ge} was positive and high for the characters having significant G×E. Probably for so highly diversified reasons. The genotypes 'EC 98307' and 'EC 98329' have consistently better performances.

In 1988, Ghosdastidaret *et al.* made an experiment with genotype-environment interaction in mustard under late sowing condition. It was found that only three characters *viz.* plant height up to 1^{st} branch and number of seeds per siliqua had homogenous experimental error. Absence of genotype-year interaction was observed in case of number of primary branches only. Pooled estimates of genetic parameters showed that plant height up to 1^{st} branches had moderately high heritability and moderately high genetic advance.

Brandle and Mevethy (1988) studied the genotype×environment interaction and stability analysis of seed yield of *Brassica napus* cultivars which were grown at 9 different sites for 3 years. They reported that the genotype×year and genotype×year×sites interactions were significant, but the genotype×sites interaction was not significant. They also reported year, sites and replications in that order had the greatest effects on the standard error of mean of a cultivar.

Kundu and Khurana (1988) worked on stability for yield and its components with 30 toria genotype under six environments and six characters. They observed that G×E interactions were significant. The linear G×E component was observed for primary and secondary branches, seeds per siliqua, 100seed weight and seed yield which were predictable. Genotype "TH69", "TH-84", 'TK8493' and Sangan showed an average stability.

Kundu and Khurana (1988) worked on stability for yield and its components with 30 toria genotype under six environments and six characters. They observed that G×E interactions were significant. The linear G×E component was observed for primary, secondary branches, seeds per siliqua, 100 seed weight and yield which were predictable. Genotype "TH69", "TH-84", "TK8493", "TGC-2" and Sangam showed an average stability.

Khandakar *et al.* (1989) studied the yield stability of 10 varieties of jute has been tested in a wide range of environments at three zonal stations. The effect of variety had much influence whereas the effect of environment (sowing date) was highly significant. The interaction between variety-environment was significant whereas variety-station and station-environment were not significant. The variety 0-9897, Uganda mutant had higher yield although stations when cap-1, cap-2 and cap-4 and higher yields in chandina station only. The varieties with higher yield (0-9897 and Uganda mutant) had less stability whereas the variety with lower yield (0-4 and CVL-1) had higher stability across environments. The higher yield maintained an inverse relation with wider stability to environments.

Samad (1991) made an experiment on the genotype×environment interaction of six agronomical characters in fifteen rape seed (*Brassica campestris* L.) cultivars in six consecutive years. He showed that genotype×environment interactions were significantly operative in the experiment. He observed that all the genotypes for plant height and number of pods/plant failed to show the stable performances, while some of the genotypes like polar, Toti-9, Tori-7 and sampad were predicted to show the stable performances. In this regard they considered the number of secondary branches, number of seeds/pod and yield/plant characters.

Ahmed *et al.* (1993) studied stability of seed yield in tossa jute cultivars (*Corcorus olitorias* L.) under late seeding condition. They calculated regression co-efficient along with deviation from regression and found that cultivar 0.9897 showed better seed yield stability, while chaital and OM-1 were found suitable for favourable environment only.

In 1994, Das *et al.* worked on stability for physiological maturity and kernel yield over locations in maize (*Zea mays* L.) genotypes. They were evaluated ten composite varieties of maize for stability of physiological maturity and kernel yield at five different locations *viz.* Joidebpur, Jamalpur, Jessore, Ishurdi and Hathazari during rabi season. They found that the performances of the varieties varied with the environments indicating the presence of genotype×environment interactions.

Dutta *et al.* (1995) investigated effects of photoperiod and temperature on flowering and grain yield of lentil cultivars L_5 and L_{9-12}. Performance of two lentil varieties (L_5 and L_{9-12}) were recorded at different dates revealed that date of sowing had spectacular effect on the vegetative and reproductive growth and yield of lentil. L_5 and L_{9-12} both showed reduction in seed yield due to later sowings. It was evident that L_5 showed less photosensitivity then L_{9-12} resulting in more stability in seed yield due to late sowings. The yield potential of the two cultivars at normal dates of sowing up to first week of November recorded similar values.

Bhutani *et al.* (1997) made an experiment on yield stability in potato (*Solanum tuberosum* L.). In their experiment, they evaluated twelve varieties or hybrids of potato for the stability test of tuber yield over five years. They got significant differences among varieties/hybrids, years and varieties×year components of variation. They showed that both linear and non-linear components of variations were significant with the preponderance of linear component. MS/82 variety/hybrid was high yielding and responsive to good environmental conditions. They also reported that two varieties or hybrids namely, PS/M-75 and JI-5857 gave 14.0 and 11.0 per cent significantly higher than the best released variety 'Kufri Badshah'. Hybrid JH-222 was identified to be good genotype for poor environmental conditions.

In an experiment of genotype×environment interaction, Shafiyoul (1997) selected some morphological characters under soil moisture stress condition in chickpea (*Cicer arietinum* L.). In the genotype×environment interaction, he estimated regression co-efficient, genotypic and environmental and joint regression analysis. Genotype and environmental items were significant for all the characters. Joint regression analysis indicated that linear portion of G×E interaction was not significant for most of the characters. With above average regression value for most of the genotypes showed that they would likely respond in better environments only. However, he concluded that the varieties ICCV- 92133 and PAO- 299/ for PHFF, ICCV- 83105 for PHMF and all the genotypes for NSBFF were likely to be stable in varied environmental condition.

Stability analysis was carried out by Roy *et al.* (1999). They considered characters days to 50% silking, plan height, ear height, days to maturity and grain yield per hectors with 20 exotic and local genotypes of maize across three different locations of Bangladesh. Genotype×environment interaction was not significant for all the characters. The nonlinear component was significant for all the characters. The reactions of the genotypes were different in different locations and stability varied among the genotypes in suitable for the entire environment for all the characters. Significant regression co-efficient was observed for days to 50% silking and days to maturity in all the genotypes. The genotypes, Poza Rica 9224, Poza Rica 9227 and EV 89345-1 were found stable for grain yield per hectre where as Jalna 9128, Poza Rice 9224 and Poza Rica 9227 were found stable for plant height. The genotypes Across 9128 and Across 9136 were observed more or less stable over locations.

Islam *et al.* (2000) made an experiment with eighteen chickpea (*Cicer arietinum* L.) lines for germination test for the two characters such as the length of radicle (RL) and the length of plumule (LP). The response of individual genotypes was determined by the analysis of joint regression on the mean values of genotype over a range of days (days considered as environment). The analysis showed that the response of seedling growth in all 18 lines was linear as the regression and regression co-efficient were largely significant for all the genotypes. The differences between the genotypes both for the plumule and radicle were largely due to different environment as environment item was highly significant. Moreover, significant genotype-environment interaction indicated that different genotypes responded differently in different days.

Sarker *et al.* (2000) investigated on genotype×environment interaction for seed yield and three yield contributing characters showed that the varieties interacted significantly with the environment and this interaction was accounted for by the linear function of the environmental means. Some of the interactions were independent of this linear component. Genotypes, Akber and Sonora with high mean performance, regression co-efficient greater than 1.00 together with high s^2d values were found to be suitable for average mean performance, average response and low s^2d values were suitable for all environments.

Ara *et al.* (2000) carried out the stability analysis in five advanced genotypes of tomato for yield and some of the yield component under three different environments. Genotype×environment interactions were found to be significant for all the characters. Linear component contributes positively towards genotype×environment interaction for yield while non-linear component contributed towards the rest of the characters. On the basis of three stability parametrs, the genotype, AD(OH)2 was identified as stable. The genotype AD(OH)1 might be suitable for cultivation in unfavourable environments.

MATERIALS AND METH0DS

A. *MATERIALS:*

Biometrical Genetics Laboratory of the Department of Genetics & Breeding of the University of Rajshahi, had supplied the seeds of seven chilli varieties, such as *abbreviatum, annumm, acuminatum, nigra, conoides, cerasiformis* and *fasciculatum* as materials of this investigation. Seeds of the above mentioned seven varieties of chilli were sown in the earthen pots and the seedlings were transplanted in the well-ploughed field.

In the study of Genotype×Environment interaction, ten quantitative characters of chilli (*Capsicum annuum* L.) were selected and five consecutive years (1997 - 2001) were considered as environment.

B. *METH0DS:*

The methods followed to conduct the experiment and analysis of the data were divided into the following sub-heads:

1. Collection of the Experimental Seeds.
2. Preparation of the Experimental Soil
3. Sowing of Seeds and Raising of Seedlings
4. Preparation of the Experimental Field
5. The Design and Size of Field
6. Transplantation of Seedlings
7. Maintenance of the Experimental Plant
8. Collection of Data
9. Technique of Analysis of Data

1. Collection of the Experimental Seeds:

In the eve of the experiment the seeds of the seven chilli (*Capsicum annuum* L.) varieties were supplied from the Biometrical genetics laboratory, Department of Genetics & Breeding, University of Rajshahi.

2. Preparation of the Experimental Soil:

The soil for sowing the seeds of the chilli varieties was prepared with the mixing up of 50% soil, 25% cowdung and 25% ash.

3. Sowing of Seeds and raising of Seedlings:

After mixing up of these materials, earthen pots were filled and the seeds were sown on the soil in the pots. Every pot was marked with the name of respective variety sown in the pot. Finally, water was rinsed on the pots.

4. Preparation of the Experimental Field:

The experimental field, in which plants were grown, was adjoining the Third Science Building of the University of Rajshahi and the experiment was done during the optimum-growing season in all the 5 years (i.e. 1997, 1998, 1999, 2000 and 2001). The field was ploughed repeatedly for four to five times and leveled with ladder properly.

5. The Design and Size of Field:

The design of the experiment was randomized completely block design. The experimental field was comprised an area of 1755700 (1810 × 970) sq.cm in each year. The field was consisted of two replications, each replication contained 5 plots, each plot was consisted with two rows and each row was contained 5 plants. The space between rows was 60 cm. and between plants was 45 cm.

6. Transplantation of Seedlings:

After four to five weeks of seeding of seeds in the pots, the seedlings were transplanted in the field, such a way that each row contains 5 seedlings of the same variety. After transplantation of seedlings they were irrigated with water.

7. Maintenance of the Experimental Plant:

Regular weeding and hoeing and irrigation were done. When the seedlings were acclimatized and adapted with the environment irrigation times was lengthen.

8. Collection of Data:

Data were collected on individual plant basis. Observations were recorded for different quantitative characters from the seven varieties. Ten plants had been selected and data were taken. All the measurements were done in C G S system.

Data were measured and recorded on the following characters:

a) Number of primary branches at first flowering stage (NPBFF):

The number of main branches, which arose from the stem, was counted as the number of primary branches. Data were taken at the time of first flowering stage.

b) Leaf area at first flowering stage (LAFF):

At the first flowering stage, length and breadth of a medium sized leaf was measured as the area of leaf.

c) Number of leaf at first flowering stage (NLFF):

The total number of leaf bearing the plant at the time of blooming the first flower was counted as number of leaf at first flowering stage.

d) Number of Secondary branches at first flowering stage (NSBFF):

The number of secondary branches, which came out from the primary branches, was counted and recorded at the time of first flowering stage.

e) Plant height at first flowering stage (PHFF):

Plant height was measured in cm. from the base of the stem to the top of the plant at first flowering stage.

f) Number of primary branches at maximum flowering stage (NPBMF):

The number of primary branches, which came out from the primary branches, was counted and recorded at the time of maximum flowering stage.

g) Leaf area at maximum flowering stage (LAMF):

At the maximum flowering stage, length and breadth of a medium sized leaf was measured as the area of leaf.

h) Number of leaf at maximum flowering stage (NLMF):

The total number of leaf bearing the plant at the time of blooming the maximum flower was counted as number of leaf at first flowering stage.

i) Number of Secondary branches at maximum flowering stage (NSBMF):

The number of secondary branches, which came out from the primary branches, was counted and recorded at the time of maximum flowering stage.

j) Plant height at maximum flowering stage (PHMF):

Plant height was measured in cm. from the base of the stem to the top of the plant at maximum flowering stage.

9. Technique of Analysis of Data:

The collected data were analysed following the Bimetrical techniques developed by Mather (1949) based on the mathematical model of Fisher *et al.* (1932) and that of Eberhart and Russell (1966) and Jinks and Perkins (1968).

The collected data were analysed on this view under the following sub-heads:

a). *Study of Variability:*

In the analysis of study of variability, mean, standard deviation, standard error of mean, co-efficient of variability in percentage and range was calculated. The techniques used are described under the following sub-heads:

i) Mean ($\overline{X}$):

Data on individual plant were added together then divided by the total number of observation and the mean was obtained as follows:

$$\text{Mean } \left(\overline{X}\right) = \frac{\sum_{i=1}^{n} X_i}{n}$$

Here,

X_i = The individual reading recorded on each of the plant

$\overline{X}$ = The mean of all the readings

Σ = Summation

n = Number of observation

i = 1, 2, 3,4 to n

ii) Standard Deviation (Sd):

Standard deviation is the average deviation of the individual observations from mean. It was calculated as the square root of the variance as follows:

$$Sd = \sqrt{S^2}$$

Where,

S^2 = Variance

Sd = Standard deviation.

iii) Standard error of mean ($Se_{\bar{x}}$):

If, instead of taking one sample, several samples are considered, it will be found that standard deviation of different samples will also vary. This variation is measured be the standard error, which was calculated as follows:

$$Se = \frac{Sd}{\sqrt{n}}$$

Where,

Se = Standard error of mean

Sd = Standard deviation

n = Total number of individuals.

Standard error of mean gives an idea as to how any mean obtained from a sample may differ the true hypothetical mean of the population.

iv) Co-efficient of variability in percentage (CV%):

Co-efficient of variability in percentage (CV%) was calculated according to the following formula:

$$CV\% = \frac{Sd}{\bar{X}} \times 100$$

Where,

Sd = Standard deviation

$\bar{X}$ = Line mean

CV% = Co-efficient of variability in percentage.

v) Range:

The difference between the highest and the lowest values of the population is the measure of range of a given character.

b). *Analysis of Variance:*

Variance is a measure of dispersion of a population. Thus, the analysis of variance is done for testing the significant differences among the population. Variance analysis for each of the characters was carried out separately on mean value of 10 plants.

In the present investigation, the variance due to different sources, such as varieties, replications, years, V×R, V×Y, Y×R, V×Y×R were analysed as per the following plan:

Total $_{SS}$ → df = (VYRP-1) = 699

- Treatmen $_{SS}$ df = (VRY -1) = 69
  - Variety$_{SS}$ (V_{SS}) df = (V - 1) = (7 - 1) = 6
  - Year $_{SS}$ (Y_{SS}) df = (Y - 1) = (5-1) = 4
  - Replication $_{SS}$ (R_{SS}) df = (R -1) = (2-1) = 1
  - (V×R) $_{SS}$ df = (V-1)(R-1) = (7-1)(2-1) = 6
  - (V×Y) $_{SS}$ df = (V-1)(Y-1) = (7-1)(5-1) = 24
  - (Y × R)$_{SS}$ df = (Y-1)(R-1) = (5-1)(2-1) = 4
  - (V×Y×R) $_{SS}$ df = (V-1)(Y-1)(R-1) = 24
- Within error $_{SS}$ df = VRY (p - 1) = 630

Where,

Total $_{SS}$ = $\Sigma(VRYP)^2$ - CF

$$\text{Tratment}_{SS} = \frac{\sum_{ijk}\left(V_i Y_j R_k\right)^2}{p} - CF$$

Error $_{SS}$ = Total $_{SS}$ - Tratment $_{SS}$

$$\text{Variety}_{SS} = \frac{\sum_{i}\left(V_{i.}\right)^2}{pry} - CF$$

$$\text{Year}_{SS} = \frac{\sum_{j}\left(Y_{.j}\right)^2}{vrp} - CF$$

$$(V\times R)_{SS} = \frac{\sum_{ik}\left(V_i R_k\right)^2}{py} - CF - V_{SS} - R_{SS}$$

$$(V\times Y)_{SS} = \frac{\sum_{ij}(V_iY_j)^2}{pr} - CF - V_{SS} - Y_{SS}$$

$$(Y\times R)_{SS} = \frac{\sum_{ij}(Y_jR_k)^2}{pv} - CF - Y_{SS} - R_{SS}$$

$$(V\times Y\times R)_{SS} = \frac{\sum_{ijk}(V_iY_jR_k)^2}{p} - CF - V_{SS} - Y_{SS} - R_{SS} - V\times R_{SS} - V\times Y_{SS} - Y\times R_{SS}$$

V_i = The value of ith varieties

Y_j = The total of jth environments (year)

V_iY_j = The value of ith variety in jth environments

$V_iY_jR_k$ = The value of ith varieties of jth environments of kth replications

CF = Correction Factor = Gt^2/N

N = Total no of observation = (VRYP)

The analysis of variance of a mixed model was used, where variety (V) is fixed, year (Y) replication (R) effects random. The expectations in the analysis are shown in the following table:

Table 3: The expectations of mean (EMS) table used for analysis of variance.

ITEMS	DF	MS	EMS
Varieties (V)	(V-1)	MS_1	$\sigma^2_w + p\sigma^2_{VRY} + pR\sigma^2_{VY} + pY\sigma^2_{VR} + pRY\sigma^2_V$
Replication	(R-1)	MS_2	$\sigma^2_w + pV\sigma^2_{RY} + pV\sigma^2_R$
Year (Y)	(Y-1)	MS_3	$\sigma^2_w + pV\sigma^2_{RY} + pVR\sigma^2_Y$
V×R	(V-1) (R-1)	MS_4	$\sigma^2_w + rp\,\sigma^2_{VRY} + pY\sigma^2_{VR}$
V×Y	(V-1) (Y-1)	MS_5	$\sigma^2_w + p\sigma^2_{VRY} + pR\sigma^2_{VY}$
R×Y	(R-1) (Y-1)	MS_6	$\sigma^2_w + pV\sigma^2_{RY}$
V×R×Y	(V-1) (R-1) (Y-1)	MS_7	$\sigma^2_w + p\sigma^2_{VRY}$
Within error	VRY(p-1)	MS_8	σ^2_w

Where,

V, R, Y and P designate the number of varieties, replications, years and plants, respectively.

MS_1 = mean square of variety

MS_2 = mean square of replication

MS_3 = mean square of years

MS_4 = mean square of variety × replication

MS_5 = mean square of variety × year

MS_6 = mean square of year × replication

MS_7 = mean square of variety × replication × year

MS_8 = mean square of within error

$pY\sigma^2_{VR}$ = variety × replication

$pR\sigma^2_{VY}$ = variety × year

$pV\sigma^2_{RY}$ = year × replication

$p\sigma^2_{VRY}$ = variety × replication × year

σ^2_w = Variance due to within error

c). *Components of variation:*

Components of variation were genotypic (σ^2_v), phenotypic (σ^2_p), VY interaction (σ^2_{VY}), RY interaction (σ^2_{RY}), VRY interaction (σ^2_{VRY}) and within error variance (σ^2_w). They were measured as follows:

genotypic (variety) variance (σ^2_V) = $$\frac{MS_1 - \{(MS_4 - MS_7) + MS_5\}}{pry}$$

variety × replication inrteraction (σ^2_{VR}) = $$\frac{MS_4 - MS_7}{py}$$

variety × year interaction (σ^2_{VY}) = $$\frac{MS_5 - MS_7}{pr}$$

replication × year interaction (σ^2_{RY}) = $$\frac{MS_6 - MS_8}{pv}$$

variety × replication × year interaction ((σ^2_{VRY})= $$\frac{MS_7 - MS_8}{p}$$

Within error variance (σ^2_w) = MS_8

Phenotypic variance = $\sigma^2_V + \sigma^2_{VR} + \sigma^2_{VY} + \sigma^2_{VRY} + \sigma^2_w$

Where.

R = Number of replications (r)

V = Number of varieties (v)

Y = Number of years (y)

P = Number of plants (p)

d). *Co-efficient of variability (CV):*

Deviation is also expressed by the co-efficient of variation given by the formula of Burton and De Vane (1953) as follows:

$$\text{Co-efficient of variability (CV)} = \frac{S^2}{\overline{\overline{X}}} \times 100$$

Co-efficient of variability at different levels were calculated as follows:

1) Phenotypic Co-efficient of variability (PCV)= $\frac{\sigma^2_p}{\overline{\overline{X}}} \times 100$

2) Genotypic Co-efficient of variability (GCV) = $\frac{\sigma^2_g}{\overline{\overline{X}}} \times 100$

3) within error Co-efficient of variability (ECV) = $\frac{\sigma^2_e}{\overline{\overline{X}}} \times 100$

Where,

$\overline{X}$ = Grand mean

σ^2_p = Phenotypic variance

σ^2_g = Genotypic variance

e). *Heritability in broad sense ($h^2 b$):*

$$h^2 b = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

f). *Genetic Advance (GA):*

Genetic advance was calculated by the following formula as suggested by Lush (1949).

$$GA = K\sigma_p \left(\frac{\sigma_g^2}{\sigma_p^2} \right)$$

Where,

K = The selection differential in standard units, for the present study it is 2.06 at 5% level of signification (Lush 1949),

σ^2_g = Genotypic variance

σ_p = Square root of phenotypic variance

σ^2_p = Phenotypic variance

h). *Genetic AdvanceExpressed as percentage of Mean (GA%):*

It was calculated by the following formula.

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

Where,

$\overline{X}$ = Grand mean for the particular character.

i). *Study of Regression and Stability:*

In this section, three models were followed, which are as follows:

a). **Eberhart and Russell's (1966) Model:**

In this approach, the regression co-efficient and the deviation from regression are used as parameters of stability. As the regression of d_i on e_j is one, and regression of g_{ij} on e_j is β_i, therefore, the b_i value of Eberhart and Russell's model is $b_i = 1 + \beta_i$ and $\beta_i = b_i - 1$.

Eberhart and Russell (1966) used the following model to study the stability of varieties under different environments.

$$Y_{ij} = m + \beta_i I_j + \sigma_{ij}$$

Where,

i varies from 1to V, the number of varieties and

j varies from 1 to Y, the number of years

Yij = Mean of the varieties overall the environments

m = Mean of all the varieties overall the environments

βi = The regression co-efficient of the ith lines on the environmental index which measures the response of this varieties to varying environments.

I_j = The environmental index which is defined as the deviation of mean of all the varieties at a given environment from the overall mean.

$$= \frac{\sum_i Y_{ij}}{L} - \frac{\sum_i \sum_j Y_{ij}}{LI}$$

With

$$\sum_j I_j = 0$$

and σ_{ij} = The deviation from the regression of ith varieties at jth environment.

1. Computation of environmental index (I_j):

It is calculated as follows:

$$I_j = \frac{\sum_j Y_{ij}}{L} - \frac{\sum_i \sum_j Y_{ij}}{YI}$$

$$= \frac{\text{Total of the lines at jth environment}}{\text{Number of lines}} - \frac{\text{Grand total}}{\text{Total number of observation}}$$

2. Computation of regression co-efficient (b_i) for each line:

$$b_i = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

Where,

$\sum_j I_j^2$ is the sum of square of environments.

$\sum_j Y_{ij} I_j$ for each of the lines the sum of products of environmental index (I_j) with the corresponding mean $(\overline{X})$ of that varieties at each environment. These values may be obtained in the following manner:

$$[X][I_j] = \left[\sum_j Y_{ij} I_j\right] = [S]$$

Where,

$[\overline{X}]$ = Matrix of mean.

$[I_j]$ = Vector of environmental index, and

$[S]$ = Vector of sum of products.

i.e., $\sum_{j} Y_{ij} I_j$

3. Computation of $\bar{S}^2{}_{d_i}$

In general, it is obtained by subtracting the variance due to regression from σ^2_y. It is calculated as follows:

$$\bar{S}^2{}_{d_i} = \left[\frac{\sum_{ij} \sigma^2{}_{ij}}{Y-2}\right] - \frac{S^2{}_e}{r}$$

4. Computation of Standard error of Sb_i:

It was calculated as follows:

$$S_{bi} = \sqrt{\frac{\text{Remainder SS}}{SS_{(x)}}}$$

b). **Perkins' and Jinks Model:**

For the G×E interaction they proposed a model. According to their model the specification is as follows:

In this model, Y_{ij} considered as mean performance. For describing Y_{ij} the mean performance of the i^{th} variety in j^{th} location, they proposed following model:

$$Y_{ij} = m + d_i + e_j + g_{ij} + e_{ij}$$

where, m is the general mean,

d_i is the additive genetic effect,

e_j is the additive environmental effect,

g_{ij} is the genotype×environmental interaction effect, and

e_{ij} is the error associated with each observation.

With i varieties from 1 to s, the number of genotypes and j environment (year) from 1 to t, the number of environments.

m, the overall mean which is estimated as

$$m = \frac{Y_{..}}{st} = \frac{\sum_{i=1}^{s} \sum_{j=1}^{t} Y_{ij}}{st}$$

d_i is the genetical deviation of the i^{th} genotype and is estimated as

$$d_i = \frac{\sum_{i=1} Y_{i.}}{S} - m$$

e_j is the additive environmental deviation of the j^{th} environment and is estimated as

$$e_j = \frac{\sum_{i=1}^{t} Y_{ij}}{S} - m$$

Finally g_{ij} the genotype-environment interaction of the i^{th} genotype and j^{th} environment is estimated as

$g_{ij} = Y_{ij} - m - d_i - e_j$

Besides, the data was subjected to a standard two-way analysis of variance to test the significance of the items genotypes, environments and their interactions.

Significance of these items necessitates the inclusion of genotype-environment interaction model, where environmental effects in each genotype are a linear function of the additive environmental variance, i.e. $g_{ij} = b_i e_j$

Finally, whether these linear function differ among the genotypes is tested by the adequacy of the model,

$Y_{ij} = m + d_i + (1+b_i)e_j$

By a joint regression analysis in which the sum of squares for genotype-environmental interactions are partitioned into linear and non-linear portions following Perkins and Jinks'(1968 a, b) model, where we can separate the items.

In the joint regression analysis the G×E $_{SS}$ is partitioned into heterogeneity of regression SS and non-linear (remainder SS) portion, as follows:

G×E or V×Y$_{SS}$ →
df = (V-1)(Y-1)
= 24

→ Heterogeneity of regression$_{SS}$
d.f = (v – 1) = 6

→ Remainder$_{SS}$
d. f. = (V – 1)(Y – 2) = 18

The whole joint regression analysis is shown in the following table.

Table 2: Joint regression analysis table.

Items	DF	SS	MS	VR_1	VR_2
Genotype (variety) (V)	(V - 1)	-	MS_1	MS_1/MS_6	MS_1/MS_5
Environment (Year) (Y)	(Y - 1)	-	MS_2	MS_2/MS_6	MS_2/MS_5
V×Y	(V - 1) × (Y - 1)	-	MS_3	MS_3/MS_6	MS_3/MS_5
a) Heterogeneity of regression	(V - 1)	-	MS_4	MS_4/MS_6	MS_4/MS_5
b) Remainder	(V - 1) (Y - 2)	-	MS_5	MS_5/MS_6	
Within error	VYR (p- 1)	-	MS_6		

1. Stability parameters:

In the Perkins' and Jinks' model, two parameters were considered as stability parameters, such as regression co-efficient (β_i) and the deviation from regression ($\bar{S}^2_{d_i}$)

i). Regression co-efficient (β_i):

The regression co-efficient of this model is calculated as

$\beta_i = b_i - 1$

here, b_i is the regression co-efficient calculated as in the Eberhart and Russell (1966) model.

ii). Deviation from regression ($\bar{S}^2_{d_i}$):

The deviation from regression ($\bar{S}^2_{d_i}$), in this model, is also calculated as in the Eberhart and Russell's (1966) model.

iii). Freeman and Perkins' (1971) model:

In this model, Y_{ijk} is the mean performance in the k^{th} replication of i^{th} genotype in the j^{th} environment. They proposed the following model:

$Y_{ijk} = m + d_i + e_j + g_{ij} + e_{ijk}$

Where,

m, d_i, e_j and g_{ij} are respectively general mean, additive genetic effect, additive environmental effect and genotype environmental interaction calculated in the same way as Perkins' and Jinks' model.

e_{ijk} is the error associated with k^{th} observation.

$e_{ijk} = Y_{ijk} - m - d_i - e_j - g_{ij}$

By a joint regression analysis, in which the sum of square of environment (year) is partitioned into combined regression SS and residual SS (1) as per this model. Here the sum of squares for genotype-environmental interactions is partitioned into heterogeneity of regression and residual (2) following Freeman and Perkins' (1971) model.

The skeletons are as follows:

Environment $_{SS}$
df = (Y – 1) = 4

→ Combined regression $_{SS}$
df = 1

→ Residual $_{SS}$
df = (Y – 2) = 3

G×E or V×Y$_{SS}$
df= (V-1)(Y-1) = 24

→ Heterogeneity of regression SS
d.f = (v – 1) = 6

→ Residual (2) SS
d. f. = (V – 1)(Y – 2) = 18

The whole joint regression analysis is shown in the following table

Table 2: Joint regression analysis table.

Items	DF	SS	MS	VR
Genotype (variety) (V)	(V - 1)	-	MS_1	MS_1/MS_6
Environment (Year) (Y)	(Y - 1)	-	MS_2	MS_2/MS_6
Combined regression	1	-	MS_3	MS_3/MS_4
Residual (1)	(Y – 2)	-	MS_4	MS_4/MS_8
V×Y	(V - 1) × (Y - 1)	-	MS_5	MS_5/MS_8
a) Heterogeneity of regression	(V - 1)	-	MS_6	MS_6/MS_7
b) Residual (2)	(V - 1) (Y - 2)	-	MS_7	MS_5/MS_6
Within error	VY (p- 1)	-	MS_8	

1. Stability parameters:

In this model, regression co-efficient (b_i) and deviation from regression ($\overline{S}^2{}_{d_i}$) are measured as stability parameters.

(i). Regression co-efficient (b_i):

For the calculation of regression co-efficient the following steps are to be considered.

a. Estimation of environmental index:

According to this model environmental index is estimated in two ways: i) Divide the replications into groups, so that the one group may be used for measuring the average performance of varieties in various environments and the other group, averaging over the varieties is used for estimating the environmental index. ii) Use one or more varieties as check and assess the environmental index on the basis of their performance.

$$Z_i = Y_{.i} - \overline{Y}_{..}$$

Where, Z_i = environmental index

$Y_{.j}$ = The total over all the varieties under j[th] environment and

$$\overline{Y}_{..} = \frac{\sum_i \sum_j Y_{ij}}{Total\ number\ of\ observations}$$

b. Computation of regression co-efficient (b_i) for each line:

$$b_i = \frac{\sum_j Y_{ij} Z_i}{\sum_j Z_i^2}$$

Where,

$\sum_j Z_i^2$ is the sum of square of environments.

$\sum_j Y_{ij} Z_i$ for each of the lines the sum of products of environmental index (Z_i) with the corresponding mean of that varieties at each environment. These values may be obtained in the following manner:

$$[Y][Z] = [S]$$

$$[Y][Z] = \sum_j Y_{ij} Z_i = [S]$$

Where,

$[Y]$ = Matrix of mean.

$[Z]$ = Vector of environmental index, and

$[S]$ = Vector of sum of products $= \sum_{j} Y_{ij} Z_i$

i.e., $\sum_{j} Y_{ij} I_j$

c. Computation of $\bar{S}^2{}_{d_i}$

In general, it is obtained by subtracting the variance due to regression from $\sigma^2{}_y$. It is calculated as follows:

$$\bar{S}^2{}_{d_i} = \left[\frac{\sum_{ij} \sigma^2{}_{ij}}{(Y-2)} \right] - \frac{S^2{}_e}{r}$$

Where,

$$\sum_{j} \delta_{ij}{}^2 = \delta^2{}_{v_i} - b \sum_{j} Y_{ij} Z_i$$

and $\frac{S^2{}_e}{r}$ = Error mean square.

RESULTS

A. *STUDY OF VARIABILITY*

To test of variability of chilli varieties under study, the range, mean with standard error and co-efficient of variability in percentage were estimated and are described separately. Obtained values are given in Table 1A – 1J.

1. Range: The highest and the lowest values of a population are the measurement of range. The values for ranges in ten different characters were different.

Number of secondary branches at maximum flowering stage (NSBMF):

The highest range of variation for NSBMF was observed in the variety *nigra* (6 – 33) in 1997, while the lowest range of variation was found in the variety *fasciculatum* (6 – 17).

In 1998, the highest range of variation for NSBMF was observed for the variety *fasciculatum* (6 – 12) and the lowest range of variation was found in the variety *abbreviatum* and *nigra* with the value of 4 – 12.

In 1999, *abbreviatum* showed the highest range of variation with the value of (9 – 33) and the lowest range of variation (9 – 19) was shown by the variety *conoides*.

The highest range of variation for NSBMF was observed in the variety *conoides* (5 – 19) for the year 2000, while the lowest range of variation for the same year was found in the variety *fasciculatum* (13 – 19).

In 2001, the highest range of variation for NSBMF was observed for the variety *abbreviatum* (7– 30) and the lowest range of variation was found in the variety *conoides* with the value of 4 – 12.

Number of Secondary branches at first flowering stage (NSBFF):

In 1999, *abbreviatum* showed the highest range of variation with the value of (2 – 20) and the lowest range of variation (3 – 13) was shown by the variety *conoides*.

In 1998, the highest range of variation for NSBFF was observed for the variety *acuminatum* (0 – 11) and the lowest range of variation was found in the varieties *fasiculatum* and *conoides* with the value of 1 – 6 and 0 – 5, respectively.

The highest range of variation for NSBFF was observed in the variety *conoides* (0 – 8) for the year 1999, while the lowest range of variation for the same year was found in the variety *cerasiformis* (0 – 2).

In 2000, *annuum* showed the highest range of variation with the value of (0 – 6) and the lowest range of variation (0 – 4) was shown by the variety *nigra.*

The highest range of variation for NSBFF was observed in the variety *abbreviatum* (3 – 18) for the year 2001, while the lowest range of variation for the same year was found in the variety *fasiculatum* (9 – 18).

Plant height at maximum flowering stage (PHMF):

The highest range of variation for PHMF was observed in the variety *conoides* (23.5 – 71.5) in 1997, while the lowest range of variation was found in the variety *fasciculatum* (23.2 – 42.9) in 1997.

In 1998, the highest range of variation for PHMF was observed for the variety *abbreviatum* (14.1 – 42.2) and the lowest range of variation was found in the variety *conoides* with the value of 22.1 – 34.9.

In 1999, *acuminatum* showed the highest range of variation with the value of (29.3 – 73.2) and the lowest range of variation (39.4 – 53.7) was shown by the variety *abbreviatum.*

The highest range of variation for PHMF was observed in the variety *annuum* (18.1 – 65.2) for the year 2000, while the lowest range of variation for the same year was found in the variety *acuminatum* (37.5 – 52.7).

In 2001, the highest range of variation for PHMF was observed for the variety *nigra* (37.2–111) and the lowest range of variation was found in the variety *cerasiformis* with the value of 42.1 – 65.3.

Number of primary branches at first flowering stage (NPBFF):

In 1997, *abbreviatum* showed the highest range of variation with the value of (5 – 17) and the lowest range of variation (3 – 10) was shown by the variety *conoides.*

In 1998, the highest range of variation for NPBFF was observed for the variety *nigra* (1 – 5) and the lowest range of variation was found in the variety *conoides, cerasiformis* and *fasiculatum* with the values of 2 – 4, 1 – 3 and 2 – 4, respectively

The highest range of variation for NPBFF was observed in the variety *abbreviatum* (1 – 10) for the year 1999, while the lowest range of variation for the same year was found in the variety *annuum* (2 – 8).

In 2000, *acuminatum* showed the highest range of variation with the value of 1 – 8 and the lowest range of variation (0 – 6) was shown by the variety *nigra.*

The highest range of variation for NPBFF was observed in the variety *acuminatum* (1 – 7) for the year 2001, while the lowest range of variation for the same year was found in the variety *cerasiformis* (2 – 4).

Number of primary branches at first flowering stage (NPBFF):

The highest range of variation for PHFF was observed in the variety *acuminatum* (16.1 – 57.5) in 1997, while the lowest range of variation was found in the variety *conoides* (15.8 – 31.5) in 1997.

In 1998, the highest range of variation for PHFF was observed for the variety *cerasiformis* (15 – 44) and the lowest range of variation was found in the variety *acuminatum* with the value of 12.5 – 18.5.

In 1999, *nigra* showed the highest range of variation with the value of 22.1 – 50.5 and the lowest range of variation (19.3 – 38.1) was shown by the variety *abbreviatum.*

The highest range of variation for PHFF was observed in variety *fasiculatum* (14.1 – 31.1) for the year 2000, while the lowest range of variation for the same year was found in the variety *cerasiformis* (16.1 – 23.4).

In 2001, the highest range of variation for PHFF was observed for the variety *acuminatum* (14.1– 62) and the lowest range of variation was found in the variety *cerasiformis* with the value of 18.1 – 39.1.

Leaf area at first flowering stage (LAFF):

In 1997, *nigra* showed the highest range of variation with the value of 7.2 – 46.5 and the lowest range of variation (8 – 19.5) was shown by the variety *ceraciformis.*

In 1998, the highest range of variation for LAFF was observed for the variety *fasiculatum* (6 – 23.8) and the lowest range of variation was found in the variety *abbreviatum* with the value of 1 – 4.

The highest range of variation for LAFF was observed in the variety *acuminatum* (11 – 36.7) for the year 1999, while the lowest range of variation for the same year was found in the variety *cerasiformis* (7.3 – 22.).

In 2000, *cerasiformis* showed the highest range of variation with the value of 4.1 – 25 and the lowest range of variation (9.7 – 16.27) was shown by the variety *annuum.*

The highest range of variation for LAFF was observed in the variety *acuminatum* (2.8 – 22.5) for the year 2001, while the lowest range of variation for the same year was found in the variety *cerasiformis* (6.8 – 16.8).

Leaf area at maximum flowering stage (LAMF):

The highest range of variation for LAMF was observed in the variety *acuminatum* (8 – 18) in 1997, while the lowest range of variation was found in the variety *cerasiformis* (7.5 – 18.5) in 1997.

In 1998, the highest range of variation for LAMF was observed for the variety *annuum* (2.8 – 14.9) and the lowest range of variation was found in the variety with the value of 3 – 9.6.

In 1999, *fasciculatum* showed the highest range of variation with the value of 2.5 – 21.6 and the lowest range of variation (3.1 – 10) was shown by the variety *acuminatum.*

The highest range of variation for LAMF was observed in the variety *cerasiformis* (3.1 – 15.45) for the year 2000, while the lowest range of variation for the same year was found in the variety *conoides* (16.1 – 23.4).

In 2001, the highest range of variation for LAMF was observed for the variety *conoides* (3.1– 16.5) and the lowest range of variation was found in the variety *annuum* with the value of 7.2 – 15.1.

Number of primary branches at maximum flowering stage (NPBMF):

In 1997, *abbreviatum* showed the highest range of variation with the value of (3 – 7) and the lowest range of variation (3 –10) was shown by the variety *conoides.*

In 1998, the highest range of variation for NPBMF was observed for the variety *acuminatum* (0 – 4) and the lowest range of variation was found in the variety *abbreviatum* with the value of 1 – 2.

The highest range of variation for NPBMF was observed in the variety *annuum* (2 – 18) for the year 1999, while the lowest range of variation for the same year was found in the variety *nigra* (2 – 8).

In 2000, *acuminatum* showed the highest range of variation with the value of 1 – 8 and the lowest range of variation (1 – 4) was shown by the variety *conoides*..

The highest range of variation for NPBMF was observed in the variety *acuminatum* (1 – 7) for the year 2001, while the lowest range of variation for the same year was found in the variety *nigra* (2 – 5).

Number of leaf at maximum flowering stage (NLMF):

The highest range of variation for NLMF was observed in the variety *conoides* (105 – 580) in 1997, while the lowest range of variation was found in the variety *fasciculatum* (102 – 203) in 1997.

In 1998, the highest range of variation for NLMF was observed for the variety *acuminatum* (31 – 189) and the lowest range of variation was found in the variety *abbreviatum* with the value of 84 - 157.

In 1999, *annuum* showed the highest range of variation with the value of 411 – 1023 and the lowest range of variation (321 – 621) was shown by the variety *fasciculatum*.

The highest range of variation for NLFF was observed in the variety *nigra* (114 – 587) for the year 2000, while the lowest range of variation for the same year was found in the variety *fasciculatum* (315 – 517).

In 2001, the highest range of variation for NLFF was observed for the variety *fasciculatum* (95– 201) and the lowest range of variation was found in the variety *conoides* with the value of 101 – 165.

Number of leaf at first flowering stage (NLFF):

The highest range of variation for NLFF was observed in the variety *nigra* (6 – 17.82) in 1997, while the lowest range of variation was found in the variety *fasciculatum* (5 – 13.4) in 1997.

In 1998, the highest range of variation for NLFF was observed for variety *acuminatum* (4.1 – 16.2) and the lowest range of variation was found in the variety *fasciculatum* with the value of 2.7 – 9.6.

In 1999, *fasciculatum* showed the highest range of variation with the value of 2 – 21.6 and the lowest range of variation (5.06 – 11.16) was shown by the variety *acuminatum.*

The highest range of variation for NLFF was observed in the variety *cerasiformis* (3.0 – 16.79) for the year 2000, while the lowest range of variation for the same year was found in the variety *conoides* (5.3 – 9.2).

In 2001, the highest range of variation for NLFF was observed for the variety *conoides* (3.1– 16.5) and the lowest range of variation was found in the variety *abbreviatum* with the value of 5.7 – 13.8.

2. Standard Error of Mean:

Values of mean with standard error obtained from different quantitative characters of seven varieties of chilli in five consecutive years (1997 - 2001) were different and are presented in Table 1A – 1J. For each of the characters as calculated, the values of mean showed variation from year to year in each variety.

Number secondary branches at maximum flowering stage (NSBMF):

For this character the highest mean with the standard error was 18.65 ± 2.74 in the variety *conoides*, while the lowest mean with standard error was 11.55 ± 3.058 in the variety *annuum* in 1997.

In 1998, the highest mean with standard error was 20.3 ± 1.8988 for the variety *fasciculatum* and the lowest value of mean with standard error was 5.35 ± 1.1838 for the variety *acuminatum.*

The variety *nigra* showed the highest mean with the standard error with the value of 20.7 ± 4.0078 and *fasciculatum* showed the lowest mean with standard error with the value of 14.25 ± 2.4275 in the year 1999.

The highest value of mean with the standard error was calculated in 2000 for *fasciculatum* with the value of 15.7 ± 0.1987 for NSBMF and the lowest mean with the standard error was estimated in the same year for the variety *cerasiformis* with the value of 7.9 ± 2.0410.

In 2001, the highest mean with the standard error was 30.25 ± 2.5521 for the variety *annuum* and the lowest value of mean with standard error was 18.85 ± 2.4439 for the variety *fasciculatum*.

Number of Secondary branches at first flowering stage (NSBFF):

The variety *nigra* showed the highest mean with standard error with the value of 10.25 ± 2.325 and *annuum* showed the lowest mean with the standard error of 7.0 ± 2.3114 in the year 1997.

In 1998, the highest mean with the standard error was 5.55 ± 2.6000 for the variety *acuminatum* and the lowest value of mean with the standard error was 2.1 ± 0.9680 for the variety *abbreviatum*.

The highest mean with the standard error as calculated for *conoides* was 2.65 ± 0.9110 and for NSBFF the lowest mean with the standard error as estimated for variety *cerasiformis* was 1.35 ± 0.7377 in 1999.

For this character the highest mean with the standard error was 3.2 ± 0.9441 in the variety *acuminatum*, while the lowest mean with the standard error was 1.85 ± 0.7377 in the variety *cerasiformis* in 2000.

In 2001, the highest mean with the standard error was 16.75 ± 6.0584 for the variety *cerasiformis* and the lowest value of mean with the standard error was 7.05 ± 2.2709 for the variety *abbreviatum*.

Plant height at maximum flowering stage (PHMF):

For this character the highest mean with the standard error was 55.92 ± 3.08 in the variety *nigra*, while the lowest mean with the standard error was 32.43 ± 3.39 in the variety *fasciculatum* in 1997.

In 1998, the highest mean with the standard error was 38.5 ± 3.6390 for the variety *fasciculatum* and the lowest value of mean with the standard error was 29.85 ± 4.3390 for the variety *acuminatum*.

The variety *annuum* showed the highest mean with the standard error with the value of 53.78 ± 5.2990 and *acuminatum* showed the lowest mean with the standard error with the value of 31.76 ± 9.5210 in the year 1999.

The highest value of mean with the standard error was calculated for *acuminatum* with the value of 44.96 ± 3.2970 for PHMF and the lowest mean with standard error was estimated in the same year for the variety *fasciculatum* with the value of 29.03 ± 2.2990 in 2000.

In 2001, the highest mean with the standard error was 71.86 ± 11.4710 for the variety *nigra* and the lowest value of mean with standard error was 51.01 ± 6.0770 for the variety *conoides*.

Number of primary branches at first flowering stage (NPBFF):

The variety *fasciculatum* showed the highest mean with the standard error with the value of 11.5 ± 2.5911 and *conoides* showed the lowest mean with the standard error with the value of 6.05 ± 0.8780 in the year 1997.

In 1998, the highest mean with the standard error was 4.0 ± 1.1330 for the variety *cerasiformis* and the lowest value of mean with the standard error was 2.15 ± 0.3790 for the variety *annuum*.

The highest mean with the standard error was calculated for *fasciculatum* with the value of 5.8 ± 1.1100 and the lowest mean with the standard error was estimated for the variety *cerasiformis* with the value of 5 ± 0.6324 in 1999.

For this character the highest mean with the standard error was 3.8 ± 0.7400 in the variety *acuminatum*, while the lowest mean with the standard error was 3.00 ± 1.0140 in the variety *fasciculatum* in 2000.

In 2001, the highest mean with the standard error was 5.25 ± 1.4260 for the variety *fasciculatum* and the lowest value of mean with the standard error was 3.30 ± 0.6800 for the variety *abbreviatum*.

Plant height at first flowering stage (PHFF):

For this character the highest mean with the standard error was 45.21 ± 2.6790 in the variety *nigra*, while the lowest mean with the standard error was 25.20 ± 5.2170 in the variety *fasciculatum* in 1997.

In 1998, the highest mean with the standard error was 25.89 ± 1.6600 for the variety *nigra* and the lowest value of mean with the standard error was 18.55 ± 2.5811 for the variety *abbreviatum*.

The variety *nigra* showed the highest mean with the standard error with the value of 35.05 ± 3.7470 and *abbreviatum* showed the lowest mean with the standard error with the value of 23.96 ± 2.0780 in the year 1999.

The highest mean with the standard error was calculated for *acuminatum* with the value of 27.67 ± 1.6310 and the lowest mean with the standard error was estimated for the variety *cerasiformis* with the value of 17.52 ± 1.4922 in 2000.

In 2001, the highest mean with the standard error was 51.19 ± 5.9660 for the variety *nigra* and the lowest value of mean with the standard error was 32.64 ± 4.9670 for the variety *conoides.*

Leaf area at first flowering stage (LAFF):

The variety *nigra* showed the highest mean with the standard error with the value of 15.54 ± 4.3990 and *abbreviatum* showed the lowest mean with the standard error with the value of 11.7 ± 1.1074 in the year 1997.

In 1998, the highest mean with the standard error was 11.86 ± 2.3250 for the variety *nigra* and the lowest value of mean with the standard error was 7.51 ± 1.4390 for the variety *fasiculatum.*

The highest mean with the standard error was calculated for *nigra* with the value of 20.49 ± 3.6470 and the lowest mean with the standard error was estimated for the variety *fasciculatum* with the value of 16.55 ± 2.1700 in 1999.

For this character the highest mean with the standard error was 14.03 ± 2.5830 in the variety *abbreviatum*, while the lowest mean with the standard error was 12.20 ± 1.8043 in the variety *fasciculatum* in 2000.

In 2001, the highest mean with the standard error was 15.59 ± 3.2730 for the variety *nigra* and the lowest value of mean with the standard error was 12.52 ± 2.1490 for the variety *annuum.*

Leaf area at maximum flowering stage (LAMF):

For this character the highest mean with the standard error was 11.39 ± 1.6500 in the variety *nigra*, while the lowest mean with the standard error was 7.82 ± 1.0394 in the variety *fasciculatum* in 1997.

In 1998, the highest mean with the standard error was 7.12 ± 1.3290 for the variety *nigra* and the lowest value of mean with the standard error was 5.54 ± 0.8060 for the variety *fasciculatum*.

The variety *abbreviatum* showed the highest mean with the standard error with the value of 10.50 ± 2.0920 and *fasciculatum* showed the lowest mean with the standard error with the value of 6.16 ± 2.0290 in the year 1999.

The highest value of mean with the standard error was calculated for *nigra* with the value of 7.92 ± 1.1900 and the lowest mean with the standard error was estimated for the variety *fasciculatum* with the value of 6.08 ± 0.4520 in 2000.

In 2001, the highest mean with the standard error was 12.0 ± 1.5120 for the variety *fasciculatum* and the lowest value of mean with the standard error was 9.1 ± 1.6110 for variety *acuminatum*.

Number of primary branches at maximum flowering stage (NPBMF):

The variety *abbreviatum* showed the highest mean with the standard error with the value of 12.55 ± 4.4670 and *cerasiformis* showed the lowest mean with the standard error with the value of 7.05 ± 1.2580 in the year 1997.

In 1998, the highest mean with the standard error was 3.85 ± 0.6979 for the variety *fasciculatum* and the lowest value of mean with the standard error was 2.7 ± 0.8970 for the variety *acuminatum*.

The highest value of mean with the standard error was calculated for *annuum* with the value of 12.65 ± 2.7460 and the lowest mean with the standard error was estimated for the variety *conoides* with the value of 6.95 ± 1.1269 in 1999.

For this character the high mean with the standard error was 8 ± 1.6470 in the variety *conoides*, while the lowest mean with the standard error was 4.25 ± 1.3560 in the variety *cerasiformis* in 2000.

In 2001, the highest mean with the standard error was 6.75 ± 2.6630 for the variety *fasiculatum* and the lowest value of mean with the standard error was 3.2 ± 0.3854 for the variety *nigra*.

Number of leaf at maximum flowering stage (NLMF):

For this character the highest mean with the standard error was 264.15 ± 43.47 in the variety *abbreviatum*, while the lowest mean with the standard error was 140.05 ± 12.65 in the variety *fasciculatum* in 1997.

In 1998, the highest mean with the standard error was 107.8 ± 17.79 for the variety *cerasiformis* and the lowest mean with the standard error was 64.65 ± 17.65 for the variety *acuminatum*.

The variety *annuum* showed the highest mean with the standard error with the value of 652.6 ± 150.3 and *conoides* showed the lowest mean with the standard error with the value of 288 ± 61.0260 in the year 1999.

The highest value of mean with the standard error as calculated for *nigra* was 397.4 ± 105.54 and the lowest mean with the standard error as estimated for the variety *conoides* was 229.5 ± 87.7033 in 2000.

In 2001, the highest mean with the standard error was 133.9 ± 14.7772 for the variety *cerasiformis* and the lowest value of mean with the standard error was 109.5 ± 18.45 for the variety *fasciculatum*.

Number of leaf at first flowering stage (NLFF):

The variety *nigra* showed the highest mean with the standard error with the value of 11.39 ± 1.6571 and *fasiculatum* showed the lowest mean with the standard error with the value of 7.8 ± 1.0394 in the year 1997.

In 1998, the highest mean with the standard error was 7.12 ± 1.3290 for the variety *nigra* and the lowest value of mean with the standard error was 5.54 ± 0.8064 for the variety *fasciculatum*.

The highest value of mean with the standard error as calculated for *abbreviatum* was 10.55 ± 2.0920 and the lowest mean with the standard error as estimated for the variety *fasciculatum* was 6.16 ± 0.0290 in 1999.

For this character the highest mean with the standard error was 7.96 ± 1.1901 in the variety *nigra*, while the lowest mean with the standard error was 6.08 ± 0.4520 in the variety *fasiculatum* in 2000.

In 2001, the highest mean with the standard error was 12.01 ± 1.5120 for the variety *fasciculatum* and the lowest mean with the standard error was 9.1 ± 1.6113 for the variety *acuminatum*.

3. Co-efficient of Variability in Percentage (C V %):

The co-efficient of variability in percentage (C V %) in different years in each variety showed a noticeable differences for different characters under study, and the values obtained in the present work are presented in Table 1A – 1J.

Number of secondary branches at maximum flowering stage (NSBMF):

The highest C V % was recorded in the variety *annuum* with the value of 156.67 in 1997 and the lowest C V % was noted in the variety *fasciculatum* with the value of 60.82.

In 1998, the highest C V % was 130.9 in the variety *acuminatum* and the lowest C V % was 55.34 in the variety *fasiculatum*.

The variety *cerasiformis* showed the highest C V % with the value of 161.14 and the variety *conoides* showed the lowest C V % with the value of 56.1 in the year 1999.

For this character, the highest C V % was 152.8 in the variety *cerasiformis*, while the lowest C V % was in variety *abbreviatum* with the value of 70.37 in 2000.

The highest C V % was recorded in the variety *annuum* with the value of 421.50 in 1997 and the lowest C V % was noted in the variety *nigra* with the value of 44.12 for this character.

Number of Secondary branches at first flowering stage (NSBFF):

In 1997, the highest C V % was 195.65 in the variety *annuum* and the lowest C V % was 68.15 in the variety *conoides*.

The highest C V % was recorded in the variety *acuminatum* with the value of 282.29 in 1998 and the lowest C V % was noted in the variety *fasiculatum* with the value of 104.21 for this character.

The variety *fasciculatum* showed the highest c. v. % with the value of 536.50 and the variety *nigra* showed the lowest C V % with the value of 134.14 in the year 1999.

The highest C V % was recorded in the variety *fasciculatum* with the value of 264.38 in 2000 and the lowest C V % was noted in the variety *annuum* with the value of 116.64 for this character.

For this character, the highest C V % was 222.63 in the variety *cerasiformis,* while the lowest C V % was in the variety *annuum* with the value of 73.83 in 2001.

Plant height at maximum flowering stage (PHMF):

The highest C V % was recorded in the variety *annuum* with the value of 98.14 in 1997 and the lowest C V % was noted in the variety *nigra* with the value of 32.7 for this character.

In 1998, the highest C V % was 85.98 in the variety *abbreviatum* and the lowest C V % was 33.10 in the variety *cerasiformis.*

The ariety *acuminatum* showed the highest C V % with the value of 92.95 and the variety *conoides* showed the lowest C V % with the value of 7.38 in the year 1999.

For this character, the highest C V % was 884.93 in the variety *annuum,* while the lowest C V % was in the variety *acuminatum* with the value of 43.38 in 2000.

The highest C V % was recorded in the variety *nigra* with the value of 94.48 in 1997 and the lowest C V % was noted in the variety *cerasiformis* with the value of 35.66 for this character.

Number of primary branches at first flowering stage (NPBFF):

In 1997, the highest C V % was 126.21 in the variety *annuum* and the lowest C V % was 80.04 in the variety *conoides.*

The highest C V % was recorded in the variety *abbreviatum* with the value of 207.49 in 1998 and the lowest C V % was noted in the variety *nigra* with the value of 96.24 for this character.

The variety *abbreviatum* showed the highest C V % with the value of 141.44 and the variety *acuminatum* showed the lowest C V % with the value of 69.75 in the year 1999.

The highest C V % was recorded in the variety *fasciculatum* with the value of 200 in 2000 and the lowest C V % was noted in the variety *annuum* with the value of 112.00 for this character.

For this character, the highest C V % was 209.35 in the variety *acuminatum,* while the lowest C V% was in the variety *nigra* with the value of 106.30 in 2001.

Plant height at first flowering stage (PHFF):

The highest C V% was recorded in the variety *conoides* with the value of 154.81 in 1997 and the lowest C V% was noted in the variety *cerasiformis* with the value of 62.25 for this character.

In 1998, the highest C V% was 83.23 in the variety *abbreviatum* and the lowest C V% was 37.80 in the variety *nigra.*

The variety *annuum* showed the highest C V% with the value of 70.36 and the variety *fasiculatum* showed the lowest C V% with the value of 37.84 in the year 1999.

For this character, the highest C V% was 81.94 in the variety *fasiculatum,* while the lowest C V% was in the variety *acuminatum* with the value of 34.37 in 2000.

The highest C V% was recorded in the variety *acuminatum* with the value of 124.84 in 1997 and the lowest C V% was noted in the variety *nigra* with the value of 68.95 for this character.

Leaf area at first flowering stage (LAFF):

In 1997, the highest C V% was 167.42 in the variety *nigra* and the lowest C V% was 55.82 in the variety *abbreviatum.*

The highest C V% was recorded in the variety *abbreviatum* with the value of 119.989 in 1998 and the lowest C V% was noted in the variety *acuminatum* with the value of 101.23 for this character.

The variety *abbreviatum* showed the highest C V% with the value of 141.50 and the variety *acuminatum* showed the lowest C V% with the value of 80.11 in the year 1999.

The highest C V% was recorded in the variety *cerasiformis* with the value of 159.3 in 2000 and the lowest C V % was noted in the variety *annuum* with the value of 57.55 for this character.

For this character, the highest C V % was 124.18 in the variety *nigra,* while the lowest C V % was in the variety *fasciculatum* with the value of 32.54 in 2001.

Leaf area at maximum flowering stage (LAMF):

The highest C V % was recorded in the variety *conoides* with the value of 96.39 in 1997 and the lowest C V % was noted in the variety *acuminatum* with the value of 67.22 for this character.

In 1998, the highest C V % was 150.21 in the variety *annuum* and the lowest C V% was 73.52 in the variety *conoides.*

The variety *fasciculatum* showed the highest C V % with the value of 194.86 and the variety *acuminatum* showed the lowest C V % with the value of 60.31 in the year 1999.

For this character, the highest C V % was 153.71 in the variety *cerasiformis,* while the lowest C V % was in the variety *fasciculatum* with the value of 43.96 in 2000.

The highest C V % was recorded in the variety *acuminatum* with the value of 104.78 in 1997 and the lowest C V % was noted in the variety *nigra* with the value of 59.99 for this character.

Number of primary branches at maximum flowering stage (NPBMF):

In 1997, the highest C V % was 210.58 in the variety *abbreviatum* and the lowest C V % was 69.81 in the variety *conoides.*

The highest C V % was recorded in the variety *abbreviatum* with the value of 171.36 in 1998 and the lowest C V % was noted in the variety *acuminatum* with the value of 79.81 for this character.

The variety *abbreviatum* showed the highest C V % with the value of 248.00 and the variety *cerasiformis* showed the lowest C V % with the value of 96.66 in the year 1999.

The highest C V % was recorded in the variety *fasiculatum* with the value of 233.42 in 2000 and the lowest C V % was noted in the variety *nigra* with the value of 71.26 for this character.

For this character, the highest C V % was 179.35 in the variety *abbreviatum*, while the lowest C V % was in the variety *acuminatum* with the value of 88.19 in 2001.

Number of leaf at maximum flowering stage (NLMF):

The highest C V % was recorded in the variety *annuum* with the value of 138.83 in 1997 and the lowest C V % was noted in the variety *fasiculatum* with the value of 53.29 for this character.

In 1998, the highest C V % was 181.76 in the variety *abbreviatum* and the lowest C V % was 46.79 in the variety *fasiculatum*.

The variety *annuum* showed the highest C V % with the value of 136.27 and the variety *abbreviatum* showed the lowest C V % with the value of 81.45 in the year 1999.

For this character, the highest C V % was 181.19 in the variety *abbreviatum*, while the lowest C V % was in the variety *acuminatum* with the value of 51.19 in 2000.
The highest C V % was recorded in the variety *acuminatum* with the value of 100.42 in 2001 and the lowest C V % was noted in the variety *nigra* with the value of 57.43 for this character.

Number of leaf at first flowering stage (NLFF):

In 1997, the highest C V % was 96.39 in the variety *conoides* and the lowest C V % was 67.22 in the variety *acuminatum*.

The highest C V % was recorded in the variety *annuum* with the value of 150.19 in 1998 and the lowest C V % was noted in the variety *conoides* with the value of 73.52 for this character.

The variety *cerasiformis* showed the highest C V % with the value of 117.80 and the variety *acuminatum* showed the lowest C V % with the value of 60.31 in the year 1999.

The highest C V % was recorded in the variety *cerasiformis* with the value of 153.71 in 2000 and the lowest C V % was noted in the variety *conoides* with the value of 59.99 for this character.

For this character, the highest C V % was 104.76 in the variety *acuminatum*, while the lowest C V % was in the variety *nigra* with the value of 88.19 in 2001.

Table 1A: Ranges (highest and lowest value), means with standard error and co-efficient of variability (C V %) of character NSBMF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		NSBMF				
		1997	1998	1999	2000	2001
abbreviatum	Range	4 – 22	4 – 12	9 – 33	6 – 13	7 – 30
	Mean with SE	14.7 ± 2.39	6.5 ± 0.676	17.85 ± 4.15	9 ± 1.069	25.35 ± 2.286
	C V %	96.49	61.53	137.68	70.27	53.37
annuum	Range	2 – 17	4 – 12	10 – 30	6 – 18	10 – 32
	Mean with SE	11.55 ± 3.05	7.3 ± 1.01	17.8 ± 3.38	13.3 ± 1.85	30.25 ± 21.55
	C V %	156.67	82.41	112.38	82.43	421.5
acuminatum	Range	11 – 24	2 – 14	10 – 30	6 – 14	8 – 27
	Mean with SE	18.5 ± 2.699	5.35 ± 1.18	16.65 ± 3.33	10.2 ± 1.46	19.8 ± 2.67
	C V %	86.31	130.90	118.46	85.01	79.88
nigra	Range	6 – 33	4 – 12	12 – 30	6 – 15	8 – 28
	Mean with SE	16.15 ± 3.92	13.4 ± 2.61	20.7 ± 4.01	10.8 ± 1.83	22.1 ± 1.84
	C V %	143.76	116.05	114.54	100.24	49.32
conoides	Range	7 – 26	4 – 14	9 – 19	5 – 19	15 – 25
	Mean with SE	18.65 ± 2.73	8.75 ± 1.42	16.15 ± 1.53	12.5 ± 2.5	20.15 ± 1.51
	C V %	86.79	96.46	56.08	118.38	44.12
cerasiformes	Range	8 – 24	6 – 14	9 – 30	4 – 13	16 – 24
	Mean with SE	13.55 ± 2.01	12 ± 1.46	17.2 ± 4.684	7.9 ± 2.041	20.3 ± 2.057
	C V %	87.77	72.16	161.1	152.8	59.96
fasciculatum	Range	6 – 17	6 – 24	10 – 24	13 – 19	12 – 30
	Mean with SE	15.5 ± 1.598	20.3 ± 1.89	14.25 ± 2.427	15.7 ± 1.98	18.85 ± 2.44
	C V %	60.82	55.33	100.78	74.8	76.70

Table 1 B: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C V%) of character NSBFF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		NSBFF				
		1997	1998	1999	2000	2001
abbreviatum	Range	2 – 20	0 – 8	0 – 4	0 – 5	3 – 8
	Mean with SE	9.25 ± 2.07	2.1 ± 0.968	2.25 ± 0.7791	2.25 ± 0.779	7.05 ± 2.276
	C V %	132.95	272.72	204.87	204.87	191.06
annuum	Range	2 – 18	0 – 6	0 – 4	0 – 6	3 – 16
	Mean with SE	7 ± 2.311	3.1 ± 0.824	1.45 ± 0.596	2.85 ± 0.561	11.75 ± 1.46
	C V %	195.35	157.37	243.34	116.63	73.82
acuminatum	Range	3 – 20	0 – 11	0 – 4	0 – 6	4 – 17
	Mean with SE	8.95±2.4868	5.55 ± 2.648	1.85 ± 0.718	3.2 ± 0.944	10.45 ± 2.200
	C V %	164.38	282.28	229.65	174.55	124.56
nigra	Range	5 – 19	0 – 8	0 – 4	0 – 4	3 – 16
	Mean with SE	10.25 ± 2.32	3.35 ± 1.424	1.7 ± 0.385	1.85 ± 0.737	11.7 ± 1.541
	C V %	134.21	251.61	134.13	235.92	77.9607
conoides	Range	3 – 13	0 – 5	0 – 8	1 – 6	3 – 16
	Mean with SE	8.95 ± 1.303	2.95 ± 1.048	2.65 ± 0.911	2.3 ± 0.512	12.75 ± 3.015
	C V %	86.14	210.19	203.38	131.87	139.91
cerasiformes	Range	4 – 15	0 – 8	0 – 2	1 – 6	6 – 17
	Mean with SE	8.75 ± 1.446	2.95 ± 1.258	1.35 ± 0.737	2.65 ± 0.971	16.1 ± 6.058
	C V %	97.81	252.42	323.30	216.94	222.63
fasciculatum	Range	3 – 12	1 – 6	0 – 4	0 – 5	9 – 12
	Mean with SE	7.55 ± 1.66	2.95 ± 0.519	1.95 ± 1.76	2.55 ± 1.13	9.65 ± 3.476
	C V %	130.75	104.20	536.50	264.37	213.14

Table 1C: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C.V.%) of character PHMF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		PHMF				
		1997	1998	1999	2000	2001
abbreviatum	Range	40.2 – 77.5	14.1 – 42.2	39.4 – 53.7	24.2 – 46.1	28.3 – 70.3
	Mean with SE	51.04 ± 4.176	29.85 ± 4.339	45.7 ± 3.6223	32.2 ± 3.267	51.0 ± 3.704
	C V %	48.41	85.98	7.91	59.86	42.90
annuum	Range	21.2 – 53.2	19.9 – 39.1	52 – 79	18.1 – 65.2	26.0 – 75.0
	Mean with SE	37.40 ± 6.204	30.72 ± 3.142	53.78 ± 5.29	20.16 ± 30.16	53.93 ± 5.78
	C V %	98.13	60.51	9.85	884.92	63.49
acuminatum	Range	28.2 – 51.2	20.7 – 39.3	29.3 – 73.2	37.5 – 52.7	34 – 72
	Mean with SE	44.35 ± 3.90	30.04 ± 2.673	31.76 ± 29.52	44.9 ± 3.297	55.14 ± 6.613
	C V %	52.15	52.65	92.95	43.38	70.95
nigra	Range	47 – 58.5	26.1 – 47	32.2 – 58.8	22.1 – 57.2	37.2 – 111
	Mean with SE	55.92 ± 3.08	37.08 ± 3.22	49.6 ± 4.12	45.19 ± 5.22	71.86 ± 11.47
	C V %	32.68	51.49	8.31	68.35	94.48
conoides	Range	23.5 – 71.5	22.1 – 34.9	23.1 – 56.3	18.1 – 52.3	43.1 – 70.2
	Mean with SE	47.88 ± 5.77	33.99 ± 2.43	54.53 ± 4.03	36.45 ± 3.37	51.01 ± 6.017
	C V %	71.35	42.35	7.38	54.75	69.79
cerasiformes	Range	20.2 – 51.5	25.2 – 39.3	23.1 – 61.2	15.2 – 52.3	42.1 – 65.3
	Mean with SE	43.33 ± 4.096	35.28 ± 1.973	39.65 ± 4.605	29.47 ± 5.963	53.7 ± 3.2353
	C V %	55.93	33.10	11.62	119.68	35.66
fasciculatum	Range	23.2 – 42.9	26.2 – 47.3	20.7 – 56.2	20.3 36.1	31.0 – 72.3
	Mean with SE	32.435 ± 3.39	38.5 ± 3.63	34.77 ± 3.016	29.03 ± 2.299	57.39 ± 8.636
	C V %	61.84	55.9256	8.67	46.86	89.02

Table 1D: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C.V.%) of character NPBFF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		NPBFF				
		1997	1998	1999	2000	2001
abbreviatum	Range	5 – 17	0 – 2	1 – 10	1 – 6	1 – 5
	Mean with SE	11.15 ± 2.87	2.4 ± 0.841	5.3 ± 1.26	3.35 ± 0.677	3.3 ± 0.680
	C V %	152.48	207.49	141.44	119.58	121.96
annuum	Range	1 – 11	0 – 4	2 – 8	1 – 6	2 – 7
	Mean with SE	5.85 ± 1.60	2.15 ± 0.37	5.15 ± 1.219	3.25 ± 0.615	3.55 ± 0.726
	C V %	162.21	104.52	140.08	112.00	120.99
acuminatum	Range	2 – 12	0 – 4	3 – 10	1 – 8	1 – 7
	Mean with SE	8.1 ± 2.103	2.4 ± 0.650	5.45 ± 0.642	3.8 ± 0.740	3.6 ± 1.273
	C V %	153.60	160.29	69.74	115.31	209.34
nigra	Range	5 – 13	1 – 5	2 – 8	0 – 6	2 – 5
	Mean with SE	7.35 ± 1.404	3.95 ± 0.642	5.45 ± 1.061	3.05 ± 0.932	3.45 ± 0.619
	C V %	113.05	96.23	115.24	180.92	106.30
conoides	Range	3 – 10	2 – 4	2 – 10	1 – 4	2 – 5
	Mean with SE	6.05 ± 0.818	3.15 ± 0.8627	5.6 ± 0.841	3.1 ± 0.8246	3.65 ± 0.895
	C V %	80.04	162.02	88.92	157.37	145.12
cerasiformes	Range	3 – 12	1 – 3	2 – 9	1 – 5	2 – 4
	Mean with SE	6.55 ± 1.247	4 ± 1.13	5 ± 0.632	3.45 ± 1.152	3.35 ± 0.911
	C V %	112.65	167.70	74.83	197.54	160.89
fasciculatum	Range	5 – 15	2 – 4	2 – 10	1 – 6	2 – 6
	Mean with SE	11.5 ± 2.59	3.75 ± 0.815	5.8 ± 1.110	3 ± 1.014	5.25 ± 1.426
	C V %	133.30	128.58	113.32	200	160.78

Table 1E: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C.V.%) of character PHFF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		PHFF 1997	1998	1999	2000	2001
abbreviatum	Range	27 – 53.2	9.3 – 25.5	19.3 – 33.1	12.1 – 27.3	22.9 – 50
	Mean with SE	33.94 ± 4.185	18.35 ± 2.581	23.96 ± 2.078	22.08 ± 2.742	34.87 ± 4.845
	C V %	72.95	83.23	51.32	73.46	82.21
annuum	Range	26 – 48.5	10.6 – 30.5	17.1 – 41.5	18.1 – 35.1	26.5 – 60.1
	Mean with SE	31.23 ± 6.861	20.91 ± 2.630	29.61 ± 3.522	24.36 ± 2.563	37.71 ± 6.84
	C V %	129.9	74.41	70.36	62.25	107.3
acuminatum	Range	16.1 – 57.5	19.5 – 18.5	21.1 – 40	17.1 – 34.5	14.1 – 62
	Mean with SE	34.88 ± 6.49	23.45 ± 3.632	29.69±3.07988	27.67 ± 1.6314	35.23 ± 7.435
	C V %	110.18	91.62	61.37	34.87	124.
nigra	Range	38 – 56.2	20.1 – 32.5	22.1 – 50.5	17 – 30.1	27.0 – 73
	Mean with SE	45.21 ± 2.67	25.987 ± 1.663	35.05 ± 3.747	26.37 ± 1.788	51.195 ± 5.966
	C V %	35.05	37.80	63.25	40.12	68.95
conoides	Range	15.8 – 31.5	15.5 – 30.5	21.5 – 42.3	12.1 – 23.4	29.1 – 48
	Mean with SE	28.71 ± 7.51	22.7 ± 1.6546	32.21 ± 2.1863	21.87 ± 2.524	32.64 ± 4.96
	C V %	154.8	43.12	40.15	68.29	90.04
cerasiformes	Range	22.8 – 39.5	15 – 44	17.7 – 33.4	16.1 – 23.4	18.1 – 39.1
	Mean with SE	30.91 ± 3.28	20.75 ± 2.595	26.54 ± 3.126	17.52 ± 1.491	33.38 ± 5.98
	C V %	62.95	73.98	69.6	50.38	106.0
fasciculatum	Range	16.5 – 35.5	15.3 – 29.3	19.1 – 33.1	14.1 – 31.1	21.1 – 60
	Mean with SE	25.20 ± 5.21	21.12 ± 1.68	25.67 ± 1.642	21.95 ± 3.045	36.55 ± 5.72
	C V %	122.46	47.14	37.84	81.94	92.59

Table 1F: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C. V.%) of character LAFF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		LAFF				
		1997	1998	1999	2000	2001
abbreviatum	Range	3 – 17	1 – 4	1 – 12	2 – 21	2 – 14
	Mean with SE	11.73 ± 1.107	9.07 ± 1.841	17.54 ± 4.196	14.0 ± 2.58	12.6 ± 1.17
	C V %	55.82	119.97	141.5	108.	55.2
annuum	Range	7.65 – 18.17	2.6 – 20.3	8.4 – 26.6	9.7 – 16.23	6.7 – 21
	Mean with SE	11.92 ± 2.570	8.797 ± 1.76	17.20 ± 3.334	12.48 ± 1.214	12.52 ± 2.149
	C V %	127.50	118.6	114.6	57.54	101.5
acuminatum	Range	5.9 – 25.5	4.1 – 21.2	11 – 36.7	8.82 – 19.7	2.8 – 22.5
	Mean with SE	14.72 ± 3.069	9.705 ± 1.660	18.65 ± 2.525	12.9 ± 1.413	12.6 ± 2.618
	C V %	123.3	101.2	80.11	64.71	122.
nigra	Range	7.2 – 46.5	6.6 – 19.5	9.4 – 30.9	5.9 – 21	8.0 – 19
	Mean with SE	15.54 ± 4.399	11.86 ± 2.325	20.49 ± 3.647	13.95 ± 2.048	15.59 ± 3.273
	C V %	167.42	115.9	105.3	86.842	124.1
conoides	Range	5.8 – 21.1	6 – 10.2	9.45 – 36.5	7 – 18.72	6.3 – 18
	Mean with SE	12.68 ± 2.488	10.92 ± 2.145	19.87 ± 3.829	13.93 ± 2.031	14.52 ± 1.602
	C V %	116.00	116.1	113.9	86.26	65.27
cerasiformes	Range	8 – 19.5	5.76 – 18.0	7.3 – 22	4.1 – 25	6.8 – 16.8
	Mean with SE	13.099 ± 2.002	9 ± 1.694	16.3 ± 2.313	12.59 ± 3.3	14.19 ± 1.466
	C V %	90.41	111.4	83.69	159.29	61.13
fasciculatum	Range	9.8 – 23.7	6 – 23.8	9.1 – 23.8	7 – 20.8	9.8 – 16.2
	Mean with SE	13.56 ± 2.390	7.51 ± 1.439	16.55 ± 2.175	12.20 ± 1.804	12.94 ± 0.712
	C V %	104.25	113.42	77.74	87.47	32.54

Table 1G: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C.V.%) of character LAMF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		LAMF				
		1997	1998	1999	2000	2001
abbreviatum	Range	5.3 – 14.6	2.9 – 11.78	5.52 – 15.1	3.96 – 9.76	5.7 – 16.8
	Mean with SE	9.16 ± 1.331	6.25 ± 1.19	10.55 ± 2.092	7.71 ± 0.972	10.37 ± 1.42
	C V %	85.89	113.2	117.3	74.64	80.9
annuum	Range	5 – 14.8	2.8 – 14	4.9 – 11.6	4.21 – 13	7.2 – 15.1
	Mean with SE	9.82 ± 1.475	6.00 ± 1.525	8.91 ± 1.458	7.523 ± 1.289	9.9 ± 1.319
	C V %	88.79	150.2	96.84	101.4	78.44
acuminatum	Range	8 – 18	4 – 11.1	3.1 – 10.9	3.1 – 11.6	4 – 13
	Mean with SE	10.60 ± 1.204	6.17 ± 1.446	8.00 ± 0.816	7.87 ± 1.137	9.1 ± 1.611
	C V %	67.2192	138.5	60.30	85.52	104.7
nigra	Range	4.2 – 13	4.5 – 13.5	5.59 – 13.1	4.2 – 15.8	6.5 – 19.5
	Mean with SE	11.393 ± 1.65	7.120 ± 1.329	9.31 ± 1.545	7.96 ± 1.190	11.92 ± 1.20
	C V %	86.04	110.4	98.18	88.45	59.99
conoides	Range	5.29 – 14.3	3 – 10.4	3.24 – 11.78	5 – 9.69	3.1 – 16.5
	Mean with SE	9.63 ± 1.569	6.69 ± 0.83	6.8 ± 0.881	7.30 ± 0.659	11.31 ± 1.44
	C V %	96.39	73.5232	75.81	53.42	75.74
cerasiformes	Range	7.5 – 13.3	3 – 11.02	2.73 – 10	3.1 – 15.14	6 – 16.3
	Mean with SE	8.45 ± 1.1158	5.81 ± 1.219	6.23 ± 1.241	7.13 ± 1.854	11.52 ± 1.49
	C V %	82.69	124.1	117.7	153.7	76.63
fasciculatum	Range	5.04 – 13.4	3 – 9.6	2.5 – 21.6	2.7 – 9.3	6.4 – 16.4
	Mean with SE	7.82 ± 1.039	5.54 ± 0.806	6.16 ± 2.029	6.08 ± 0.452	12.00 ± 1.51
	C V %	78.62	86.10	194.8	43.96	74.54

Table 1H: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C.V.%) of character NPBMF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		NPBMF				
		1997	1998	1999	2000	2001
abbreviatum	Range	3 – 17	1 – 2	1 – 10	1 – 6	1 – 5
	Mean with SE	12.5 ± 4.4671	3.7 ± 1.551	9.05 ± 2.743	5.35 ± 1.549	3.6 ± 1.079
	C V %	210.58	171.3	248.0	177.	179.35
annuum	Range	1 – 11	1 – 4	2 – 18	1 – 5	2 – 7
	Mean with SE	8.1 ± 2.096	3.2 ± 0.680	12.65 ± 2.746	6.9 ± 1.738	4 ± 0.676
	C V %	153.10	149.0	125.7	100	128.4
acuminatum	Range	2 – 12	0 – 4	3 – 10	1 – 8	1 – 7
	Mean with SE	9.05 ± 1.212	2.7 ± 0.897	9 ± 1.3416	7.6 ± 1.025	3.45 ± 0.642
	C V %	79.25	79.81	196.	110.1	88.19
nigra	Range	5 – 13	1 – 5	2 – 8	0 – 6	2 – 5
	Mean with SE	11.2 ± 1.446	3.55 ± 0.962	9.5 ± 1.715	6.15 ± 1.042	3.2 ± 0.385
	C V %	76.39	100.	160.4	71.2	106.83
conoides	Range	3 – 10	2 – 3	2 – 10	1 – 4	2 – 6
	Mean with SE	9.55 ± 1.126	3 ± 0.696	6.95 ± 1.126	8 ± 1.647	3.75 ± 0.455
	C V %	69.81	121.8	137.4	71.80	95.92
cerasiformes	Range	2 – 12	1 – 3	2 – 8	1 – 5	2 – 5
	Mean with SE	7.05 ± 1.258	3.4 ± 0.555	7.7 ± 1.173	4.95 ± 1.356	4.1 ± 1.052
	C V %	105.6	162.1	96.65	151.9	90.163
fasciculatum	Range	6 – 17	2 – 4	2 – 10	1 – 4	2 – 8
	Mean with SE	7.5 ± 0.910	3.85 ± 0.697	9.6 ± 2.448	6.25 ± 0.944	6.75 ± 2.663
	C V %	71.80	89.44	107.2	233.4	150.88

Table 11: Ranges (highest and lowest value), means with standard errors and coefficient of variability (C.V.%) of character NLMF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		NLMF				
		1997	1998	1999	2000	2001
abbreviatum	Range	4.9 – 14.6	3 – 11.78	5.4 – 14.49	3.96 – 9.76	5.7 – 13.8
	Mean with SE	9.16 ± 1.331	6.258 ± 1.198	10.55 ± 2.092	7.71 ± 0.972	10.3 ± 1.420
	C V %	85.89	113.29	117.3	74.64	80.99
annuum	Range	4.8 – 14.8	4.8 – 13.3	5.63 – 14.5	4.9 – 13.12	5.1 – 15.1
	Mean with SE	9.82 ± 1.475	5.91 ± 1.5003	8.9 ± 1.458	7.52 ± 1.2897	9.9 ± 1.3194
	C V %	88.79	150.19	96.84	101.4	78.44
aciminatum	Range	5 – 15.39	4.1 – 16.2	5.06 – 11.16	3.1 – 10.9	2.2 – 13.7
	Mean with SE	10.6 ± 1.204	6.17 ± 1.4463	8.00 ± 0.816	7.87 ± 1.1376	9.1 ± 1.6113
	C V %	67.21	138.59	60.30	85.52	104.7
nigra	Range	6 – 17.82	4.2 – 13.5	5.9 – 13.8	4.22 – 11.8	6.4 – 15.8
	Mean with SE	11.39 ± 1.65	7.12 ± 1.3298	9.3 ± 1.5453	7.96 ± 1.1901	11.92 ± 1.20
	C V %	86.04	110.4	98.18	88.45	59.99
conoides	Range	5.24 – 14.3	3 – 10.4	3.24 – 11.78	5.3 – 9.2	3.1 – 16.5
	Mean with SE	9.63 ± 1.569	6.69 ± 0.831	6.88 ± 0.881	7.30 ± 0.6595	11.3 ± 1.448
	C V %	96.39	73.52	75.81	53.42	75.74
cerasiformes	Range	4.9 – 15	3 – 11.02	2.4 – 11.8	3 – 16.79	6 – 19.8
	Mean with SE	8.45 ± 1.181	5.81 ± 1.219	6.2 ± 1.241	7.13 ± 1.8548	11.5 ± 1.492
	C V %	82.69	124.1	117.7	153.7	76.63
fasciculatum	Range	5 – 13.4	2.7 – 9.6	2 – 21.6	2.7 – 9.31	6.4 – 16.4
	Mean with SE	7.82 ± 1.039	5.54 ± 0.806	6.16 ± 2.029	6.08 ± 0.452	12.0 ± 1.512
	C V %	78.62	86.10	194.86	43.96	74.54

Table 1J: Ranges (highest and lowest value), means with standard errors and co-efficient of variability (C.V.%) of character NLFF in Chilli (*Capsicum annuum* L.) in five years (1997 - 2001).

Variety		NLFF				
		1997	1998	1999	2000	2001
abbreviatum	Range	105 – 385	84 – 157	198 – 772	142 – 459	75 – 165
	Mean with SE	264.1 ± 43.47	101. ± 31.25	525. ± 72.37	277.4 ± 84.95	119.7 ± 14.7
	C V %	97.3	181.7	81.45	181.19	72.72
annuum	Range	128 – 265	40 – 123	411 – 1023	217 – 408	75 – 145
	Mean with SE	162. ± 38.16	92.8 ± 18.96	652.6 ± 150.3	323.0 ± 31.35	109.4 ± 14.2
	C V %	138.8	120.8	136.2	57.41	76.93
acuminatum	Range	135 – 286	31 – 189	381 – 989	219 – 420	90 – 170
	Mean with SE	243.4 ± 36.53	64.6 ± 17.65	623 ± 120.4	261 ± 22.587	119.6 ± 20.3
	C V %	88.81	161.5	114.4	51.19	100.41
nigra	Range	105 – 455	51 – 199	109 – 489	127 – 587	90 – 200
	Mean with SE	215.4 ± 47.92	85.4 ± 20.77	625. ± 111.7	397.4 ± 105.5	125.0 ± 12.1
	C V %	131.5	143.8	105.68	157.0	57.429339
conoides	Range	105 – 580	57 – 199	109 – 489	114 – 587	101 – 165
	Mean with SE	167 ± 30.15	97.5 ± 12.07	288 ± 61.02	229. ± 87.70	123.1 ± 13.1
	C V %	106.8	73.23	125.3	226.08	63.226539
cerasiformes	Range	81 – 240	78 – 180	201 – 489	217 – 599	101 – 170
	Mean with SE	157. ± 21.19	107. 8 ± 17.79	362.1 ± 82.82	253. ± 57.745	133.9 ± 14.7
	C V %	79.49	97.68	135.3	134.55	65.28
fasciculatum	Range	102 – 203	81 – 130	321 – 621	315 – 517	95 – 201
	Mean with SE	140.6 ± 12.65	94.9 ± 7.505	419.5 ± 73.75	375.95 ± 48.3	109.5 ± 18.4
	C V %	53.22	46.79	104.	76.09	99.69

B. *ANALYSIS OF VARIANCE:*

In the present investigation, an extensive analysis of variance for ten quantitative characters of chilli were done separately and are presented in Table 2A – 2E. With the seven varieties, 2 replications in 5 consecutive years a mixed model was followed to test main items and their interaction effects.

All the items, which were considered as the sources of variation in the experiment, were tested against their respective within error of each character. The variance ratio (VR or the F value) for the main item i.e. variety item was significant for all the characters, indicating that a real genetic difference existed among the varieties regarding those characters. Significant test for year item indicated that five consecutive years in which plants were grown, were different, for all the ten characters under study.

Replication item was non-significant for all the characters. Variety did not interacted differently with the replication (R) as the V×R item was non-significant for all the characters, except PHMF, where it was significant showing that variety interacted differently with the replications. The V×Y interaction item was significant for all the characters, indicating that all the seven varieties responded differently in different years, except LAFF, where it was non-significant, suggested that varieties did not respond in different years for this character. The years did not interact differently with the replications, as indicated by the non-significant interaction (Y×R) item for the six characters, like NPBMF, NLFF, PHFF, PHMF, NSBFF and NSBMF. Rest of the characters, namely LAMF, NLMF, LAFF and NPBFF were significant, showing that year interacted differently in different replications. The second order interaction (V×R×Y) was observed to be significant for eight characters which suggested that the varieties, years and replications interacted among themselves, except LAFF and NFBFF, where they were non-significant, indicating that varieties, years and replications did not interact among themselves.

C. *COMPONENTS OF VARIATION:*

The total phenotypic (σ^2_P) variation is partitioned into some of its components, namely genotypic (σ^2_g), variety × replication ($\sigma^2_{V\times R}$), variety × year ($\sigma^2_{V\times Y}$), year × replication ($\sigma^2_{Y\times R}$), variety × year × replication ($\sigma^2_{V\times Y\times R}$) and within error ($\sigma^2_w$). All the components were separately calculated for all ten characters, and the values are given in Table 3.

i) Total Phenotypic Variation (σ^2_P):

It is expected that the total phenotypic variation (σ^2_P) is always greater than those of σ^2_g, $\sigma^2_{V\times R}$, $\sigma^2_{V\times Y}$, $\sigma^2_{Y\times R}$, $\sigma^2_{V\times Y\times R}$ and σ^2_w. As the total variation (phenotype) is joint product of these components, and for all the characters under study phenotypic variation was greater as per expectation. A greater portion of total variation appeared mostly due to the within error variation for all the characters (Table 3). The maximum phenotypic variation was observed that for the character NLFF with a value of 16274.0 and the character NPBFF with a value of 5.95 showed the lowest phenotypic variation. The remaining characters followed with their high to low values.

ii) Genotypic variation (σ^2_g):

Genotypic variation for all the characters was calculated and is presented in Table 3. The highest genotypic variation was found for number of leaf at first flowering stage (NLAF) with a value of 492.33, while the lowest genotypic variation was recorded for the character number of secondary branches at maximum flowering stage (NABMF) with a value of – 1.245.

iii) Variation due to variety×replication ($\sigma^2_{V\times R}$):

Character, number of leaf at first flowering stage (NLFF) showed the highest value of variation due to variety×replication ($\sigma^2_{V\times R}$) with a value of 28.945, while plant height at first flowering stage (PHFF) showed the lowest value of variation due to the same item with a value of –0.848.

iv) Variation due to variety × year ($\sigma^2_{V\times Y}$):

The highest value of variation for this item shown by the character number of leaf at first flowering stage (NLFF) was 4132.85. Whereas, the lowest value of variation due to the same item was measured for the character leaf area at first flowering stage (LAFF) was – 0.92.

v) Variation due to year×replication ($\sigma^2_{Y\times R}$):

The character plant height at flowering stage (PHMF) showed the highest value of variation due to year×replication ($\sigma^2_{Y\times R}$) with a value of 1.104, while plant height at first flowering stage (NLFF) showed the lowest value of variation due to the same item with a value of – 6131.

vi) Variation due to variety × year×replication ($\sigma^2_{V\times Y\times R}$):

The highest value of variation for this item shown by the character number of leaf at first flowering stage (NLFF) was 659.35. Whereas the lowest value of variation due to the same item was measured for the character number of primary branches at maximum flowering stage (NPBMF) was 0.437.

vii) Variation due to environment (σ^2_w):

The character number of leaf at first flowering stage (NLFF) showed the highest value of variation due to environment (σ^2_w) with a value of 10965.0, while number of primary branches at first flowering stage (NPBFF) showed the lowest value of variation due to the same item with a value of 4.538.

D. ***CO-EFFICIENTS OF VARIABILITY:***

In respect of calculation of co-efficient of variability, phenotypic (P C V), genotypic (G C V), interactions (V×R cv, V×Y cv, Y×R cv and V×Y×R$_{c.\ v.}$) and error (E C V) were estimated for ten quantitative characters separately over five consecutive years (1997 - 2001) and the results obtained are given in Table 4.

i) Phenotypic co-efficient of variability (P C V):

The highest value of phenotypic co-efficient of variability (P C V) was measured for the character NLFF with the value of 6740.3, while the lowest phenotypic co-efficient of variability was measured for the character NLMF with the value of 105.99. The remaining characters, such as NSBMF, NSBFF, PHMF, NPBFF, PHFF, LAFF, LAMF and NPBMF shows the values of 496.54, 270.31, 556.59, 126.04, 268.29, 192.38, 106.2 and 144.4, respectively.

ii) Genotypic co-efficients of variability (G C V):

Estimates of genotypic co-efficients of variability (G C V) was the highest for NLFF with a value of 203.89 and the lowest genotypic co-efficients of variability was estimated for the character NSBMF with a value of –8.081. The other G C V values were 2.191 for NSBFF, 25.84 for PHMF, 3.20 for NPBFF, 45.15 for PHFF, 8.70 for LAFF, 3.54 for LAMF, 2.08 for NPBMF, 3.54 for NLMF.

iii) V×R interaction co-efficients of variability ($V\times R_{C\,V}$):

The highest value of V×R interaction co-efficient of variability ($V\times R_{C\,V}$) measured for the character NLFF was 11.99, while the lowest V×R interaction co-efficient of variability measured for the character NSBFF was –4.85. The remaining characters, such as NSBMF, PHMF, NPBFF, PHFF, LAFF, LAMF, NPBMF and NLMF shows the values of –2.09, 5.27, -1.18, -2.94, -2.43, -1.72, -0.64, -1.72, respectively.

iv) V×Y interaction co-efficients of variability ($V\times Y_{C\,V}$):

Estimates of V×Y interaction co-efficients of variability ($V\times Y_{C.V}$) was the highest for NLFF with a value of 1711.6 and the lowest V×Y interaction co-efficient of variability was estimated for the character LAFF with a value of –6.81. The other $V\times Y_{C\,V}$ values were 52.99 for NSBMF, 5.13 for NSBFF, 66.414 for PHMF, 19.84 for NPBFF, 17.09 for PHFF, 3.36 for LAMF, 24.5 for NPBMF, 3.36 for NLMF.

v) Year×replication interaction co-efficient of variability ($Y\times R_{C\,V}$):

The highest value of Y×R interaction co-efficient of variability ($Y\times R_{C.V}$) was measured for the character NPBFF with the value of 5.24, while the lowest Year×replication interaction co-efficient of variability was measured for the character NLFF with the value of –1.91. The remaining characters such as NSBMF, NSBFF, PHMF, PHFF, LAFF, LAMF, NPBMF and NLMF showed the values of 1.87, 0.68, 2.59, -1.63, 4.73, 5.12, 1.19, 5.0, respectively for $Y\times R_{C\,V}$.

vi) Variety×year×replication interaction co-efficient of variability ($V\times Y\times R_{C\,V}$):

Estimates due toV×Y×R interaction co-efficients of variability ($V\times Y\times R_{C\,V}$) was the highest for the NLFF with a value of 273.07 and the lowest V×Y×R interaction co-efficients of variability was estimated for the character NPBFF with a value of 2.83. The other $V\times Y\times R_{C\,V}$ values were 28.89 for NSBMF, 44.1 for NSBFF, 42.69 for PHMF, 14.8 for PHFF, 6.40 for LAFF, 8.63 for LAMF, 6.75 for NPBMF, 8.72 for NLMF.

vii) Environmental (Error) co-efficient of variability (E C V):

The highest value due to co-efficient of variability ($Y\times R_{CV}$) was measured for the character NLFF with a value of 4541.4, while the lowest environmental co-efficient of variability was measured for the character NLMF with a value of 87.11. The remaining characters such as NSBMF, NSBFF, PHMF, NPBFF, PHFF, LAFF, LAMF and NPBMF showed the values of 422.95, 223.07, 422.77, 96.12, 195.7, 181.8, 87.26, 114.68, respectively for E C V.

E. *HERITABILITY (h^2b), GENETIC ADVANCE (GA) AND GENETIC ADVANCE EXPRESSED AS PERCENTAGE OF MEAN (G. A.%):*

Heritability, the genetic portion (effect) is transmitted from parent to offspring in comparison to the total or phenotypic variation of a population, is measured to detect the genetic effect possessed by a character, which is transmittable to the descendants. In addition to this genetic advance and genetic advance expressed as percentage of mean were separately calculated for all the characters under study and the results obtained are presented in Table 5.

1. Heritability (h^2_b):

The character PHFF showed the highest heritability with a value of 16.83, while the lowest heritability value was recorded for the character NSBMF with a value of –1.63. The heritability values of the remaining characters were calculated to be 0.81 for NSBFF, 4.57 for PHMF, 2.54 for NPBFF, 4.52 for LAFF, 3.34 for LAMF, -1.44 for NPBMF, 3.34 for NLMF and 3.03 for NLFF.

2. Genetic Advance (G A%):

The highest value of G A was noted for the character NLFF with a value of 7.95 and the lowest value was recorded for the character NSBMF with a value of –0.29. In other cases, values for G A were 0.065, 1.46, 0.13, 3.05, 0.48, 0.21, -0.09 and 0.21 for NSBFF, PHMF, NPBFF, PHFF, LAFF, LAMF, NPBMF and NLMF, respectively.

3. Genetic Advance expressed as percentage of mean (G A %):

The character PHFF showed the highest G A % with a value of 10.57, while the lowest G A % value was recorded for the character NSBMF with a value of –1.90. G A % values of the remaining characters were calculated to be 1.17 for NSBFF, 3.43 for PHMF, 2.7 for NPBFF, 3.51 for LAFF, 2.44 for LAMF, -1.40 for NPBMF, 2.44 for NLMF and 3.29 for NLFF.

Table 2A – 2E: Analysis of variance of G×E interaction of 7 genotypes for different characters in Chilli (*Capsicum annuum* L.)

Table 2A

Items	DF	LAMF			NPBMF		
		SS	MS	VR	SS	MS	VR
Varieties	6	256.93	42.82	5.84**	167.95	27.99	3.77**
Years	4	1880.59	470.15	64.10***	4300.00	1075.00	144.59***
Replications	1	0.16	0.16	0.02NS	7	7	0.94
VxR	6	44.10	7.36	1.00 NS	58.4	9.73	1.31
VxY	24	485.86	20.24	2.76*	1046.03	43.59	5.86**
YxR	4	150.10	37.51	5.11*	51.36	12.84	1.73
VxYxR	24	291.86	12.16	1.65*	236.24	9.84	1.59*
Within Error	630	4652.83	7.39		4713.8	7.45	
Total	699	7762.36			10580.79		

*, ** and *** indicate **significance** at 5%, 1% and 0.1%, respectively.

Table 2B

Items	DF	NLMF			NLFF		
		SS	MS	VR	SS	MS	VR
Varieties	6	256.82	42.80	5.85**	905383.1	150897.2	13.76***
Years	4	1889.11	472.28	64.49***	15362143	3840536	350.22***
Replications	1	0.099	0.099	0.01	12449.01	12449.01	1.14
VxR	6	44.52	7.42	1.01	114040.9	19006.82	1.73
VxY	24	486.99	20.29	2.77*	2405198	100216.6	9.14**
YxR	4	147.03	36.76	5.02**	42572.22	10643.06	0.97
VxYxR	24	293.06	12.21	1.66*	351190.5	14632.94	1.33
Within Error	630	4642.71	7.37		6952430	11035.6	
Total	699	7760.33			26145406		

*, ** and *** indicate **significance** at 5%, 1% and 0.1%, respectively.

Table 2C

Items	DF	LAFF			PHFF		
		SS	MS	VR	SS	MS	VR
Varieties	6	697.03	116.17	4.72**	8747.397	1457.9	25.82***
Years	4	5158.45	1289.61	52.38***	23786.51	5946.627	105.3***
Replications	1	14.72	14.72	0.59	2.473417	2.473	0.04
VxR	6	100.72	16.78	0.68	340.817	56.803	1.01
VxY	24	355.82	14.83	0.60	4749.355	197.890	3.50*
YxR	4	277.89	69.47	2.82*	94.506	23.627	0.42
VxYxR	24	665.74	27.74	1.12	1984.977	82.71	1.5
Within Error	630	15608.48	24.78		35805.48	56.83	
Total	699	22878.86			75511.51		

*, ** and *** indicate **significance** at 5%, 1% and 0.1%, respectively.

Table 2D

Items	DF	NPBFF			PHMF		
		SS	MS	VR	SS	MS	VR
Varieties	6	221.49	36.92	8.134***	12830.6	2138.43	11.89***
Years	4	2427.19	606.79	133.7***	48991.1	12247.78	68.07***
Replications	1	6.81	6.80	1.5	26.42	26.42	0.15
VxR	6	18.41	3.07	0.68	2842.04	473.67	2.63*
VxY	24	590.65	24.61	5.42**	22242.65	926.78	5.15**
YxR	4	87.39	21.85	4.81*	1028.84	257.21	1.42
VxYxR	24	117.45	4.9	1.07	7231.98	361.6	2.01*
Within Error	630	2877.3	4.57		114067.96	179.92	
Total	699	6346.68			209261.59		

*, ** and *** indicate significance at 5%, 1% and 0.1%, respectively.

Table 2E

Items	DF	NSBFF			NSBMF		
		SS	MS	VR	SS	MS	VR
Varieties	6	247.11	41.18	3.33*	793.7	132.28	2.03*
Years	4	9959.82	2489.9	201.43***	12986.24	3246.56	49.84***
Replications	1	0.12	0.12	0.009	30.45	30.45	0.47
VxR	6	140.11	23.35	1.89	561.13	93.52	1.44
VxY	24	1019.62	42.48	3.44*	6548.45	272.85	4.2**
YxR	4	59.99	14.998	1.21	341.31	85.33	1.31
VxYxR	24	735.93	30.66	2.47*	2192.71	91.36	1.4
Within Error	630	7837.1	12.44		41296	65.55	
Total	699	19999.8			64750		

*, ** and *** indicate significance at 5%, 1% and 0.1%, respectively.

Table 3: Components of Variation for the ten quantitative Characters of seven varieties in Chilli (*Capsicum annuum* L.)

Characters	σ^2_P	σ^2_G	$\sigma^2_{V\times R}$	$\sigma^2_{V\times Y}$	$\sigma^2_{Y\times R}$	$\sigma^2_{V\times Y\times R}$	σ^2_W
NSBMF	76.47	-1.245	-0.322	8.161	0.288	4.45	65.135
NSBFF	14.98	0.122	-0.269	0.284	0.038	2.444	12.361
PHMF	240.7	10.995	2.242	28.26	1.104	18.168	179.92
NPBFF	5.950	0.151	-0.056	0.936	0.247	0.133	4.538
PHFF	77.39	13.024	-0.848	4.932	-0.469	4.277	56.475
LAFF	26.05	1.178	-0.33	-0.92	0.640	0.866	24.61
LAMF	8.931	0.298	-0.144	0.287	0.431	0.725	7.338
NPBMF	9.361	-0.135	-0.041	1.588	0.077	0.437	7.435
NLMF	8.91	0.297	-0.144	0.281	0.420	0.733	7.322
NLFF	16274	492.33	28.945	4132.85	-.6131	659.35	10965

Table 4: Co-efficient of variability for ten quantitative characters of seven varieties in chilli (*Capsicum annuum* L.)

Characters	P C V	G C V	VxRc v	VxYc v	YxRc v	VxYxRc v	E C V
NSBMF	496.54	-8.081	-2.092	52.99	1.872	28.89	422.95
NSBFF	270.31	2.191	-4.852	5.1320	0.679	44.095	223.1
PHMF	565.59	25.839	5.267	66.406	2.594	42.693	422.8
NPBFF	126.0	3.199	-1.18	19.84	5.237	2.825	96.1
PHFF	268.29	45.152	-2.943	17.09	-1.626	14.8	195.7
LAFF	192.3	8.7027	-2.43	-6.81	4.731	6.401	181.8
LAMF	106.20	3.54	-1.72	3.36	5.12	8.625	87.3
NPBMF	144.40	-2.08	-0.641	24.50	1.190	6.751	114.7
NLMF	105.99	3.54	-1.72	3.35	5.002	8.719	87.1
NLFF	6740.3	203.89	11.99	1711.6	-1.910	273.07	4541.4

Table 5: Heritability (h^2_b), Genetic Advance (G. A.) and Genetic Advance expressed as percentage of mean (G. A. %) for the ten characters of seven varieties in chilli (*Capsicum annuum* L.).

Characters	h^2_b	G. A.	G. A.%
NSBMF	-1.63	-0.29	-1.90
NSBFF	0. 81	0.065	1.17
PHMF	4.57	1.46	3.43
NPBFF	2.54	0.13	2.70
PHFF	16.83	3.05	10.57
LAFF	4.52	0.48	3.51
LAMF	3.34	0.21	2.44
NPBMF	-1.44	-0.09	-1.40
NLMF	3.34	0.21	2.44
NLFF	3.03	7.95	3.29

F. *STUDY OF G×E INTERACTION:*

In this respect, regression and stability analysis were separately done on the basis of three models, i.e. i) Eberhart and Russell (1966) model, ii) Perkins' and Jinks (1968) model and iii) Freeman and Perkins' (1971) model. The results are as follows:

1. Eberhart and Russell's (1966) Model:

a) Genotypic and Environmental Mean:

In this case, five consecutive years (from 1997 to 2001) seven varieties of chilli were tested on the basis of ten quantitative characters. Being the same data the genotypic and environmental means were same as described in the next model.

b) Joint Regression Analysis:

In the joint regression analysis, the total sum of square is partitioned into variety sum of square and environment + (variety × environment) and pooled error. The other main feature of this analysis is that the sum of square due to variety×environment is further partitioned into two parts, i.e. S.S. due to variety×location (linear) which is in fact SS due to regression and SS due to deviation from linearity of response (i.e., S S due to pooled deviation). The later can be further partitioned as many components as the number of varieties with (S – 2) degrees of freedom each.

Variety item is significant for the character, NPBFF, PHFF, LAFF and NLFF, while the other characters were non-significant. The items, environment (linear) and variety × environment (linear) were also significant for all the characters, when tested with pooled deviation (Table 6A – 6E).

Table 6A: Analysis of variance for regression analysis according to Eberhart and Russell's (1966) model for NSBMF and NSBFF.

Sources	DF	NSBMF			NSBFF		
		SS	MS	F	SS	MS	F
Total	34	1016.4			561.33		
Varieties	6	39.69	6.61	0.91	12.36	2.06	1.77
Environment + (Varieties×Env.)	28	976.54	34.88	4.8*	548.97	19.6	16.1**
Environment (Linear)	1	649.31	649.3	88.95**	497.99	497.9	414.99***
Variety×Env.(Linear)	6	496.56	82.76	11.38**	472.33	78.72	64.72***
Pooled deviation	21	152.76	7.27		25.66	1.22	
abbreviatum	3	0.898			9.59		
annuum	3	46.64			2.75		
acuminatum	3	34.12			3.63		
nigra	3	12.88			1.57		
conoides	3	18.37			1.25		
cerasiformis	3	14.3			6.85		
fasciculatum	3	25.53			0.03		
Pooled error	630	2891.7	4.59		919.8	1.46	

*, ** and *** indicate significance at 5%, 1% and 0.1% respectively.

Table 6B: Analysis of variance for regression analysis according to Eberhart and Russell's (1966) model for PHMF and NPBFF.

Sources	DF	PHMF			NPBFF		
		SS	MS	F	SS	MS	F
Total	34	4203.2			161.96		
Varieties	6	641.5	106.9	2.28	11.1	1.85	4.44*
Environment + (Varieties×Env.)	28	3561.6	127.2	2.71	150.9	5.39	12.95**
Environment (Linear)	1	2449.5	2449.9	52.1**	121.4	121.4	291.73***
Variety×Env.(Linear)	6	1132.6	188.8	4.02*	112.6	18.77	45.12***
Pooled deviation	21	986.9	46.99		8.73	0.42	
abbreviatum	3	86.11			1.49		
annuum	3	253.39			1.34		
acuminatum	3	254.76			0.76		
nigra	3	56.757			0.78		
conoides	3	110.50			1.01		
cerasiformis	3	25.22			0.56		
fasciculatum	3	200.20			2.79		
Pooled error	630	10577.7	16.79		144.9	0.23	

*, ** and *** indicate significance at 5%, 1% and 0.1% respectively.

Table 6C: Analysis of variance for regression analysis according to Eberhart and Russell's (1966) model for PHFF and LAFF.

Sources	DF	PHFF			LAFF		
		SS	MS	F	SS	MS	F
Total	34	1864.2			310.57		
Varieties	6	437.4	72.9	13.3**	34.86	5.81	7.3*
Environment + (Varieties×Env.)	28	1426.8	50.96	9.32*	275.71	9.85	12.5**
Environment (Linear)	1	1189.3	1189.3	217.4***	257.9	257.9	326.5***
Variety×Env.(Linear)	6	1074.4	179.1	32.7***	241.3	40.2	50.8***
Pooled deviation	21	114.93	5.5		16.6	0.79	
abbreviatum	3	20.81			3.23		
annuum	3	5.62			0.32		
acuminatum	3	10.34			3.05		
nigra	3	7.74			1.70		
conoides	3	27.19			3.19		
cerasiformis	3	12.61			2.09		
fasciculatum	3	30.62			3.01		
Pooled error	630	2444.4	3.88		806.4	1.28	

*, ** and *** indicate significance at 5%, 1% and 0.1% respectively.

Table 6D: Analysis of variance for regression analysis according to Eberhart and Russell's (1966) model for LAMF and NPBMF.

Sources	DF	LAMF			NPBMF		
		SS	MS	F	SS	MS	F
Total	34	131.17			275.7		
Varieties	6	12.85	2.14	2.22	8.39	1.4	0.78
Environment + (Varieties×Env.)	28	118.3	4.23	4.4	267.3	9.6	5.3*
Environment (Linear)	1	94.03	94.03	96.9***	215	215	120.1***
Variety×Env.(Linear)	6	73.74	12.3	12.72**	1772	29.55	16.46**
Pooled deviation	21	20.29	0.97		37.7	1.8	
abbreviatum	3	5.45			9.08		
annuum	3	1.52			10.81		
acuminatum	3	3.55			2.01		
nigra	3	0.7			2.53		
conoides	3	1.63			7.13		
cerasiformis	3	2.99			0.5		
fasciculatum	3	4.46			5.6		
Pooled error	630	352.8	0.56		308.7	0.49	

*, ** and *** indicate significance at 5%, 1% and 0.1% respectively.

Table 6E: Analysis of variance for regression analysis according to Eberhart and Russell's (1966) model for NLMF and NLFF.

Sources	DF	NLMF			NLFF		
		SS	MS	F	SS	MS	F
Total	34	131.65			933636.2		
Varieties	6	12.8	2.14	2.2	45269.2	7544.9	4.8*
Environment + (Varieties×Env.)	28	118.8	4.2	4.4*	888367	31727.4	20.2**
Environment (Linear)	1	94.5	94.5	97.1***	768107	768107	488.2***
Variety×Env.(Linear)	6	74.0	12.34	12.8**	735066	122511	77.9**
Pooled deviation	21	20.4	0.97		33041	1573.4	
abbreviatum	3	5.43			5147.4		
annuum	3	1.62			4163.1		
acuminatum	3	3.53			9316.9		
nigra	3	0.70			867.4		
conoides	3	1.65			842.4		
cerasiformis	3	3.00			437.5		
fasciculatum	3	4.49			12266.5		
Pooled error	630	352.8	0.56		488495.7	775.39	

*, ** and *** indicate significance at 5%, 1% and 0.1% respectively.

c) Stability Parameters:

Regression co-efficient and the deviation from regression are used as the parameters of stability in this model.

i). Regression co-efficient (b_i):

For studying the G×E interaction, the regression technique is unique among the most widely used methods for investigation the response pattern of individual genotype. The regression analysis of the V values of g_{ij} on the corresponding e_j values was done. The results of the regression co-efficients (b_i) of seven genotypes for the ten characters are shown in Table 7A – 7J.

The regression co-efficients are in fact the measure of response to increments in an improving environment. As these increments were measured by the mean of all the genotypes under consideration must have a regression coefficient of unity. Regression co-efficient (b_i) > 1.00, b_i = 1.00 and b_i < 1.00 indicates above average, average and below average response by a genotype. The negative b_i values indicate the genotype will best response only in poor environment.

Number of secondary branches at maximum flowering stage (NSBMF):

Three varieties namely, *abbreviatum*, *annuum* and *acuminatum* showed above average response having the regression co-efficients (b_i) values greater than 1.00, and the values are 1.5476 ± 0.0984, 1.6820 ± 0.7091 and 1.1183 ± 0.6066 respectively for this character. In the character, regression co-efficients are 0.9204 ± 0.3726 for variety *nigra*, 0.8551 ± 0.4449 for variety *conoides* and 0.9102 ± 0.3965 for variety *cerasiformis* all these values are about to 1.00, indicating that they were average response. The variety *fasciculatum* showed negative value (-0.0337 ± 0.5247), indicating that it was responsive only to poor environment.

Number of Secondary branches at first flowering stage (NSBFF):

For this character the regression co-efficients are 1.1338 ± 0.1485 for *nigra*, 1.1071 ± 0.1323 for *conoides* and 1.4238 ± 0.3103 for *cerasiformis*. The regression co-efficients for all the three varieties are greater than 1.00 showing significant regression co-efficient exhibited the above average response. Variety *annuum* was average responsive having 0.9732 ± 0.0.1965. Rest of the characters such as *abbreviatum*, *acuminatum* and *fasciculatum* showed below average response with the value of 0.7046 ± 0.3672, 0.8395 ± 0.2257 and 0.8177 ± 0.0203, respectively.

Plant height at maximum flowering stage (PHMF):

Two varieties, namely *annuum* and *nigra* showed above average response having the regression co-efficients (b_i) greater than 1.00, and the values are 1.3240 ± 0.8508 and 1.3393 ± 0.4027, respectively for these characters. In this character, regression co-efficients are 0.9771 ± 0.4960 for variety *abbreviatum* 0.9356 ± 0.2684 for variety *cerasiformis* and 0.9211 ± 0.7563 for variety *fasciculatum.* All these values are about to 1.00, indicating that they were average responsive. The varieties *acuminatum* and *conoides* showed below average response having the value of 0.7117 ± 0.8532 and 0.7908 ± 0.5629, respectively.

Number of primary branches at first flowering stage (NPBFF):

For this character, the regression co-efficient is 1.6768 ± 0.2929 for the variety *abbreviatum*, 1.5569 ± 0.4012 for the variety *fasciculatum*, all these values are greater than 1.00, so the varieties showing significant regression co-efficient exhibited the above average response. For this character other regression co-efficient is 0.6619 ± 0.2775 for *annuum,* 0.8194 ± 0.0.2119 for *nigra*, 0.6321 ± 0.2412 for *conoides*, 0.6150 ± 0.1805 for *cerasiformis.* All these values are less than 1.00, so, the varieties showed below average response. The variety *acuminatum* was average responsive having 1.0377 ± 0.2092.

Plant height at first flowering stage (PHFF):

In case of PHFF, the variety *acuminatum* (0.7241 ± 0.2466), *conoides* (0.6757 ± 0.4), *fasciculatum* (0.8453 ± 0.4245) show below average response; the variety *abbreviatum* (1.0764 ± 0.3499), *annuum* (0.9772 ± 0.1819), *cerasifofinis* (0.9873 ± 0.2723) show average response; *nigra* (1.7158 ± 0.2134) shows above average response.

Leaf area at first flowering stage (LAFF):

Regarding LAFF, the regression co-efficient is 0.9828 ± 0.2979 for *abbreviatum*, 0.9865 ± 0.0135 for *annuum*, 1.0457 ± 0.2876 for *acuminatum*, 1.02645 ± 0.2148 for *nigra*, 1.0677 ± 0.2945 for *conoides* and 1.03881 ± 0.0.2856 for *fasciculatum*. All these regression co-efficients are equal to 1.00. So they show average response. The variety *cerasiformis* was below the average response having 0.8818 ± 0.2382.

Leaf area at maximum flowering stage (LAMF):

For this character the regression co-efficient is 0.7660 ± 0.6368 for the variety *abbreviatum*, 0.8482 ± 0.3361 for the variety *annuum*, 0.7314 ± 0.5137 for *acuminatum*, all these values are less than 1.00, so the varieties showing significant regression co-efficient exhibited the below average response. For this character other regression co-efficient is 1.1185 ± 0.2279 for *nigra*, 1.0485 ± 0.3486 for *conoides*, 1.1625 ± 0.4715 for *cerasiformis* and 1.3246 ± 0.5761 for *fasciculatum*. All these values are equal to 1.00 so, the varieties showed average response.

Number of primary branches at maximum flowering stage (NPBMF):

In case of NPBMF, the variety *cerasifofmis* (0.6593 ± 0.1330), *conoides* (0.8862 ± 0.0.4818), *fasciculatum* (0.6181 ± 0.4270) show below average response; the variety *abbreviatum* (1.2885 ± 0.5435), *annuum* (1.2207 ± 0.5931), *acuminatum* (1.0765 ± 0.2560) and *nigra* (1.2505 ± 0.2868) show average response.

Number of leaf at maximum flowering stage (NLMF):

For this character the regression co-efficient is 0.7652 ± 0.6343 for the variety *abbreviatum*, 0.8628 ± 0.3436 for the variety *annuum*, 0.7303 ± 0.5117 for *acuminatum*. All these values are less than 1.00, so the varieties showing significant regression co-efficient exhibited the below average response. The other regression co-efficients are 1.1159 ± .2275 for *nigra*, 1.0455 ± 0.3498 for *conoides*, 1.1594 ± 0.4717 for *cerasiformis* and 1.3206 ± 0.5770 for *fasciculatum*, which were equal to 1.00, so, the varieties showed average response.

Number of leaf at first flowering stage (NLFF):

Regarding NLFF, the regression co-efficients are 1.0032 ± 0.2165 for *abbreviatum*, 1.2827 ± 0.2913 for *acuminatum*, 1.3434 ± 0.0889 for *nigra*, which are equal to 1.00. So, they indicated average response. The other values are 0.4624 ± 0.879 for *conoides*; 0.6286 ± 0.0631 for *cerasiformis* and 0.8836 ± 0.3343 for *fasciculatum*. All these regression co-efficients are less than 1.00. So, they indicated below average response.

Table 7A – 7J: Regression analysis of ten quantitative characters of seven varieties in chilli (*Capsicum annuum* L.) according to Eberhart & Russell's model.

7A) Number of Secondary branch at maximum flowering stage (NSBMF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	223.07	14.68	1.548	143.55	222.17	0.898543
annuum	309.07	16.04	1.682	156.02	262.44	46.64127
aciminatum	150.13	14.1	1.118	103.73	116.00	34.12067
nigra	91.46	16.62	0.920	85.38	78.58	12.88278
conoides	86.19	15.24	0.855	79.32	67.83	18.36508
ceracsiformes	91.16	14.19	0.910	84.43	76.85	14.31107
fasciculatum	25.64	16.93	-0.034	-3.13	0.11	25.5376
Pooled	976.74		7	649.3	823.98	152.757

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7B) Number of secondary branch at first flowering stage (NSBFF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	22.9	4.58	0.70466	50.1306	35.325	9.59303
annuum	26.15	5.23	0.97324	69.2381	67.3855	2.7475
aciminatum	30	6	0.83955	59.7271	50.1441	3.62588
nigra	28.85	5.77	1.1338	80.6605	91.4531	1.56991
conoides	29.6	5.92	1.10714	78.7637	87.2025	1.2455
ceracsiformes	31.8	6.36	1.42381	101.292	144.22	6.85196
fasciculatum	24.65	4.93	0.81779	58.1791	47.5785	0.02945
Pooled	193.95	38.79	7	497.991	523.309	25.6632

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7C) Plant Height at Maximum Flowering stage (PHMF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	420.278	42.01	0.9772	341.957	334.16	86.1193
annuum	866.833	39.2015	1.32408	463.343	613.504	253.329
aciminatum	432.030	41.25	0.71173	249.060	177.264	254.766
nigra	684.467	51.9333	1.33932	468.677	627.71	56.7571
conoides	329.395	44.773	0.79089	276.761	218.888	110.508
ceracsiformes	331.537	40.288	0.93561	327.402	306.319	25.2178
fasciculatum	497.145	38.426	0.92117	322.352	296.943	200.203
Pooled	3561.68	297.882	7	2449.55	2574.79	986.9

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7D) Number of primary branch at first flowering stage (NPBFF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	50.235	5.1	1.67682	29.0711	48.7469	1.48809
annuum	8.932	3.99	0.66196	11.4764	7.59694	1.33506
aciminatum	19.428	4.67	1.0377	17.9907	18.669	0.75897
nigra	12.42	4.65	0.81943	14.2064	11.6411	0.77888
conoides	7.937	4.31	0.63215	10.9596	6.92816	1.00884
ceracsiformes	7.123	4.47	0.61501	10.6625	6.55757	0.56543
fasciculatum	44.817	5.86	1.55693	26.9925	42.0253	2.79166
Pooled	150.892	33.05	7	121.359	142.165	8.72692

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7E) Plant height at first flowering stage (PHFF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	217.677	26.641	1.07643	182.89	196.869	20.8081
annuum	167.893	28.7681	0.97727	166.042	162.269	5.6237
aciminatum	99.4305	30.188	0.72414	123.034	89.0942	10.3363
nigra	506.779	36.7635	1.71382	291.184	499.037	7.74189
conoides	104.771	27.627	0.67574	114.81	77.5817	27.1894
ceracsiformes	178.22	25.8235	0.9873	167.746	165.615	12.605
fasciculatum	152.022	26.108	0.84529	143.618	121.399	30.6225
Pooled	1426.79	201.919	7	1189.33	1311.87	114.927

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7F) Leaf area at first flowering stage (LAFF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	38.8637	12.9994	0.98284	36.2136	35.5921	3.27162
annuum	36.1809	12.5869	0.98651	36.3489	35.8585	0.32241
aciminatum	43.3456	13.7201	1.04579	38.5333	40.2978	3.04784
nigra	40.5222	15.4906	1.02645	37.8207	38.821	1.70116
conoides	45.2026	14.3896	1.06773	39.3417	42.0063	3.19627
ceracsiformes	28.8307	13.0473	0.85187	31.388	26.7385	2.09227
fasciculatum	42.7675	12.5562	1.03881	38.2762	39.7618	3.00572
Pooled	275.713	94.7901	7	257.922	259.076	16.6373

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, resp[illegible]ly.

7G) Leaf area at maximum flowering stage (LAMF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	13.3314	8.8129	0.76606	10.2903	7.88302	5.44838
annuum	11.184	8.4439	0.84828	11.3947	9.66583	1.51822
aciminatum	10.7316	8.3509	0.73143	9.82507	7.1863	3.54527
nigra	17.5027	9.541	1.1185	15.0245	16.8049	0.69782
conoides	16.4023	8.3638	1.04856	14.085	14.769	1.6333
ceracsiformes	21.142	7.8325	1.16258	15.6166	18.1555	2.98643
fasciculatum	28.0283	7.5226	1.32461	17.7932	23.5689	4.45932
Pooled	118.322	58.8676	7	94.0294	98.0335	20.2887

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7H) Number of primary branch at maximum flowering stage (NPBMF)

Variety	Total SS	Mean (m+d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	60.065	6.85	1.28845	39.5739	50.9891	9.07594
annuum	56.578	6.97	1.22074	37.4942	45.7707	10.8073
aciminatum	37.607	6.36	1.0765	33.0641	35.5936	2.01344
nigra	50.563	6.72	1.25059	38.411	48.0363	2.52666
conoides	31.255	6.25	0.88623	27.22	24.1232	7.1318
ceracsiformes	13.897	5.44	0.65937	20.252	13.3535	0.54352
fasciculatum	17.337	6.79	0.61812	18.9852	11.7352	5.60182
Pooled	267.302	45.38	7	215	229.601	37.7005

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7I) Number of leaf at maximum flowering stage (NLMF)

Variety	Total SS	Mean (m + d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	13.3314	8.8129	0.76524	10.3259	7.90181	5.42959
annuum	11.6668	8.4244	0.8628	11.6423	10.0449	1.62184
aciminatum	10.7316	8.3509	0.73037	9.85539	7.1981	3.53348
nigra	17.5027	9.541	1.11595	15.0582	16.8042	0.69849
conoides	16.4023	8.3638	1.04555	14.1083	14.751	1.65131
ceracsiformes	21.142	7.8325	1.15942	15.6448	18.1388	3.00316
fasciculatum	28.0283	7.5226	1.32068	17.8208	23.5354	4.49283
Pooled	118.805	58.8481	7	94.4556	98.3742	20.4307

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

7J) Number of leaf at first flowering stage (NLFF)

Variety	Total SS	Mean (m +d_i)	b_i	SP (XY)	Reg. SS	Rem. SS
abrriviatum	115591	257.73	1.00325	110086	110444	5147.42
annuum	217916	268.12	1.39571	153150	213753	4163.05
aciminatum	189878	262.34	1.28277	140758	180561	9316.86
nigra	198914	289.84	1.34345	147416	198047	867.411
conoides	24313.6	181.03	0.46249	50749.2	23471.2	842.355
ceracsiformes	43804.9	203.1	0.62867	68983.2	43367.4	437.511
fasciculatum	97949.3	228.1	0.88366	96963.6	85682.8	12266.5
Pooled	888367	1690.26	7	768107	855326	33041.1

Reg. SS and Rem. SS indicate, Regression SS and Remainder SS, respectively.

ii. Deviation mean square or deviation from regression ($\bar{S}^2{}_{d_i}$):

Actually deviation from regression is a consistent performance of a variety (genotype) over a range of environments i.e. it measures the unpredictable irregularities in response to the environments. In this experiment, years were considered as a range of environments in which seven varieties were grown. In the stability analysis (Table 8A – 8J) the $\bar{S}^2{}_{d_i}$ values were highly heterogenous as indicated by the significant remainder item when they were tested with their respective within error in all the characters under study.

In addition to this, the individual genotypic $\bar{S}^2{}_{d_i}$ were also tested with respective individual genotypic error (i.e. test value, the last column in the Table 8A – 8J). The obtained values of $\bar{S}^2{}_{d_i}$ of ten quantitative characters of seven varieties studied are shown in Table 8aA– 8J.

Number of secondary branches at maximum flowering stage (NSBMF):

For this character all the genotypes showed non-significant deviation mean square ($\bar{S}^2{}_{d_i}$) from regression, except *abbreviatum*. These non-significant results indicated that the varieties showed stability for this trait (Table 8A).

Number of Secondary branches at first flowering stage (NSBFF):

Regarding this character, all the genotypes, except *fasiculatum* showed non-significant deviation mean square ($\bar{S}^2{}_{d_i}$) from regression. It indicated that varieties have high stable quality for this trait (Table 8B).

Plant height at maximum flowering stage (PHMF):

Here, 4 genotypes, namely *abbreviatum, nigra, conoides* and *cerasiformis* showed stable performance having non-significant ($\bar{S}^2{}_{d_i}$) values. Whereas, rest of the varieties showed significant deviation mean square ($\bar{S}^2{}_{d_i}$), indicating that they were not stable for this character (Table 8C).

Number of primary branches at first flowering stage (NPBFF):

For this character all the genotypes showed non-significant deviation mean squares ($\bar{S}^2{}_{d_i}$) from regression. These non-significant results indicated that the varieties showed stability for this trait (Table 8D).

Plant height at first flowering stage (PHFF):

Regarding this character, all the genotypes showed non-significant deviation mean square ($\overline{S}^2{}_{d_i}$) from regression. It indicated that varieties have high stable quality for this trait (Table 8E).

Leaf area at first flowering stage (LAFF):

For this character all the genotypes showed non-significant deviation mean squares ($\overline{S}^2{}_{d_i}$) from regression, except *annuum*. These non-significant results indicated that the varieties showed stability for this trait (Table 8F).

Leaf area at maximum flowering stage (LAMF):

In this case, all genotypes showed stable quality having non-significant ($\overline{S}^2{}_{d_i}$) values (Table 8G).

Number of primary branches at maximum flowering stage (NPBMF):

Regarding this character, all the genotypes showed non-significant deviation mean square ($\overline{S}^2{}_{d_i}$) from regression. It indicated that varieties have high stable quality for this trait (Table 8H).

Number of leaf at maximum flowering stage (NLMF):

In this regard, all the genotypes showed stable quality having non-significant ($\overline{S}^2{}_{d_i}$) values (Table 8I).

Number of leaf at first flowering stage (NLFF):

For this character all the genotypes showed highly significant deviation mean square ($\overline{S}^2{}_{d_i}$) from regression. These significant results indicated that the varieties showed non-stability for this trait (Table 8J).

Table 8A – 8J: Stability test of ten characters of chilli (*Capsicum annuum* L.) according to the Eberhart and Russell's (1966) model.

8A) Number of secondary branches at maximum flowering stage (NSBMF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	14.68	1.5476	± 0.0984	-4.29022	1.89583
annuum	16.04	1.6820	± 0.7091	10.95735	13.6589
acuminatum	14.1	1.1183	± 0.6065	6.783818	11.6826
nigra	16.62	0.9204	± 0.3726	-0.29548	7.17852
conoides	15.24	0.8551	± 0.4449	1.531955	8.5709
cerasiformes	14.19	0.9102	± 0.3927	0.180619	7.566
fasciculatum	16.93	-0.0337	± 0.5247	3.922795	10.1069

8B) Number of secondary branches at first flowering stage (NSBFF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	4.58	0.7046	± 0.3672	1.7376	6.19452
annuum	5.23	0.9732	± 0.1965	-0.5442	3.31512
acuminatum	6	0.8395	± 0.2257	-0.2514	3.80835
nigra	5.77	1.1338	± 0.1485	-0.9368	2.50592
conoides	5.92	1.1071	± 0.1323	-1.0449	2.23204
cercsiformes	6.36	1.4238	± 0.3103	0.82392	5.23525
fasciculatum	4.93	0.8177	± 0.0203	-1.4503	0.34323

8C) Plant height at maximum flowering stage (PHMF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	42.01	0.9772	± 0.4960	11.9164	18.5601
annuum	39.20	1.3240	± 0.8508	67.6528	31.8326
acuminatum	41.25	0.7117	± 0.8532	68.1321	31.9228
nigra	51.93	1.3393	± 0.4027	2.12899	15.0675
conoides	44.77	0.7908	± 0.5619	20.0458	21.0245
cerasiformes	40.28	0.9356	± 0.2684	-8.3841	10.0435
fasciculatum	38.42	0.9211	± 0.7563	49.9442	28.2986

8D) Number of primary branches at first flowering stage (NPBFF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	5.1	1.6768	± 0.2929	0.2696	2.43974
annuum	3.99	0.6619	± 0.2775	0.21859	2.3109
acuminatum	4.67	1.0377	± 0.2092	0.02656	1.74237
nigra	4.65	0.8194	± 0.2119	0.0332	1.76508
conoides	4.31	0.6321	± 0.2412	0.10985	2.00882
cercsiformes	4.47	0.6150	± 0.1805	-0.038	1.5039
fasciculatum	5.86	1.5569	± 0.4012	0.70412	3.34165

8E) Plant height at first flowering stage (PHFF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	26.64	1.0764	± 0.3499	3.05972	9.12318
annuum	28.76	0.9772	± 0.1819	-2.0018	4.74287
acuminatum	30.18	0.7241	± 0.2466	-0.4309	6.43002
nigra	36.76	1.7138	± 0.2134	-1.2957	5.56485
conoides	27.62	0.6757	± 0.4000	5.18682	10.4287
cerasiformes	25.82	0.9873	± 0.2723	0.32536	7.10071
fasciculatum	26.10	0.8452	± 0.4245	6.33118	11.0675

8F) Leaf area at first flowering stage (LAFF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	12.999	0.9828	± 0.2979	-0.1869	3.61753
annuum	12.586	0.9865	± 0.0935	-1.17	1.13562
acuminatum	13.720	1.0457	± 0.2876	-0.2615	3.49161
nigra	15.490	1.0264	± 0.2148	-0.7104	2.60857
conoides	14.389	1.0677	± 0.2945	-0.212	3.57562
cerasiformes	13.047	0.8518	± 0.2382	-0.58	2.89294
fasciculatum	12.556	1.0388	± 0.2856	-0.2755	3.46741

8G) Leaf area at maximum flowering stage (LAMF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	8.812	0.7660	± 0.6368	1.2562	4. 66835
annuum	8.443	0.8482	± 0.3361	-0.0538	2.46432
acuminatum	8.350	0.7314	± 0.5137	0.62184	3.76578
nigra	9.541	1.1185	± 0.2279	-0.3273	1.67071
conoides	8.363	1.0485	± 0.3486	-0.0155	2.55602
cerasiformes	7.832	1.1625	± 0.4715	0.43555	3.45626
fasciculatum	7.522	1.3246	± 0.5761	0.92652	4.22342

8H) Number of primary branches at maximum flowering stage (NPBMF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	6.85	1.2884	± 0.5435	2.53424	6.02526
annuum	6.97	1.2207	± 0.5931	3.11137	6.5749
acuminatum	6.36	1.0765	± 0.2560	0.18008	2.83792
nigra	6.72	1.2505	± 0.2868	0.35115	3.17909
conoides	6.25	0.8862	± 0.4818	1.88619	5.34109
cerasiformes	5.44	0.6593	± 0.1330	-0.3099	1.47447
fasciculatum	6.79	0.6181	± 0.4270	1.3762	4.73363

8J) Number of leaf at maximum flowering stage (NLMF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	8.812	0.7652	± 0.6343	1.24723	4.6603
annuum	8.424	0.8628	± 0.3466	-0.022	2.54703
acuminatum	8.350	0.7303	± 0.5117	0.6152	3.75951
nigra	9.541	1.1159	± 0.2275	-0.3298	1.67151
conoides	8.363	1.0455	± 0.3498	-0.0122	2.57007
cerasiformes	7.832	1.1594	± 0.4717	0.43842	3.46593
fasciculatum	7.522	1.3206	± 0.5770	0.93498	4.23926

8J) Number of leaf at first flowering stage (NLFF)

Variety	Mean	b_i	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	257.73	1.0032	± 0.2165	940.421	143.4911
annuum	268.12	1.3957	± 0.1947	612.299	129.0435
acuminatum	262.34	1.2827	± 0.2913	2330.23	193.0477
nigra	289.84	1.3434	± 0.0889	-486.25	58.90367
conoides	181.03	0.4624	± 0.0876	-494.6	58.04672
cerasiformes	203.1	0.6286	± 0.0631	-629.55	41.83353
fasciculatum	228.1	0.8836	± 0.3343	3313.46	221.5088

2. Perkins' and Jinks' (1968) Model:

a) Genotypic and Environmental Mean:

Genotypic mean: Means of 7 genotypes and 5 years (environment) were estimated that on 10 quantitative characters namely, NSBMF, NSBFF, PHMF, NPBMF, PHFF, LAFF, LAMF, NPBMF, NLMF and NLFF. Mean performances of these characters of 7 varieties over 5 consecutive years (considered as environment) were computed and are given in Table 9A – 9J. Table 9A – 9J also indicated that the differences among the genotypes were marked for the ten quantitative characters. Genotypic mean of different characters were as follows:

NSBMF: The highest mean for this character was recorded in the variety *fasciculatum* and the lowest mean was observed in the variety *acuminatum.*

NSBFF: For this character, the highest mean was observed in the variety *cerasiformis* and the lowest mean was recorded in the variety *abbreviatum.*

PHMF: In this trait, the variety *nigra* gave the highest mean value and the lowest mean was shown in the variety *fasciculatum.*

NPBFF: The highest mean for this character was recorded in the variety *fasiculatum* and the lowest mean was observed in the variety *annuum.*

PHFF: For this character, the highest mean was observed in the variety *nigra* and the lowest mean was recorded in the variety *cerasiformis.*

LAMF: In this trait, the variety *nigra* gave the highest mean value and the lowest mean was shown in variety *fasciculatum.*

NPBMF: The highest mean for this character was recorded in the variety *annuum* and the lowest mean was observed in the variety *cerasiformis.*

NLMF: For this character, the highest mean was observed in the variety *nigra* and the lowest mean was recorded in the variety *fascSiculatum.*

LAFF: In this trait, the variety *nigra* gave the highest mean value and the lowest mean was shown in the variety *fasciculatum.*

NLFF: The highest mean for this character was recorded in the variety *annuum* and the lowest mean was observed in the variety *conoides* in 5 years.

Environmental (year) mean: Environmental means performances of all ten quantitative characters over seven genotypes were calculated and is shown in the same Table 9A.

In this regard, the character NSBMF showed the increasing tendency in 2001 having the highest mean value, while it showed decreasing tendency in 1998 having lowest mean value.

In 2001, the character NSBFF indicated increasing effect but in 1999 showed decreasing effect with the lowest value.

In this regard, the character NPBFF showed the increasing tendency in 1999 having the highest mean value, while it showed decreasing tendency in 1998 having lowest mean value.

In 2001, the character PHFF indicated increasing effect but in 1998 showed decreasing effect with the lowest value.

Having the highest mean value, LAMF showed increasing tendency in 2001, whereas the same character showed the decreasing effect in 1998 with the lowest value.

In this regard, the character NPBMF showed the increasing tendency in 1997 having the highest mean value, while it showed decreasing tendency in 1998 having the lowest mean value.

Having the highest mean value, NLMF showed increasing tendency in 2001, whereas the same character showed the decreasing effect in 1998 with the lowest value.

In 1999, the character NPFF indicated increasing effect but in 1998 showed decreasing effect with the lowest value.

b) Joint Regression Analysis:

According to this model, Y_{ij} is the mean performance. For describing Y_{ij} , the mean performance of i^{th} variety in j^{th} locations, they proposed following model:

$Y_{ij} = m + d_i + e_j + g_{ij} + e_{ij}$. The overall mean (m) for all the characters calculated and the genetical deviation (d_i) of the i^{th} genotypes is estimated as $d_i = (Y_{i.} /S) - m$. The Y_i values for the seven genotypes and corresponding estimates of $m + d_i$ were given in Table 10a – 10j. The additive environmental deviation (e_j) of j^{th} environment (year) is estimated as, $E_j = (Y_{.j}/t) - m$. The $Y_{.j}$ values for the 5 environments are the column total and the corresponding estimates $m + e_j$ were given in Table 10A – 10J. There are st = 35 genotype×environmental (variety×year) interaction (g_{ij}) components. In the joint regression analysis, a standard two way analysis of variance was done to separate all the three components namely, genotype (variety), environment (year) and their interaction. The degrees of freedom sum of squares and mean square for ten quantitative characters are presented in Table 10A –10J. For the test of significance of three items, error variance was included. In the present data it came from the p =10 plants of each genotype in each variety in each year. Summing up of all the 35 sum of squares each for p – 1 = 9 degrees of freedom. These on summing gives an overall within sum of squares for VYR (p – 1) = 630 degrees of freedom and indicated to be as "within error". The within error is used to total significance of the three items e.g. genotype (variety), environment (year) and G×E interaction and results are given in Table 10A –10J.

For NSBMF, 3 item namely, variety, environment and genotype×environment interaction were highly significant when tested against within error. On the other hand, when tested with remainder only environment was significant but variety and interaction were non-significant. Variety, environment and g×e were highly significant when tested with within error and environment was also significant and variety and g×e were non-significant when tested with the remainder for the NSBFF character.

Table 10C, for the character PHFF, showed that variety, environment and g×e were highly significant when tested against within error, and only environment was significant but other two items were non-significant when tested with remainder.

For NPBFF, 3 item namely, variety, environment and genotype×environment interaction were highly significant when tested against within error. On the other hand, when tested with remainder all three items were also significant.

Variety, environment and g×e were highly significant when tested with within error and variety and environment were also significant but g×e were non-significant when tested with remainder for PHFF.

Table 10F, for the character LAFF, showed that variety, environment and g×e were highly significant when tested against within error, and variety and environment were also significant but g×e was non-significant when tested against remainder.

For LAMF, 3 item namely, variety, environment and genotype×environment interaction were highly significant when tested against within error. On the other hand, when tested against remainder only environment was significant but variety and interaction were non-significant. Variety, environment and g×e were highly significant when tested with within error and environment was also significant but variety and g×e were non-significant when tested with the remainder for the NPBMF character. Table 10I, for the character NLMF, showed that variety, environment and g×e were highly significant when tested against within error, and environment was also significant but variety and g×e were non-significant when tested against the remainder.

For NLFF, 3 items, namely variety, environment and genotype×environment interaction were highly significant when tested against both the within error and remainder.

Further, to test whether the environmental effect for each of the seven varieties are a linear function of the additive environmental values and also whether linear function differ among the seven varieties, a joint regression analysis was done.

In this respect, the sum of squares for genotype×environment interactions are partitioned into linear and non-linear components. A linear regression analysis of the t values of g_{ij} on the corresponding e_j values for each of the seven genotypes was separately done. The degrees of freedom for variation in g_{ij} (Y – 1) of which 1 is for linear regression sum of square (Y – 2) for remainder.

Summing up over all V regression sum of squares gave total sum of squares for v i.e. 7 degrees of freedom. In the joint regression analysis this was partitioned into a joint regression sum of squares for 1 degrees of freedom and heterogeneity of regression sum of squares for V – 1 degrees of freedom. Because of restrain $\Sigma b_i = 0$ the joint regression sum of squares is zero and the heterogeneity sum of regression for the total sum of squares for regression for V – 1 degrees of freedom. Similarly, in each of the V i.e. 7 separate regression analysis there is a remainder sum of squares which is the sum of square for genotype × environment interaction minus the regression sum of squares. Summing over all V remainder sum of square a total remainder sum of square was obtained.

The heterogeneity of regression of all the ten characters under study was highly significant when tested against their respective within error. While, the heterogeneity of regression of 5 characters, namely NSBMF, NSBFF, NPBFF, PHFF and NLFF were also significant but the rest of the characters were non-significant for this item when tested with the remainder mean square. Remainder item was highly significant for all the characters when tested against the within error, and the results are elaborately described in Table 10A – 10J. In the joint regression analysis, variety × year (i.e. genotype ×environment) interaction are therefore, a linear function of the additive environmental values, and the linear regression co-efficient (b_i) significantly different between varieties. Some of the variety×year interactions are therefore, a linear function of the additive environmental values, and the linear regression co-efficients (b_i) were significantly different and the residual significant interactions are accounted for by the non-linear components.

Table 9A –9J: Genotypic and environmental mean and Regression analysis of seven genotypes in chilli (*Capsicum annuum* L.) in five years according to Perkins' and Jinks (1968) model:

9A) Number of secondary branch at maximum flowering stage (NSBMF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_j$)
1997	2173	310.429
1998	1471	210.143
1999	2412	344.571
2000	1588	226.857
2001	3136	448

Genotypes (Varieties)

Variety	Total SS	Mean	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	223.073	14.68	1.5476	143.557	222.174	0.89854
annuum	309.077	16.04	1.6820	156.023	262.436	46.6413
aciminatum	150.125	14.1	1.1183	103.733	116.004	34.1207
nigra	91.463	16.62	0.9204	85.3757	78.5802	12.8828
conoides	86.192	15.24	0.8551	79.3193	67.8269	18.3651
cerasiformes	91.162	14.19	0.9102	84.4311	76.8509	14.3111
fasciculatum	25.643	16.93	-0.0337	3.1268	0.1054	25.5376
Total	976.735	107.8	7	649.312	823.978	152.757

9B) Number of secondary branch at first flowering stage (NSBFF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_j$)
1997	1214	173.429
1998	459	65.5714
1999	264	37.7143
2000	353	50.4286
2001	1589	227

Genotypes (Varieties)

Variety	Total SS	Mean	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	44.918	4.58	0.70466	50.1306	35.325	9.59303
annuum	70.133	5.23	0.97324	69.2381	67.3855	2.7475
aciminatum	53.77	6	0.83955	59.7271	50.1441	3.62588
nigra	93.023	5.77	1.1338	80.6605	91.4531	1.56991
conoides	88.448	5.92	1.10714	78.7637	87.2025	1.2455
cerasiformes	151.072	6.36	1.42381	101.292	144.22	6.85196
fasciculatum	47.608	4.93	0.81779	58.1791	47.5785	0.[illegible]
Total	548.972	38.79	7	497.991	523.[illegible]	

9C) Plant height at maximum flowering stage (PHMF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_j$)
1997	6247.2	892.457
1998	4709.5	672.786
1999	6197.8	885.4
2000	4751.38	678.769
2001	7882.3	1126.04

Genotypes (Varieties)

Variety	Total SS	Mean($m+d_i$)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	420.279	42.01	0.9772	341.957	334.16	86.1193
annuum	866.833	39.201	1.3240	463.344	613.504	253.329
acuminatum	432.03	41.25	0.7117	249.06	177.264	254.766
nigra	684.467	51.933	1.3393	468.678	627.71	56.7571
conoides	329.396	44.773	0.7908	276.761	218.888	110.508
cerasiformes	331.537	40.288	0.9356	327.402	306.319	25.2178
fasciculatum	497.145	38.426	0.9211	322.352	296.943	200.203
Total	3561.687	297.88	7	2449.56	2574.79	986.9

9D) Number of primary branch at flowering stage (NPBFF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_j$)
1997	1131	161.571
1998	436	62.2857
1999	755	107.857
2000	460	65.7143
2001	523	74.7143

Genotypes (Varieties)

Variety	Total SS	Mean($m+d_i$)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	50.235	5.1	1.6768	29.0711	48.7469	1.48809
annuum	8.932	3.99	0.66196	11.4764	7.59694	1.33506
acuminatum	19.428	4.67	1.0377	17.9907	18.669	0.75897
nigra	12.42	4.65	0.81943	14.2064	11.6411	0.77888
conoides	7.937	4.31	0.63215	10.9596	6.92816	1.00884
cerasiformes	7.123	4.47	0.61501	10.6625	6.55757	0.56543
fasciculatum	44.817	5.86	1.55693	26.9925	42.0253	2.79166
Total	150.89	33.05	7	121.359	142.165	[illegible].72692

9E) Plant height at first flowering stage (PHFF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_i$)
1997	4602	657.429
1998	3065.65	437.95
1999	4055	579.286
2000	3237.4	462.486
2001	5231.86	747.409

Genotypes (Varieties)

Variety	Total SS	Mean($m+d_i$)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	217.677	26.64	1.0764	182.89	196.869	20.8081
annuum	167.893	28.76	0.9772	166.042	162.269	5.6237
acuminatum	99.4305	30.18	0.7241	123.034	89.0942	10.3363
nigra	506.779	36.76	1.7138	291.184	499.037	7.74189
conoides	104.771	27.67	0.6757	114.81	77.5817	27.1894
cerasiformes	178.22	25.82	0.9873	167.746	165.615	12.605
fasciculatum	152.022	26.10	0.8452	143.618	121.399	30.6225
Total	1426.793	201.93	7	1189.33	1311.87	114.927

9F) Leaf area at maximum flowering stage (LAMF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_i$)
1997	1338.03	191.147
1998	872.12	124.589
1999	1121.07	160.153
2000	1031.84	147.406
2001	1523.7	217.671

Genotypes (Varieties)

Variety	Total SS	Mean($m+d_i$)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	13.3314	8.8129	0.7660	10.2903	7.88302	5.44838
annuum	11.184	8.4439	0.8482	11.3947	9.66583	1.51822
acuminatum	10.7316	8.3509	0.731	9.82507	7.1863	3.54527
nigra	17.5027	9.541	1.1185	15.0245	16.8049	0.69782
conoides	16.4023	8.3638	1.0485	14.085	14.769	1.6333
cerasiformes	21.142	7.8325	1.1625	15.6166	18.1555	2.98643
fasciculatum	20.576	7.5226	1.3246	17.7932	23.5689	4.45932
Total	110.87	58.867	7	94.0294	98.0335	20.2887

9G) Number of primary branch at maximum flowering stage (NPBMF)

Environments (i.e. years).

Environments	Total	Mean (μ +e_i)
1997	1300	185.714
1998	468	66.8571
1999	1289	184.143
2000	904	129.143
2001	577	82.4286

Genotypes (Varieties)

Variety	Total SS	Mean(m+d_i)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	60.065	6.85	1.2884	39.5739	50.9891	9.07594
annuum	56.578	6.97	1.2207	37.4942	45.7707	10.8073
acuminatum	37.607	6.36	1.0765	33.0641	35.5936	2.01344
nigra	50.563	6.72	1.2505	38.411	48.0363	2.52666
conoides	31.255	6.25	0.8862	27.22	24.1232	7.1318
cerasiformes	13.897	5.44	0.6597	20.252	13.3535	0.54352
fasciculatum	17.337	6.79	0.6182	18.9852	11.7352	5.60182
Total	267.302	45.38	7	215	229.601	37.7005

9H) Number of leaf at maximum flowering stage (NLMF)

Environments (i.e. years).

Environments	Total	Mean (μ +e_i)
1997	1338.03	191.147
1998	870.17	124.31
1999	1121.07	160.153
2000	1031.84	147.406
2001	1523.7	217.671

Genotypes (Varieties)

Variety	Total SS	Mean(m+d_i)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	13.3314	8.812	0.7652	10.3259	7.90181	5.42959
annuum	11.6668	8.424	0.8628	11.6423	10.0449	1.62184
acuminatum	10.7316	8.350	0.7303	9.85539	7.1981	3.53348
nigra	17.5027	9.541	1.1159	15.0582	16.8042	0.69849
conoides	16.4023	8.363	1.0455	14.1083	14.751	1.65131
cerasiformes	21.142	7.832	1.1594	15.6448	18.1388	3.00316
fasciculatum	28.0283	7.522	1.3206	17.8208	23.5354	4.49283
Total	118.8051	58.84	7	94.4556	98.3742	20.4307

9I) Leaf area at first flowering stage (LAFF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_j$)
1997	1865.79	266.541
1998	1337.62	191.089
1999	2533.64	361.949
2000	1842.3	263.186
2001	1899.66	271.38

Genotypes (Varieties)

Variety	Total SS	Mean(m+d_i)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	38.8637	12.99	0.9828	36.2136	35.5921	3.27162
annuum	36.1809	12.58	0.9865	36.3489	35.8585	0.32241
acuminatum	43.3456	13.72	1.0457	38.5333	40.2978	3.04784
nigra	40.5222	15.49	1.0264	37.8207	38.821	1.70116
conoides	45.2026	14.38	1.0677	39.3417	42.0063	3.19627
cerasiformes	28.8307	13.04	0.8518	31.388	26.7385	2.09227
fasciculatum	42.7675	12.55	1.0388	38.2762	39.7618	3.00572
Total	275.7132	94.79	7	257.922	259.076	16.6373

9J) Number of leaf at first flowering stage (NLFF)

Environments (i.e. years).

Environments	Total	Mean ($\mu + e_j$)
1997	27021	3860.143
1998	12899	1842.714
1999	69935	9990.714
2000	42365	6052.143
2001	16806	2400.857

Genotypes (Varieties)

Variety	Total SS	Mean(m+d_i)	bi	SP(XY)	REG.SS	Rem. SS
abbreviatum	115591	257.73	1.0032	110086	110444	5147.42
annuum	217916	268.12	1.3957	153150	213753	4163.05
acuminatum	189878	262.34	1.2827	140758	180561	9316.86
nigra	198914	289.84	1.3434	147416	198047	867.411
conoides	24313.6	181.03	0.4624	50749.2	23471.2	842.355
cerasiformes	43804.9	203.1	0.6286	68983.2	43367.4	437.511
fasciculatum	97949.3	228.1	0.8836	96963.6	85682.8	12266.5
Total	888366.8	1690.2	7	768107	855326	33041.1

Table 10A – 10J: Joint regression analysis of genotype × environment interaction of seven genotypes over five environments in chilli.

10A) Number of secondary branch at maximum flowering stage (NSBMF)

Sources	DF	SS	MS	F1	F2
Varieties	6	39.68	6.614	127.2***	0.78
Environments	4	649.31	162.328	3120***	19.13***
VxE	24	327.42	13.646	262.2***	1.61
Heterogeneity of regression	6	174.66	29.111	559.6***	3.4
Remainder	18	152.75	8.486	163***	
Error	630	32.77	0.052		

10B) Number of secondary branch at first flowering stage (NSBFF)

Sources	DF	SS	MS	F1	F2
Varieties	6	12.35	2.059	208.6***	1.4
Environments	4	497.99	124.49	12610***	87.3***
VxE	24	50.98	2.12	215.2***	1.4
Heterogeneity of regression	6	25.32	4.219	427.4***	2.9*
Remainder	18	25.66	1.425	144.4***	
Error	630	6.22	0.01		

10C) Plant height at first flowering stage (PHFF)

Sources	DF	SS	MS	F1	F2
Varieties	6	641.53	106.92	744.1***	1.95
Environments	4	2449.6	612.39	4261***	11.17**
VxE	24	1112.1	46.34	322.5***	0.85
Heterogeneity of regression	6	125.2	20.87	145.3***	0.38
Remainder	18	986.9	54.83	381.5***	
Error	630	90.5	0.144		

10D) Number of primary branches at first flowering stage (NPBFF)

Sources	DF	SS	MS	F1	F2
Varieties	6	11.07	1.85	509.2***	3.81*
Environments	4	121.36	30.34	8370.3***	62.6***
VxE	24	29.53	1.231	339.5***	2.5
Heterogeneity of regression	6	20.81	3.468	956.7***	7.15*
Remainder	18	8.73	0.485	133.8***	
Error	630	2.29	0.004		

10E) Plant height at first flowering stage (PHFF)

Sources	DF	SS	MS	F1	F2
Varieties	6	437.37	72.895	1616***	11.4**
Environments	4	1189.33	297.331	6592***	46.6***
VxE	24	237.468	9.895	219.4***	1.5
Heterogeneity of regression	6	122.541	20.424	452.8***	3.2
Remainder	18	114.927	6.39	141.6***	
Error	630	28.417	0.045		

10F) Leaf area at first flowering stage (LAFF)

Sources	DF	SS	MS	F1	F2
Varieties	6	34.85	5.81	295.4***	6.3*
Environments	4	257.92	64.48	3279***	69.7***
VxE	24	17.79	0.742	37.7***	0.802
Heterogeneity of regression	6	1.15	0.193	9.78***	0.208
Remainder	18	16.64	0.925	47***	
Error	630	12.39	0.02		

10G) Leaf area at first flowering stage (LAMF)

Sources	DF	SS	MS	F1	F2
Varieties	6	12.846	2.141	365.3***	1.89
Environments	4	94.029	23.507	4011***	20.9**
VxE	24	24.292	1.012	172.7***	0.898
Heterogeneity of regression	6	4.004	0.667	113.9***	0.592
Remainder	18	20.288	1.127	192.3***	
Error	630	3.693	0.006		

10H) Number of primary branches at first flowering stage (NPBMF)

Sources	DF	SS	MS	F1	F2
Varieties	6	8.397	1.399	235.7***	0.67
Environments	4	215	53.75	9052***	25.7***
VxE	24	52.301	2.179	367***	1.04
Heterogeneity of regression	6	14.601	2.433	409.8***	1.16
Remainder	18	37.70	2.094	352.7***	
Error	630	3.741	0.006		

10I) Number of leaf at maximum flowering stage (NLMF)

Sources	DF	SS	MS	F1	F2
Varieties	6	12.841	2.140	365.9***	1.9
Environments	4	94.455	23.614	4037***	20.8***
VxE	24	24.349	1.015	173.4***	0.89
Heterogeneity of regression	6	3.9185	0.653	111.7***	0.58
Remainder	18	20.430	1.135	194.1***	
Error	630	3.684	0.006		

10J) Number of leaf at first flowering stage (NLFF)

Sources	DF	SS	MS	F1	F2
Varieties	6	45269.2	7544.8	861.4***	4.1*
Environments	4	768107	192027	21925***	104.6***
VxE	24	120260	5010.8	572.1***	2.73*
Heterogeneity of regression	6	87218.8	14536.5	1659.7***	7.9*
Remainder	18	33041.1	1835.6	209.6***	
Error	630	5517.8	8.758		

c) Stability Parameters:

In this approach also the same two parameters, regression co-efficient and deviation from regression, are used as the parameters of stability.

i). Regression Co-efficient ($1+\beta_i$):

In terms of this model, the earlier model of Eberhart and Russell is thus regression of (e_j + g_{ij}) on e_j. The regression of e_i on e_j being one, and regression of g_{ij} on e_j being β_i, the b_i value of Eberhart and Russell model is thus: $b_i = 1 + \beta_i$. So the results of regression co-efficients are same as described in previous model.

ii). Deviation mean square or deviation from regression ($\bar{S}^2{}_{d_i}$):

The deviation from regression ($\bar{S}^2{}_{d_i}$) is also same as in Eberhart and Russell's model. Obviously, the relative ranking of different genotypes in this model will in no way be different from that of Eberhart and Russell's (1966) model (Singh and Chaudhary, 1979).

3. Freeman and Perkins' (1971) Model:

a) Genotypic and Environmental Mean:

Being the same data genotypic and environmental mean were calculated in the same way as described in the previous two models.

b) Joint Regression Analysis:

The joint regression analysis of ten characters was done on seven chilli genotypes (varieties) under five different environments (years). The mean performance in k^{th} replication of i^{th} genotypes in the j^{th} environment is described as Y_{ijk} for joint regression analysis. In this model, $Y_{ijk} + m + d_i + e_j + g_{ij} + e_{ijk}$, the overall mean (m) was estimated and are presented in Table 11A – 11E.

The genetical deviation (d_i) i.e., additive genetic effect of i^{th} genotype is estimated as $d_i = (Y_{i.}/S) - m$.

The values of $Y_{i.}$ for the seven genotypes are given in Table 11A – 11E. These genetical deviation of the inbreed lines (varieties) are attributed to additive gene action.

The additive environmental deviation e_j of the j^{th} environment is calculated as $(Y_{.j}/t) - m$. The $Y_{.j}$ values are the total of five environment and also includes the corresponding estimates of $m + e_j$.

Treatment with 34 degrees of freedom was partitioned into genotype (df = 6), environment (df = 4) and their interaction (df = 24). Further, environment (year) was divided into combined regression (df = 1) and residual 1 (df = 3) and variety × environment interaction item was also partitioned into heterogeneity of regression (df = 6) and residual 2 (df = 18), in this model.

To test them, a standard two-way analysis of variance was done. In this model, the analysis of variance showed that variety and year items were highly significant for all the characters, when tested against their respective pooled error (Table 11A – 11E).

Combined regression (the main part of environment) was also highly significant for all the characters (Table 11A – 11E) when tested against pooled error.

Item residual 1 was significant for all the characters, except PHFF, when they were tested with the pooled error.

Variety × environment interaction item was highly significant for all the characters, when tested against the pooled error. Heterogeneity of regression for all the characters was non-significant when tested against residual 2, and residual 2 was also highly significant for all the characters.

Table 11A: Analysis of variance for regression analysis according to Freeman and Perkins' (1971) model for NSBMF and NSBFF.

Sources	DF	NSBMF			NSBFF		
		SS	MS	VR	SS	MS	VR
Varieties	6	84.74	14.12	28.4***	16.5	2.7	18.5**
Years	4	522.7	130.67	263.4***	448.7	112.2	754.9***
combined regression	1	493.47	493.47	50.6***	442.8	442.8	227.1***
Residual-1	3	29.23	9.74		5.9	1.95	
V×Y	24	9949.3	414.55	835.6***	1737.2	72.4	487***
Heterogeneity	6	187.4	31.24	0.1	27.9	4.65	0.05
Residual-2	18	9761.9	542.33		1709.3	94.96	
Pooled error	630	312.6	0.5		93.6	0.15	

Table 11B: Analysis of variance for regression analysis according to Freeman and Perkins' (1971) model for PHMF and NPBFF.

Sources	DF	PHMF			NPBFF		
		SS	MS	VR	SS	MS	VR
Varieties	6	839.8	139.9	79***	10.99	1.83	50.2***
Years	4	2519.7	629.9	356.6***	122.86	30.72	841.2***
combined regression	1	2316.8	2316.8	34.3***	106.43	106.43	19.43**
Residual-1	3	202.9	67.64		16.43	5.48	
V×Y	24	69005	2875	1627.6***	937.38	39.06	1069***
Heterogeneity	6	299	49.94	0.013	22.84	3.81	0.075
Residual-2	18	68706	3816.9		914.55	50.81	
Pooled error	630	1112.9	1.77		23.01	0.037	

Table 11C: Analysis of variance for regression analysis according to Freeman and Perkins' (1971) model for PHFF and LAFF.

Sources	DF	PHFF			LAFF		
		SS	MS	VR	SS	MS	VR
Varieties	6	488.44	81.41	212***	41.03	6.84	40.7***
Years	4	1328.3	332.08	864***	182.9	45.7	272***
combined regression	1	1324.1	1324.1	945***	165.1	165.1	27.8***
Residual-1	3	4.20	1.40		17.8	5.95	
V×Y	24	30913	1288.08	3349***	6951.9	289.7	1723***
Heterogeneity	6	135.1	22.51	0.013	19.23	3.21	0.008
Residual-2	18	30778.7	1709.9		6932.6	385.15	
Pooled error	630	242.28	0.38		105.91	0.16	

Table 11D: Analysis of variance for regression analysis according to Freeman and Perkins' (1971) model for LAMF and NPBMF.

Sources	DF	LAMF			NPBMF		
		SS	MS	VR	SS	MS	VR
Varieties	6	15.05	2.51	32.5***	13.56	2.26	40.34***
Years	4	125.94	31.48	407.99***	247.17	61.79	1103***
combined regression	1	97.07	97.07	10.1*	240.08	240.08	102***
Residual-1	3	28.87	9.6		7.1	2.36	
V×Y	24	2605.44	108.5	1407***	1715.9	71.5	1276***
Heterogeneity	6	12.57	2.09	0.014	10.95	1.83	0.019
Residual-2	18	2592.9	144		1704.9	94.72	
Pooled error	630	48.62	0.08		35.3	0.056	

Table 11E: Analysis of variance for regression analysis according to Freeman and Perkins' (1971) model for NLMF and NLFF.

Sources	DF	NLMF			NLFF		
		SS	MS	VR	SS	MS	VR
Varieties	6	15.1	2.51	32.61***	29411.7	4901.9	59.4***
Years	4	125.9	31.5	409***	712726	178182	2157.7***
combined regression	1	97.6	97.6	10.35***	708821	708821	544.5***
Residual-1	3	28.28	9.43		3905.37	1301.8	
V×Y	24	2603	108.5	1409.7***	3236492	134854	1633***
Heterogeneity	6	12.5	2.08	0.015	51595.1	8599	0.049
Residual-2	18	2590.5	143.92		3184897	176939	
Pooled error	630	48.47	0.077		52025.3	82.58	

c) Stability Parameters:

In this model, regression co-efficient and the deviation from regression ($\overline{S}^2_{d_i}$) were used as the parameters of stability in this model.

i). Regression co-efficient (b_i):

Regression co-efficient is a measure of response of individual genotype in the different environments. The response of individual varieties for each character to different environments are as follows:

Number of secondary branches at maximum flowering stage (NSBMF):

With respect to NSBMF, the regression co-efficient is 0.9533 ± 0.5333 for *annuum* , 1.0245 ± 0.5255 for *acuminatum*, 0.9560 ± 0.4752 for *conoides*. All the regression co-efficients were equal to 1.00. So, they showed average response to environment. The other values are 1.373 ± 0.2457 for *abbreviatum*, 0.5522 ± 0.7073 for *nigra*, 0.867 ± 0.4771 for *cerasiformis* and - 0.2628 ± 0.6693 for *fasciculatum*. The regression co-efficient of *nigra* and *cerasiformis* are less than 1.00, indicating that they were below average responsive to the environment. Variety *fasciculatum* showed negative value, indicating that it was responsive only to poor environment.

Number of Secondary branches at first flowering stage (NSBFF):

For this character the regression co-efficients are 0.5898 ± 0.395 for *abbreviatum*, 0.7466 ± 0.3666 for *annuum*, 0.6813 ± 0.4762 for *acuminatum*, 1.0855 ± 0.1536 for . *nigra*; 1.2471 ± 0.5440 for *conoides*, 1.0672 ± 0.1873 for *cerasiformis*, 0.8444 ± 0.0639 for *fasciculatum*. The regression co-efficients for *abbreviatum*, *annuum*, *acuminatum* and *fasciculatum* were less than 1.00, which with significant regression co-efficient exhibited the below average response. Rests of the values were equal to 1.00 showing average response.

Plant height at maximum flowering stage (PHMF):

In case of PHMF, *abbreviatum* (1.1065 ± 0.2552), *fasciculatum* (1.2079 ± 1.0896), *annuum* (1.2619 ± 0.5750) they showed average response. The variety *nigra* (1.3760 ± 1.5419), *conoides* (0.6494 ± 0.5814) and *cerasiformis* (0.8186 ± 0.4259) showed below average response. On the other hand, *acuminatum* (0.3422 ± 0.3362) showed above average response.

Number of primary branches at first flowering stage (NPBFF):

For this character the regression co-efficient is 1.4378 ± 0.5232 for the variety *abbreviatum*, 1.5646 ± 0.4568 for the variety *fasciculatum*, all these values were greater than 1.00, therefore, the varieties with significant regression co-efficients exhibited the above average response. For this character other regression co-efficients were 0.5009 ± 0.5496 for *annuum*, 0.9236 ± 0.5489 for *acuminatum*, 0.8863 ± 0.2668 for *nigra*, 0.4575 ± 0.3392 for *conoides*, 0.5646 ± 0.2983 for *cerasiformis*, which were less than 1.00, hence they were with below average response.

Plant height at first flowering stage (PHFF):

In case of PHFF, the variety *acuminatum* (0.6807 ± 0.2558), *conoides* (0.7862 ± 0.5732) showed below average response, the variety *abbreviatum* (1.1476 ± 0.3898), *annuum* (1.1959 ± 0.1183), *cerasifofmis* (1.1154 ± 0.4280), *fasciculatum* (1.0222 ± 0.7103) indicated average response, *nigra* (1.8760 ± 0.7310) showed above average response.

Leaf area at first flowering stage (LAFF):

Regarding LAFF, the regression co-efficient is 0.5089 ± 0.3299 for *abbreviatum*, 0.5941 ± 0.3295 for *annuum*, 0.7690 ± 0.6688 for *acuminatum*, 0.3723 ± 0.9463 for *nigra*, 0.5092 ± 0.2529 for *cerasiformis* and 0.9157 ± 0.4819 for *fasciculatum*. All these regression co-efficients were less than 1.00. So they showed below average response. The variety *conoides* was with average response having the regression co-efficients, 1.0663 ± 0.8073.

Leaf area at maximum flowering stage (LAMF):

For this character the regression co-efficients were 0.7783 ± 1.0508 for the variety *abbreviatum*, 0.6861 ± 0.0.8832 for variety *annuum*, 0.0.7282 ± 0.873 for *conoides*, which were less than 1.00, indicating that the varieties with significant regression co-efficients were of below average response. For this character other regression co-efficients were 1.3163 ± 0.9463 for *nigra*; 1.8081 ± 0.2529 for *cerasiformis* and 1.5190 ± 0.4819 for *fasciculatum* all these values are greater than 1.00. So, the varieties were with above average response. The variety *acuminatum* (1.0166 ± 0.6638) showed the average response.

Number of primary branches at maximum flowering stage (NPBMF):

In case of NPBMF, the variety *cerasifofmis* (0.7018 ± 0.2389) showed average response. While the variety *abbreviatum* (1.2825 ± 0.4802), *acuminatum* (1.1776 ± 0.2759), *conoides* (0.9982 ± 0.8675) and *fasciculatum* (0.9462 ± 0.4892) indicated average response, the variety *annuum* (1.4070 ± 0.8342), *nigra* (1.3964 ± 5281) showed above average response.

Number of leaf at maximum flowering stage (NLMF):

For this character the regression co-efficients were 0.7807 ± 0.1.0426 for the variety *abbreviatum*, 0.687 ± 0.8739 for the variety *annuum* and 0.7380 ± 0.8017 for the *conoides*, all of which were less than 1.00, so the varieties showing significant regression co-efficient exhibited the below average response. Other regression co-efficients were 1.3147 ± 0.9377 for *nigra*, 1.8013 ± 0.2494 for *cerasiformis* and 1.5158 ± 0.4709 for *fasciculatum*, all these values were greater than 1.00 so, the varieties showed above average response. While, the variety *acuminatum* (1.0156 ± 0.6565) showed average response.

Number of leaf at first flowering stage (NLFF):

Regarding NLFF, the regression co-efficients were 0.8078 ± 0.2840 for *abbreviatum*, 0.5557 ± 0.1110 for *conoides* and 0.6562 ± 0.1356 for *cerasiformis*. All of which were less than 1.00, therefore, indicated below average response. Other values were 1.2835 ± 0.1128 for *annuum*, 1.1009 ± 0.2862 for *acuminatum*, 1.1582 ± 0.2363 for *nigra* and 0.9150 ± 0.1984 for *fasciculatum*, which were equal to 1.00, therefore showed average response.

Table 12A – 12J: Regression analysis of seven genotypes in chilli (*Capsicum annuum* L.) in five years according to Freeman and Perkins' (1971) model:

12A) Number of secondary branch at maximum flowering stage (NSBMF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	225.18	1.3731	158.901	218.1934	6.986573
annuum	138.092	0.9533	110.321	105.1728	32.91917
acuminatum	153.432	1.0245	118.562	121.4734	31.95857
nigra	93.292	0.5522	63.9068	35.29238	57.99962
conoides	131.908	0.9560	110.634	105.7718	26.13617
cerasiformes	113.34	0.8670	100.332	86.99062	26.34938
fasciculatum	59.84	-0.2628	-30.4129	7.992829	51.84717
Total	915.084	5.4635	632.246	680.8873	234.1967

12B) Number of secondary branches at first flowering stage (NSBFF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	35.072	0.5898	46.622	27.4985	7.57348
annuum	54.688	0.7466	59.0174	44.0644	10.6236
acuminatum	54.628	0.6813	53.8589	36.6979	17.9301
nigra	95.012	1.0855	85.8066	93.1469	1.86506
conoides	146.34	1.2471	98.5786	122.94	23.4002
cerasiformes	92.628	1.0672	84.3574	90.0273	2.60071
fasciculatum	56.692	0.8444	66.7506	56.3686	0.32337
Total	535.06	6.2621	494.991	470.744	64.3164

12C) Plant height at maximum flowering stage (PHMF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	457.274	1.1065	392.378	434.168	23.1059
annuum	681.939	1.2619	447.481	564.676	117.263
acuminatum	884.687	0.3422	121.354	41.5298	843.158
nigra	773.395	1.3760	487.953	671.436	101.959
conoides	269.446	0.6494	230.302	149.57	119.876
cerasiformes	301.976	0.8186	290.294	237.644	64.3328
fasciculatum	938.277	1.2079	428.351	517.428	420.849
Total	4306.99	6.7626	2398.11	2616.45	1690.54

12D) Number of primary branches at first flowering stage (NPBFF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	43.008	1.4378	26.4137	37.9778	5.03022
annuum	10.16	0.5009	9.20286	4.61016	5.54984
acuminatum	21.208	0.9236	16.9677	15.6717	5.53626
nigra	15.74	0.8863	16.2829	14.4322	1.30782
conoides	5.96	0.4575	8.40571	3.84609	2.11391
cerasiformes	7.492	0.5646	10.3726	5.85657	1.63543
fasciculatum	48.74	1.5973	29.3443	46.8725	1.86755

12E) Plant height at first flowering stage (PHFF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	222.412	1.1476	173.749	199.396	23.0158
annuum	218.675	1.1959	181.07	216.554	2.12151
acuminatum	80.0623	0.6807	103.059	70.1526	9.90965
nigra	613.782	1.8760	284.039	532.88	80.9024
conoides	143.351	0.7862	119.037	93.5921	49.7584
cerasiformes	216.1	1.1154	168.872	188.36	27.7401
fasciculatum	234.628	1.0222	154.775	158.226	76.4021

12F) Leaf area at first flowering stage (LAFF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	18.9539	0.5089	26.2238	13.3457	5.60829
annuum	23.7861	0.5941	30.6151	18.1895	5.5966
acuminatum	35.7572	0.7690	39.6272	30.4745	5.28263
nigra	14.9358	0.3723	19.1863	7.14381	7.79194
conoides	60.3378	1.0663	54.9493	58.5968	1.74097
cerasiformes	23.1487	0.5092	26.2388	13.361	9.78775
fasciculatum	54.6475	0.9157	47.1872	43.2114	11.4362

12G) Leaf area at maximum flowering stage (LAMF)

Varieties	Total SS.	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	18.8428	0.7783	8.57652	6.67579	12.167
annuum	13.7831	0.6861	7.56028	5.18748	8.59564
acuminatum	16.244	1.0166	11.2019	11.3883	4.85567
nigra	28.961	1.3163	14.5043	19.0929	9.86806
conoides	13.0257	0.7282	8.02382	5.84309	7.1826
cerasiformes	36.7273	1.8081	19.9226	36.0222	0.7051
fasciculatum	27.9793	1.5190	16.7375	25.4252	2.55415

12H) Number of primary branches at maximum flowering stage (NPBMF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	50.432	1.28353	34.4663	44.2384	6.19363
annuum	71.852	1.40706	37.7834	53.1634	18.6886
acuminatum	39.288	1.17768	31.624	37.2429	2.04508
nigra	59.852	1.39642	37.4977	52.3624	7.48958
conoides	46.972	0.99827	26.8063	26.7598	20.2122
cerasiformes	14.76	0.70182	18.8457	13.2262	1.53379
fasciculatum	30.472	0.94624	25.4091	24.0431	6.42892

12I) Number of leaf at maximum flowering stage (NLMF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	18.8428	0.7807	8.67091	6.77018	12.0726
annuum	13.7252	0.6870	7.63032	5.24271	8.48246
acuminatum	16.244	1.0156	11.279	11.4554	4.78862
nigra	28.961	1.3147	14.6002	19.1951	9.76589
conoides	13.0257	0.7280	8.08547	5.88683	7.13886
cerasiformes	36.7273	1.8013	20.0048	36.0363	0.691
fasciculatum	27.9793	1.5158	16.8335	25.5164	2.46293

12J) Number of leaf at first flowering stage (NLFF)

Varieties	Total SS	bi (Reg. Co-efficient)	SP(XY)	Regression SS	Remainder SS
abbreviatum	86707.8	0.8078	95526	77169.3	9538.58
annuum	196321	1.2835	151778	194814	1506.85
acuminatum	153013	1.1009	130186	143327	9685.91
nigra	165253	1.1582	136967	158648	6604.24
conoides	37979.9	0.5557	65717.4	36522.7	1457.29
cerasiformes	53102.9	0.6562	77602.6	50927.7	2175.21
fasciculatum	103664	0.9150	108201	99006.6	4657.27

ii). Deviation mean square ($\bar{S}^2_{d_i}$):

In this model, a genotype having non-significant deviation ... mean square ($\bar{S}^2_{d_i}$) also be considered as stable one over a range of environments as in the previous models. The ($\bar{S}^2_{d_i}$) values obtained are presented in Table 13A – 13J.

Number of secondary branches at maximum flowering stage (NSBMF):

For this character, the varieties *abbreviatum, annuum, acuminatum, conoides,* and *cerasiformis* showed non-significant ($\bar{S}^2_{d_i}$) values, indicating that they were stable over the five environments. The variety *nigra* and *fasciculatum* showed significant deviation mean square values, which suggested that they were not stable for this trait.

Number of Secondary branches at first flowering stage (NSBFF):

Regarding this character, all the varieties under study showed non-significant values of ($\bar{S}^2_{d_i}$), which suggested that all genotypes were stable for this character.

Plant height at maximum flowering stage (PHMF):

In case of PHMF, all the varieties were not stable having the significant ($\bar{S}^2_{d_i}$) values, except the variety *abbreviatum*. While it showed stable performance over five environments having non-significant ($\bar{S}^2_{d_i}$) values.

Number of primary branches at first flowering stage (NPBFF):

For this character, all the varieties were stable having non-significant ($\bar{S}^2_{d_i}$) values.

Plant height at first flowering stage (PHFF):

For this character, varietes *abbreviatum, annuum, acuminatum,* , and *cerasiformis* showed non-significant ($\bar{S}^2_{d_i}$) values, indicating that they were stable over the five environments. The variety *nigra, conoides* and *fasciculatum* showed significant deviation mean square values, which suggested that they were not stable for this trait.

Leaf area at first flowering stage (LAFF):

In case of LAFF, all the varieties were not stable having the significant ($\bar{S}^2_{d_i}$) values.

Leaf area at maximum flowering stage (LAMF):

For this character, all the varieties were stable having non-significant ($\overline{S}^2{}_{d_i}$) values.

Number of primary branches at maximum flowering stage (NPBMF):

In case of NPBMF, all the varieties were not stable with the significant ($\overline{S}^2{}_{d_i}$) values.

Number of leaf at maximum flowering stage (NLMF):

For this character, all the varieties were stable having non-significant ($\overline{S}^2{}_{d_i}$) values.

Number of leaf at first flowering stage (NLFF):

Regarding this character, all the varieties under study showed significant values of ($\overline{S}^2{}_{d_i}$), which suggested that all the genotypes responded differently in different environments (years). So they were not stable for this character.

Table 13A – 13J: Stability test of ten characters of chilli (*Capsicum annuum* L.) according to the Eberhart and Russell's (1966) model.

13A) Number of secondary branches at maximum flowering stage (NSBMF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2{}_{d_i}$	Test value
abbreviatum	13.4	1.3731	± 0.2457	2.08079	5.28643
annuum	14.44	0.9533	± 0.5333	10.9730	11.475
acuminatum	14.34	1.0245	± 0.5255	10.6528	11.3064
nigra	16.94	0.5522	± 0.7079	19.3332	15.2315
conoides	14.82	0.9560	± 0.4752	8.71205	10.2247
cerasiformis	14.3	0.8670	± 0.4771	8.78312	10.2663
fasciculatum	18.1	-0.2628	± 0.6693	17.2823	14.401

13B) Number of secondary branches at first flowering stage (NSBFF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2{}_{d_i}$	Test value
abbreviatum	4.44	0.5898	± 0.3095	2.4502	5.50399
annuum	5.12	0.7466	± 0.3666	3.54119	6.51877
acuminatum	6.62	0.6813	± 0.4762	5.97668	8.46878
nigra	6.06	1.0855	± 0.1536	0.62169	2.73134
conoides	6	1.2471	± 0.5440	7.80006	9.67475
cerasiformis	5.42	1.0672	± 0.1813	0.8669	3.22534
fasciculatum	5.04	0.8444	± 0.0639	0.10779	1.13731

13C) Plant height at maximum flowering stage (PHMF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2{}_{d_i}$	Test value
abbreviatum	40.19	1.1065	± 0.2552	6.81868	9.61372
annuum	39.57	1.2619	± 0.5750	39.0876	21.6576
acuminatum	37.26	0.3422	± 1.5419	281.053	58.0744
nigra	53.26	1.3760	± 0.5362	33.9865	20.195
conoides	44.67	0.6494	± 0.5814	39.9586	21.8975
cerasiformis	40.32	0.8186	± 0.4259	21.4443	16.0416
fasciculatum	41.18	1.2079	± 1.0894	140.283	41.0292

13D) Number of primary branches at first flowering stage (NPBFF)

Varieties	Mean	bi	Sbi	$\bar{S}^2_{d_i}$	Test value
abbreviatum	4.98	1.4378	± 0.5232	1.65848	4.48563
annuum	4.2	0.5009	± 0.5496	1.84995	4.71162
acuminatum	4.72	0.9236	± 0.5489	1.84542	4.70585
nigra	4.8	0.8863	± 0.2668	0.43594	2.2872
conoides	4.2	0.4575	± 0.3392	0.70464	2.90786
cerasiformis	4.84	0.5646	± 0.2983	0.54514	2.55768
fasciculatum	6	1.5973	± 0.4568	0.62252	2.73317

13E) Plant height at first flowering stage (PHFF)

Varieties	Mean	bi	Sbi	$\bar{S}^2_{d_i}$	Test value
abbreviatum	26.01	1.1476	± 0.3898	7.47966	9.59497
annuum	28.78	1.1959	± 0.1183	0.70717	2.91308
acuminatum	29.30	0.6807	± 0.2558	3.30322	6.29592
nigra	37.42	1.8760	± 0.7310	26.9675	17.9892
conoides	28.45	0.7862	± 0.5732	16.5861	14.1079
cerasiformes	25.32	1.1154	± 0.4280	9.24671	10.5338
fasciculatujm	27.04	1.0222	± 0.7103	25.4674	17.4817

13F) Leaf area at first flowering stage (LAFF)

Varieties	Mean	bi	Sbi	$\bar{S}^2_{d_i}$	Test value
abbeiviatum	12.142	0.5089	± 0.3299	1.78538	4.73636
annuum	12.883	0.5941	± 0.3295	1.86553	4.73143
acuminatum	13.816	0.7690	± 0.3201	1.76088	4.59679
nigra	15.298	0.3723	± 0.3888	2.59731	5.58281
conoides	14.493	1.0663	± 0.1838	0.58032	2.63892
cerasiformis	12.526	0.5092	± 0.4358	3.26258	6.25708
fasciculatum	12.613	0.9157	± 0.4711	3.81205	6.76348

13G) Leaf area at maximum flowering stage (LAMF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbeiviatum	8.58	0.7783	± 1.0508	4.01707	6.97623
annuum	8.51	0.6861	± 0.8832	2.86521	5.86367
acuminatum	8.33	1.0166	± 0.6638	1.61856	4.40712
nigra	9.81	1.3163	± 0.9463	3.28935	6.28269
conoides	7.91	0.7282	± 0.8073	2.3942	5.36007
cerasiformis	7.76	1.8081	± 0.2529	0.23503	1.67941
fasciculatum	7.8364	1.51905	± 0.4814	0.85138	3.19634

13H) Number of primary branches at maximum flowering stage (NPBMF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	6.44	1.2835	± 0.4802	2.03653^{NS}	4.9774
annuum	7.34	1.4070	± 0.8342	6.22953^{NS}	8.64606
acuminatum	6.68	1.1776	± 0.2759	0.68169^{NS}	2.86012
nigra	6.84	1.3964	± 0.5281	2.49653^{NS}	5.47342
conoides	6.64	0.9982	± 0.8675	6.73739^{NS}	8.99159
cerasiformis	5.2	0.7018	± 0.2389	0.51126^{NS}	2.47693
fasciculatum	6.94	0.9462	± 0.4892	2.14297^{NS}	5.07106

13I) Number of leaf at maximum flowering stage (NLMF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	8.58	0.7807	± 1.0426	3.98572^{NS}	6.94912
annuum	8.51	0.6870	± 0.8739	2.82749^{NS}	5.82493
acuminatum	8.33	1.0156	± 0.6565	1.59621^{ns}	4.37658
nigra	9.81	1.3147	± 0.9377	3.2553^{NS}	6.25009
conoides	7.91	0.7280	± 0.8017	2.37962^{NS}	5.34373
cerasiformis	7.76	1.8013	± 0.2494	0.23033^{NS}	1.66253
fasciculatum	7.83	1.5158	± 0.4709	0.82098^{NS}	3.13874

13J) Number of leaf at first flowering stage (NLFF)

Varieties	Mean	bi	Sb_i	$\bar{S}^2_{d_i}$	Test value
abbreviatum	251.72	0.8078	± 0.2840	3138.24*	195.331
annuum	256.6	1.2835	± 0.1128	502.284*	77.6363
acuminatum	233.2	1.1009	± 0.2862	3228.64*	196.834
nigra	284.62	1.1582	± 0.2363	2201.41*	162.533
conoides	192.68	0.5557	± 0.1110	485.762*	76.3488
cerasiformis	204.82	0.6562	± 0.1356	725.069*	93.2782
fasciculatum	237.1	0.9150	± 0.1984	1552.42*	136.488

Table 14A: Comparison of regression co-efficient (b_i) and deviation [illegible] mean square ($\bar{S}^2_{d_i}$) in three models.

Characters	Varieties	Eberhart and Russell's Model		Perkins' and Jinks' Model		Freeman and Perkins' Model	
		b_i	$\bar{S}^2_{d_i}$	$\beta_I = (b_i - 1)$	$\bar{S}^2_{d_i}$	b_i	$\bar{S}^2_{d_i}$
NSBMF	*abbreviatum*	1.5476	-4.29022	0.5476	-4.29022	1.3731	2.08079
	annuum	1.6820	10.95735	0.6820	10.95735	0.9533	10.9730
	acuminatum	1.1183	6.783818	0.1183	6.783818	1.0245	10.6528
	nigra	0.9204	-0.29548	-0.796	-0.29548	0.5522	19.3332
	conoides	0.8551	1.531955	-0.1449	1.531955	0.9560	8.71205
	cerasiformis	0.9102	0.180619	-0.0898	0.180619	0.8670	8.78312
	fasciculatum	-0.0337	3.922795	-1.0337	3.922795	-0.2628	17.2823
NSBFF	*abbreviatum*	0.7046	1.7376	-0.2954	1.7376	0.5898	2.4502
	annuum	0.9732	-0.5442	-0.0268	-0.5442	0.7466	3.54119
	acuminatum	0.8395	-0.2514	-0.1605	-0.2514	0.6813	5.97668
	nigra	1.1338	-0.9368	0.1338	-0.9368	1.0855	0.62169
	conoides	1.1071	-1.0449	0.1071	-1.0449	1.2471	7.80006
	cerasiformis	1.4238	0.82392	0.4238	0.82392	1.0672	0.8669
	fasciculatum	0.8177	-1.4503	-0.1823	-1.4503	0.8444	0.10779
PHMF	*abbreviatum*	0.9772	11.9164	-0.0228	11.9164	1.1065	6.81868
	annuum	1.3240	67.6528	0.3240	67.6528	1.2619	39.0876
	acuminatum	0.7117	68.1321	-0.2883	68.1321	0.3422	281.053
	nigra	1.3393	2.12899	0.3393	2.12899	1.3760	33.9865
	conoides	0.7908	20.0458	-0.2092	20.0458	0.6494	39.9586
	cerasiformis	0.9356	-8.3841	-0.0644	-8.3841	0.8186	21.4443
	fasciculatum	0.9211	49.9442	-0.0789	49.9442	1.2079	140.283

Table 14A contd.

Characters	Varieties	Eberhart and Russell's Model		Perkins' and Jinks' Model		Freeman and Perkins' Model	
		b_i	$\bar{S}^2_{d_i}$	$\beta_I = (b_i - 1)$	$\bar{S}^2_{d_i}$	b_i	$\bar{S}^2_{d_i}$
NPBFF	*abbreviatum*	1.6768	0.2696	0.6768	0.2696	1.4378	1.65848
	annuum	0.6619	0.21859	-0.3381	0.21859	0.5009	1.84995
	acuminatum	1.0377	0.02656	0.0377	0.02656	0.9236	1.84542
	nigra	0.8194	0.0332	-0.1806	0.0332	0.8863	0.43594
	conoides	0.6321	0.10985	-0.3679	0.10985	0.4575	0.70464
	cerasiformis	0.6150	-0.038	-0.3850	-0.038	0.5646	0.54514
	fasciculatum	1.5569	0.70412	0.5569	0.70412	1.5973	0.62252
PHFF	*abbreviatum*	1.0764	3.05972	0.0764	3.05972	1.1476	7.47966
	annuum	0.9772	-2.0018	-0.0228	-2.0018	1.1959	0.70717
	acuminatum	0.7241	-0.4309	-0.2759	-0.4309	0.6807	3.30322
	nigra	1.7138	-1.2957	0.7138	-1.2957	1.8760	26.9675
	conoides	0.6757	5.18682	-0.3243	5.18682	0.7862	16.5861
	cerasiformis	0.9873	0.32536	-0.0127	0.32536	1.1154	9.24671
	fasciculatum	0.8452	6.33118	-0.172	6.33118	1.0222	25.4674
LAFF	*abbreviatum*	0.9828	-0.1869	-0.0172	-0.1869	0.5089	1.78538
	annuum	0.9865	-1.17	-0.0135	-1.17	0.5941	1.86553
	acuminatum	1.0457	-0.2615	0.0457	-0.2615	0.7690	1.76088
	nigra	1.0264	-0.7104	0.0264	-0.7104	0.3723	2.59731
	conoides	1.0677	-0.212	0.0677	-0.212	1.0663	0.58032
	cerasiformis	0.8518	-0.58	-0.1482	-0.58	0.5092	3.26258
	fasciculatum	1.0388	-0.2755	0.0388	-0.2755	0.9157	3.81205

Table 14A contd.

Characters	Varieties	Eberhart and Russell's Model		Perkins' and Jinks' Model		Freeman and Perkins' Model	
		b_i	$\bar{S}^2_{d_i}$	$\beta_I = (b_i - 1)$	$\bar{S}^2_{d_i}$	b_i	$\bar{S}^2_{d_i}$
	abbreviatum	0.7660	1.2562	-0.2340	1.2562	0.7783	4.01707
	annuum	0.8482	-0.0538	-0.1518	-0.0538	0.6861	2.86521
	acuminatum	0.7314	0.62184	-0.2686	0.62184	1.0166	1.61856
LAMF	*nigra*	1.1185	-0.3273	0.1185	-0.3273	1.3163	3.28935
	conoides	1.0485	-0.0155	0.0485	-0.0155	0.7282	2.3942
	cerasiformis	1.1625	0.43555	0.1625	0.43555	1.8081	0.23503
	fasciculatum	1.3246	0.92652	0.3246	0.92652	1.51905	0.85138
	abbreviatum	1.2884	2.53424	0.2884	2.53424	1.2835	2.03653^{NS}
	annuum	1.2207	3.11137	0.2207	3.11137	1.4070	6.22953^{NS}
	acuminatum	1.0765	0.18008	0.0765	0.18008	1.1776	0.68169^{NS}
NPBMF	*nigra*	1.2505	0.35115	0.2505	0.35115	1.3964	2.49653^{NS}
	conoides	0.8862	1.88619	-0.1138	1.88619	0.9982	6.73739^{NS}
	cerasiformis	0.6593	-0.3099	-0.3407	-0.3099	0.7018	0.51126^{NS}
	fasciculatum	0.6181	1.3762	-0.3819	1.3762	0.9462	2.14297^{NS}
	abbreviatum	0.7652	1.24723	-0.2348	1.24723	0.7807	3.98572^{NS}
	annuum	0.8628	-0.022	-0.1372	-0.022	0.6870	2.82749^{NS}
	acuminatum	0.7303	0.6152	-0.2697	0.6152	1.0156	1.59621^{ns}
NLMF	*nigra*	1.1159	-0.3298	0.1159	-0.3298	1.3147	3.2553^{NS}
	conoides	1.0455	-0.0122	0.0455	-0.0122	0.7280	2.37962^{NS}
	cerasiformis	1.1594	0.43842	0.1594	0.43842	1.8013	0.23033^{NS}
	fasciculatum	1.3206	0.93498	0.3206	0.93498	1.5158	0.82098^{NS}

Table 14A contd.

Characters	Varieties	Eberhart and Russell's Model		Perkins' and Jinks' Model		Freeman and Perkins' Model	
		b_i	$\bar{S}^2_{d_i}$	$\beta_I = (b_i - 1)$	$\bar{S}^2_{d_i}$	b_i	$\bar{S}^2_{d_i}$
NLFF	*abbreviatum*	1.0032	940.421	0.0032	940.421	0.8078	3138.24*
	annuum	1.3957	612.299	0.3957	612.299	1.2835	502.284*
	acuminatum	1.2827	2330.23	0.2827	2330.23	1.1009	3228.64*
	nigra	1.3434	-486.25	0.3434	-486.25	1.1582	2201.41*
	conoides	0.4624	-494.6	-0.5376	-494.6	0.5557	485.762*
	cerasiformis	0.6286	-629.55	-0.3714	-629.55	0.6562	725.069*
	fasciculatum	0.8836	3313.46	-0.1164	3313.46	0.9150	1552.42*

Table 14B: Comparison of partitioning the V×E interaction item (i.e. G×E) of joint regression analysis in the three models.

Characters	Eberhart and Russell's Model			Perkins and Jinks' Model		Freeman and Perkins' Model	
	Environment+ (Variety×Environment)			V×E		V×E	
	Environment (F value)	Variety×environment (Linear) (F value)	Pooled deviation (F value)	Heterogeneity of regression (F value)	Remainder (F value)	Heterogeneity of regression (F value)	Residual (F value)
NSBMF	88.95^{**}	11.38^{**}		559.6^{***}	163.0^{***}	0.06^{ns}	546.54^{***}
NSBFF	414.99^{**}	64.72^{***}		427.4^{***}	144.4^{***}	0.045^{ns}	319.73^{***}
PHMF	52.1^{**}	4.02^{**}		145.3^{***}	381.5^{***}	0.013^{ns}	1081.3^{***}
NPBFF	291.73^{**}	45.12^{***}		956.7^{***}	133.8^{***}	0.075^{ns}	695.89^{***}
PHFF	217.4^{**}	32.7^{***}		452.8^{***}	141.6^{***}	0.013^{ns}	2223.58^{***}
LAFF	326.0^{**}	50.8^{***}		9.78^{***}	47^{***}	0.008^{ns}	1146.25^{***}
LAMF	696.9^{***}	12.72^{**}		113.9^{***}	192.3^{***}	0.015^{ns}	935.39^{***}
NPBMF	120.1^{***}	16.46^{**}		409.8^{***}	357.7^{***}	0.019^{ns}	845.71^{***}
NLMF	97.1^{**}	12.8^{**}		111.7^{***}	194.1^{***}	0.015^{ns}	934.55^{***}
NLFF	488.2^{***}	77.9^{**}		1659.7^{***}	209.6^{***}	0.049^{ns}	1071.32^{**}

variability in percentage (C V %) in 1999 (Table 1A – 1J). There is scope of improvement the character possessing high C V %.

In the present investigation the analysis of variance, indicated that all the seven varieties for all the characters were significantly different from each other due to their genotypes (Table 2A – 2E). Year item was also highly significant for all the characters under study, indicating that the five consecutive years were different. Replication item was non-significant for all the characters, which suggested that they were not different from each other. V×R interaction item was also non-significant for all the characters, indicating that replication did not interact with the varieties. V×Y item was significant for all the characters, except LAFF, which suggested that varieties interacted with different years. Year interacted with replications for in four characters *viz.*, LAMF, NLMF, LAFF and NPBFF and in the rest of the characters they did not interact. The second order interaction, V×Y×R was significant for five characters. Significant second order interaction i.e. V×Y×R showed that year and replication interacted with the varieties in the five characters, such as, LAMF, NPBMF, NLMF, PHFF, and NSBFF, while in the rest of the characters they did not interact with the varieties.

The phenotypic variation is the joint product of the components of variation such as, σ^2_V, $\sigma^2_{V\times Y}$, $\sigma^2_{V\times R}$, $\sigma^2_{Y\times R}$, $\sigma^2_{V\times R\times Y}$ and σ^2_W. The components of variation showed a wide range of phenotypic variation in all the characters in seven genotypes of chilli (*Capsicum annuum* L.) in the present investigation (Table 3). Ramanujam and Thirumalachar (1967) reported the presence of the wide range of variation in a number of characters in chilli. Khaleque *et al.* (1991) also noted similar records in a number of chemical characteristics in chilli. Phenotypic variation, in the present case, was major part of the variation in all the characters. The pronounced environmental variation indicated that greater portion of the phenotypic variation was environmental in nature. Chandra (1968) observed in gram that variability was affected by environment. Another report was also made by Samad (1991) that phenotypic variation appeared to be due to the genotypic variation. However, comparatively a low genotypic variation was noted in all the characters in the present investigation which might be due to the higher sampling variance, observable from high values of the within error variance (σ^2_W). As a result a low genetic co-efficient of variability and heritability were found for all the characters. Genetic advance (GA) and genetic advance expressed as percentage of mean (GA%) were also low for all the characters (Table 4 & 5). The expression of characters may likely be conditioned by non-additive gene effect (Panse, 1957). Poddar (1993) and Nahar (1997) also obtained the low heritability for millable cane/clump in sugarcane.

According to Eberhart and Russell's (1966) model, joint regression analysis showed that (Table 6A – 6E) the variety item was significant for the characters NPBFF, PHFF, LAFF, NLFF and others were non-significant. Significant cases suggested that the genotypes were different, which justifies the inclusion of varieties as materials in the present work. Environment (year) item was highly significant for all the characters, which suggested that years were different. The item Environment + (variety ×environment) i.e. G × E was also highly significant for all the characters, when tested against respective pooled deviation. The variety × environment (linear) i.e. regression item is highly significant for all the characters. The significant G×E (linear) indicated that the genotypes studied showed similar performance (linearity) over the environments. In these cases, the genotypes had the significantly greater portion of linear relationship compared to the nonlinear one. These results are in agreement with Chaudhary and Paroda (1979), who worked on grain yield of inbreed wheat.

According to Perkins' and Jinks' (1968) model, genotypic (variety), environmental (year) and V×Y interaction items were highly significant when tested with their within error. But when tested with remainder, only year item was significant for all the characters, while variety and V×Y items were non-significant for all the cases in the joint regression analysis. Significant cases indicated that the genotypes were different, which justifies their inclusion as materials in the present investigation (Table 10A – 10J). Further, from the joint regression analysis, it is proved that G×E interaction was accounted for both the slopes of linear and nonlinear regression in most of the cases. In comparison to the non-linear one (i.e. heterogeneity of regression, which is also significant in 5 characters), some varieties had greater portion of linear relationship. These findings of both linear and nonlinear relation with environments are supported by many workers in different crops including rapeseed (Khaleque, 1975; Joarder and Eunus, 1977; Joarder *et al.* 1978; Uddin, 1979, 1983; Singh and Gupta, 1983; Uddin *et al.* 1985; Henry and Daulay, 1987, 1988a, b and Kundu and Khurana, 1988).

In the joint regression analysis of Freeman and Perkins' (1971) model, variety, environment (year) and V×Y item were significant for all the characters. In this very model, environment is divided into combined regression and residual-1. Combined regression is highly significant for all the characters, in comparison to the residual 1, indicating that environments are well measured (Table 11A – 11E)(Singh and Chaudhary, 1979). Residual 1 is significant in maximum cases, suggested that the environmental index inadequately was the index of additive environmental effect. In addition to this, in this model, G×E interaction item is divided into heterogeneity of regression and residual 2. Heterogeneity item is non-significant for all the characters when tested with residual 2, while residual 2 is highly significant for all the characters when tested against within error, indicating that varieties showed linear performance to the environments in which they were grown.

Phenotype of quantitative characters of a variety depends on its own genotype and also on environment, in which it grows. As a result with the study of genotype of a plant the study of environment is also of utmost importance. Regression analysis is only method in biometrics, by which genotypic and environmental effects are simultaneously estimated. How much a variety depends on environment to express its character is measured by regression. So, regression analysis measures the response of a genotype over environments. Consequently, if there is any stable quality of a character in a variety over different environments, it can be measured by the regression analysis. To measure the response and to find out stable quality of a character, there are many suggestions, which are given by different researchers in different investigation in the regression analysis. Finley and Wilkinson (1963) considered the linear regression as a measure of stability. Unit regression co-efficient (b_i = 1.00) and non-significant deviation from regression ($\overline{S}^2{}_{d_i}$) are the criteria of stability parameters as described by Eberhart and Russell (1966), Perkins' and Jinks (1968) and Freeman and Perkins' (1971). In addition to this, regression co-efficient is a measure of response to varying environments and the mean square deviation from linear regression is true measure of stability, which was suggested by Breese (1969), Paroda *et al.* (1973) and Langer *et al.* (1979). Potentiality of a genotype to express greater mean over environments should be most important criterion, which was stated by Banis and Gupta (1972). They also added that since the other two parameters may not have any particular utility if the genotype is potentially week.

For the selection of a stable genotype over a range of environments, on the basis of the above mentioned criteria, it may be summarised that, a) a variety having high mean performances (x), average b_i values and non-significant $\bar{S}^2_{d_i}$ values, may be considered as stable one to all the environments; b) cultivars with above average mean performances and regression co-efficients and non-significant $\bar{S}^2_{d_i}$ are sensitive to environmental changes may be recommended for favourable environment; c) a variety belonging high mean with below average response (b_i = >1.00) and non-significant $\bar{S}^2_{d_i}$ may be adapted to poor environment; d) with the less mean performance value, regression co-efficient is close to 1 and non-significant $\bar{S}^2_{d_i}$ of a variety, indicating poorly adaptable to all the environments; e) a variety having less mean performance, regression co-efficient above average and non-significan $\bar{S}^2_{d_i}$ indicating poorly adaptable to favourable environment and f) genotypes with less mean performance and regression co-efficient and non-significant $\bar{S}^2_{d_i}$ indicate poorly adaptable to unfavourable environment. In addition to this, Sb_i is also used to compare significance of b_i values. But, a variety having negative b_i value, it would be suggested to grow only in poor field management condition (Singh and Chaudhary, 1979).

Last of all, it may be postulated from the above views that to describe the performance of a genotype and the desirable stable genotypes following criteria may be considered:

1. High mean of a genotype over all the environments.
2. With very low standard error unit regression co-efficient (b_i = 1.00).
3. Deviation from regression ($\bar{S}^2_{d_i}$) need to be zero or nearly zero ($\bar{S}^2_{d_i} = 0$)

The genotypes, which showed stable performance (adaptable to all environments or similar performance to all the varying environments), on the basis of the above mentioned criteria, are *cerasiformis* for NSBMF, *annuum, nigra* and *conoides* for NSBFF, *abbreviatum* for PHMF; *acuminatum* for NPBFF; *abbreviatum, annuum* and *cerasiformis* for PHFF; *abbreviatum, acuminatum, nigra* and *conoides* for LAFF; *nigra coniodes* and *cerasiformis* for LAMF; *acuminatum* for NPBMF; *nigra,* and *conoides* for NLMF (Table 8A-8J). All the stable varieties are measured according to the Eberhart and Russell's (1966) and Perkins' and Jinks' (1968) models. But following the Freeman and Perkins' (1971) model the stable genotypes are *annuum, acuminatum* and *conoides* for NSBMF; *nigra* and *cerasiformis* for NSBFF; *abbreviatum* for PHMF; *acuminatum* for NPBFF; *abbreviatum, annuum* and *cerasiformis* for PHFF; *conoides* and *fasiculatum* for LAFF; *acuminatum* for NLMF

(Table 14A). However, all the three models showed that varieties like *abbreviatum* for PHMF, *acuminatum* for NPBFF, *abbreviatum, annuum* and *cerasiformis* for PHFF may be selected as stable genotypes for further breeding research. While, other varieties (*nigra, conoides* and *fasciculatum*) for different characters were not stable according to these three models.

Following three models it was found that variety *annuum* for NSBMF, *cerasiformis* for NSBFF, *nigra* for PHMF, *abbreviatum* and *fasiculatum* for NPBFF and for LAMF; *abbreviatum, annuum* and *nigra* for NPBMF; *fasiculatum* for NLMF were more responsive to changing environments having non-significant $\overline{S}^2{}_{d,}$ and high values of b_i. It suggested that these varieties may be recommended only for favourable environments(Singh and Chaudhary, 1979). Further, varieties, *conoides* for NSBMF, *acuminatum* and *fasiculatum* for NSBFF, *nigra* for NPBFF, *fasiculatum* for PHFF, *cerasiformis* for NLFF, NPBMF and LAFF, *annuum* for LAMFand NLMF, showed poor adaptability to all the environments as they had low mean performances, a regression co-efficient less than 1 and non-significant $\overline{S}^2{}_{d,}$ values. Singh and Rai (1989) and Singh *et al.* (1993) also found similar results in sugarcane. Nahar (1997) also in sugarcane for different quantitative characters, found that some varieties were adaptable in favourable and some were adaptable in unfavourable environments.

In the present investigation, three G×E interaction models viz., Eberhart and Russell (1966), Perkins and Jinks (1968) and Freeman and Perkins (1971) were followed for selection of stable genotypes in chilli (*Capsicum annuum* L.). Though the calculation of b_i in Eberhart and Russell's and Perkins' and Jinks' models are same,following Perkins' and Jinks' model, $b_i = 1 + \beta$; with this minor difference estimation of b_i values following Perkins' and Jinks' model helps in the confirmation of the results as were obtained in Ebarhart and Russell's model (Table 14A). In calculation of b_i values, calculation of environmental index is needed, which is different and elaborated following Freeman and Perkins' model in comparison to the other two models *viz.*, Ebarhart and Russell and Perkins' and Jinks' where it was more or less same.

Therefore, in consideration of all the above, Perkins' and Jinks' model may be considered as a suitable technique for the analysis of G×E interaction, which confirms the results as obtained following Ebarhart and Russell's model (Table 14B).

Moreover, in the joint regression analysis following Perkins' and Jinks' model a clear picture about linear and non-linear components were obtained which were lacking in Ebarhart and Russell's model and not confirmed following Freeman and Perkins' model.

SUMMARY

To select the stable genotypes in chilli (*Capsicum annuum* L.), the three G×E models, namely Eberhart and Russell's, Perkins' and Jinks' and Freeman and Perkins' were compared in the present investigation. In this respect, ten quantitative characters, namely number of secondary branches at maximum flowering stage (NSBMF), number of secondary branches at first flowering stage (NSBFF), plant height at maximum flowering stage (PHMF), number of primary branches at first flowering stage (NPBFF), number of primary branches at first flowering stage (NPBFF), leaf area at first flowering stage (LAFF), leaf area at maximum flowering stage (LAMF), number of primary branches at maximum flowering stage (NPBMF), number of leaf at maximum flowering stage (NLMF), number of leaf at first flowering stage (NLFF) were investigated in seven varieties of chilli under five consecutive years.

The range and mean with standard error in five years in each of the varieties for ten characters showed a wide range of variation. In the analysis of variance, the variety item was significantly different for all the characters under study, indicating that varieties were different from each other due to their genotypes. Year item was also significant for all the characters suggested that years were different. V×Y and V×Y×R items were significant for most of the characters, while V×R was non significant. G×E interaction was observed to be operative in this study as different varieties were responded differently in different years (which was considered as environment).

The environmental means also indicated that different environments had different effects on the genotypes. The year 2001 had a great effect for most of the characters (NSBMF, NSBFF, PHMF, PHFF, LAMF, NLMF and LAFF), while 1997 effected greatly on NPBFF and NPBMF and 1999 on NLFF.

In the analysis of joint regression, following Eberhart and Russell's and Perkins' and Jinks' models, both linear and non-linear components were found to be important. The variety×environment (linear) item was significant for all the characters. The significant linear portion indicated that in these genotypes linear relationship was more compared to non-linear one. However, following Freeman and Perkins' model, heterogeneity of

regression (i.e. non-linear portion) item was found to be non significant for all the characters.

Following all the three models. the stable genotypes were found to be *abbreviatum* for PHMF, *acuminatum* for NPBFF, *abbreviatum*, *annuum* and *cerasiformis* for PHFF. This indicated that these genotypes might be selected for further breeding research for those characters.

Though the calculation of index in the stability parameter was a bit different, the results obtained following Eberhart and Russell's and Perkins' and Jinks' models regarding this parameter ($b_i = 1+ \beta$), was similar. But following Freeman and Perkins' model, calculation of this index was elaborated and the results obtained were different in comparison to the other two models.

In case of joint regression analysis, only Perkins' and Jinks' model provided a clear picture about linear and non-linear components, which were found to be important in the materials of the present investigation.

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APPENDIX I

Constituents of MS (Murashige & Scoog, 1962) basal medium

Constituents	Amount (mg/l)
NH_4NO_3	1650
KNO_3	1900
KH_2PO_4	170
$MgSO_4.7H_2O$	370
$CaCl_2.2H_2O$	440
$FeSO_4.7H_2O$	27.8
$Na_2EDTA.2H_2O$	37.3
$MnSO_4.4H_2O$	22.3
H_3BO_3	6.2
$ZnSO_4.7H_2O$	8.6
KI	0.83
$CuSO_4.5H_2O$	0.025
$NaMoO_4.2H_2O$	0.25
$CoCl_2.6H_2O$	0.025
Myoinositol	100
Nicoticacid	0.5
Pyridoxine HCl	0.5
Thiamine HCl	0.5
Glysine	2.0

APPENDIX II

Constituents of ½ MS (Murashige & Scoog, 1962) basal medium

Constituents	Amount (mg/l)
NH_4NO_3	41.5
KNO_3	47.5
KH_2PO_4	17.5
$MgSO_4.7H_2O$	18.5
$CaCl_2.2H_2O$	22.0
$FeSO_4.7H_2O$	2.78
$Na_2EDTA.2H_2O$	3.83
$MnSO_4.4H_2O$	11.15
H_3BO_3	6.2
$ZnSO_4.7H_2O$	4.3
KI	0.83
$CuSO_4.5H_2O$	0.25
$NaMoO_4.2H_2O$	0.25
$CoCl_2.6H_2O$	0.25
Myoinositol	10.0
Nicoticacid	0.5
Pyridoxine HCl	0.5
Thiamine HCl	1.0
Glysine	2.0

ABBREVIATIONS

BAP	Benzylamino purine
C V	Co-efficient of variation
EDTA	Ethylenedinitrilo tetra acetic acid, disodium salt dihydrate
e. g.	Exampli gratia (= for example)
et al.	Et alia (= and others)
EtOH	Ethyl alcohol
G×E	Genotype and environment interaction
Kin	Kinetin
MS	Murashige and Skoog (1962) medium
NAA	Napthalene Acetic Acid
pH	Negative logarithm of hydrogen ion (H^{+}) concentration
viz.	Videlicet (= namely)
2, 4-D	2, 4-dichlorophenoxyacetic acid

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