GENETIC VARIABILITY, DIVERSITY AND PHENOTYPIC STABILITY OF NAGA KING CHILLI (*Capsicum chinense* Jacq.)

Thesis

Submitted to

NAGALAND UNIVERSITY

In partial fulfillment for the degree

of

Doctor of Philosophy (Agriculture)

in

GENETICS AND PLANT BREEDING

By

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Affectionately Dedicated

to my loving

MOM and my BROTHER.

STUDENT'S DECLARATION

I, **Mr. Chubatemsu Ozukum** hereby declare that the subject matter of this Thesis is the record of work done by me, that the contents of this Thesis did not form the basis of the award of any previous Degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree to any other University/Institute.

This is submitted to SASRD, Nagaland University for the Degree of Doctor of Philosophy (Agriculture) in Genetics and Plant Breeding.

……..

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CERTIFICATE - I

This is to certify that the Thesis entitled **"Genetic variability, diversity and phenotypic stability of Naga King Chilli (*Capsicum chinense* Jacq.)"** submitted to Nagaland University in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) in the discipline of Genetics and Plant Breeding, is a record of research work carried out by **Mr. Chubatemsu Ozukum**, Registration No. 559/2014, under my personal supervision and guidance.

All help received by him/her have been duly acknowledged.

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CERTIFICATE - II

This is to certify that the Thesis entitled **"Genetic variability, diversity and phenotypic stability of Naga King Chilli (*Capsicum chinense* Jacq.)"** submitted by **Mr. Chubatemsu Ozukum**, Admission No. Ph-141/12, Registration No. 559/2014, to Nagaland University in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Agriculture) in the discipline of Genetics and Plant Breeding has been examined by us in a viva voice held on..... and has been found satisfactory/ unsatisfactory

Signature

Dr. Kigwe Seyie …….
Supervisor

…….
External Examiner …….....

Members of the Advisory Committee: **Signature**

1. Prof. Sapu Changkija ……...…….
2. Dr. Malini Barthakur Sharma .....……
3. Dr. H. P. Chaturvedi .....……
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LIST OF ABBREVIATIONS

bi	-	Regression coefficient
cm	-	Centimetre
CD	-	Critical Difference
ºC	-	Degree Celsius
E	-	East
et al.	-	*et allia* (and others/co-workers)
Fig.	-	Figure
F-test	-	Fisher's test
GA	-	Genetic Advance
GCV	-	Genotypic coefficient of variation
σ^2g	-	Genotypic variance
gm	-	Gram
ha	-	Hectare
h^2bs	-	Heritability in broad sense (%)
i.e.	-	Id est (that is)
kg	-	Kilogram
Max.	-	Maximum
MSL	-	Mean Sea Level
m	-	Metre
MT	-	Metric Tonnes
Min.	-	Minimum
NU	-	Nagaland University
N	-	North
No.	-	Number
%	-	Per cent
PCV	-	Phenotypic coefficient of variation
σ^2p	-	Phenotypic variance
RBD	-	Randomized Block Design
r_g	-	Genotypic correlation coefficient

SASRD	-	School of Agricultural Sciences and Rural Development
Sl. No.	-	Serial number
S	-	South
SEm±	-	Standard error of mean
S^2di	-	Deviation mean square
viz.	-	Videlicet (Namely)
W	-	West

CHAPTER - I

NTRODUCTION

INTRODUCTION

A vegetable is any part of a plant that is consumed by humans as food as part of a savory meal. The term "vegetable" is somewhat arbitrary, and largely defined through culinary and cultural tradition. It normally excludes other food derived from plants such as fruits, nuts and cereal grains, but includes seeds such as pulses. The original meaning of the word *vegetable*, still used in biology, is to describe all types of plant, as in the terms "vegetable kingdom" and "vegetable matter". Originally, vegetables were collected from the wild by hunter-gatherers and entered cultivation in several parts of the world, probably during the period 10,000 BC to 7,000 BC, when a new agricultural way of life developed. At first, plants which grew locally would have been cultivated, but as time went on, trade brought exotic crops from elsewhere to add to domestic types. Nowadays, most vegetables are grown all over the world as climate permits, and crops may be cultivated in protected environments in less suitable locations.

The origin of vegetable culture in India could be traced back to very ancient times around 10,000 BC. The toys, pendants, earthen ware, vase etc of the Harappa civilization were found to contain the shape of horticultural produce like lemons. Later with arrival of Portuguese several new vegetables such as tomato, potato, carrot, cassava, pumpkins and chillies were introduced in India. The vegetable culture in India has undergone great revolution changes with the passage of time owing to their nutritional, medicinal values, diversified uses, high productivity, potentiality of value addition and export. India now grows maximum number of vegetable crops due to diversity of agro-climatic condition and occupies second largest producer of vegetables with total estimated production of 16,21,87,000 metric tonnes from an area of 9.21 million hectares with productivity of 17.62 tonnes per hectare next to China which is the largest producer of vegetables producing about 49.51% of the world's produce from an area of 2,45,61,000 hectares with a productivity of 23.4 metric tonnes per hectare.

Chilli is a spice-cum-vegetable crop having high commercial importance is cultivated worldwide, valued for their sensory attributes of colour, pungency and flavor (Pino *et al.*, 2007). Chilli peppers are economically important because of the vast consumption of their diverse varieties. It is cultivated exclusively in tropical and temperate zones of the world and

grown on more than 1.5 million hectares worldwide (FAO, 2007). It is a dicotyledonous flowering plant belonging to the family Solanaceae. India is the largest producer, consumer and exporter of chillies in the world. It contributes about 36% to global chilli production and exports about 20% of its total production. The Amazon is an important centre of diversity for chilli particularly of the genus *Capsicum chinense* although over the last decade the degradation of the genus due to anthropic pressure has been intense. There are about twenty-two wild and five cultivated species under the genus *Capsicum,* the cultivated species being *C. annuum, C. baccatum, C. chinense, C. frutescens* and *C. pubescens* (Bosland,1994). The fruits vary in shape (globular to sub conical) and colour. The colour of each *Capsicum* variety is variable from green, yellow or white for the unripe fruit and turning to red, dark red, brown and sometimes almost black in the ripe stage. Ripe pepper (*Capsicum sp*.) fruits can display a range of colours from white to deep red (Ha *et. al.,* 2007). But there are also controversies regarding the individual species status of *annuum, chinense* and *frutescens.* This was questioned by several researchers like McLeod *et al.* (1979, 1982), Pickersgill (1988), and many others and was attributed to the fact that the wild relatives of these three species tend to show taxonomically important similarities. But it is now accepted in the world scientific communities that *Capsicum* species originated in the New world and therefore nomenclature of *C. chinense* could also be described as a misnomer. This particular species was so named by the Dutch botanist Nikolaus Joseph von Jacquin (1727-1817) as he collected the seeds of these plants from China, thus having a concept that this type of chilli might have originated in China (Bosland, 1996).

Capsicum chinense Jacq. cv. King Chilli is native to North-Eastern India more particularly to Nagaland (Bhagowati and Changkija 2009). It is locally known by various names in different regions such as 'Bhoot jolokia' or 'Bih jolokia' in Assam,'Naga King Chilli' in Nagaland, 'Umorok' in Manipur and 'Ghostpepper' by the western media. It is also known by the names,'Saga jolokia', 'Indian mystery chilli' and 'Indian rough chilli' (after the chilli's rough skin), Meghvanshi *et al*. (2010). *Capsicum chinense* Jacq. or bhoot jolokia has received the attention of scientific community throughout the world due to its unique aroma and has been acknowledged as the hottest chilli in the world , measuring 1,001304 Scoville Heat Units (SHU) (Guinness Book of World Records 2006). However as of September 2015, the top position for the world's hottest chilli has changed four times and as of now the Naga

King chilli comes in the fifth position superseded by **the Infinity chilli (1,067,286 SHU), Trinidad Scorpion Butch T Pepper (500,000 - 1,463,700 SHU), Trinidad Moruga Scorpion (1,200,000 - 2,000,000 SHU) and Carolina Reaper (1,500,000-2,200,000 SHU) which is considered as the hottest chilli.** Most of the chilli species and varieties cultivated in India contain around 1% capsaicin but Naga King chilli has around 2–4% capsaicin as reported by various researchers (Mathur *et al*., 2000 and Sanatombi and Sharma, 2008). The pungent principle of chilli fruit is capsaicinoids, a family of compounds that give them the characteristic pungent taste. In nature, the two major capsaicinoids, capsaicin and dihydrocapsaicin account for 90 % of the total pungency in chilli fruits (Suzuki *et al*., 1980). Capsaicin is mainly used as a spice, as food additive, and in pharmacological applications. The Naga king chilli, possibly, the only chilli that contains genes of both *Capsicum frutescens* and *C. chinensis,* is used conventionally in treating various human ailments. As a medicine, capsaicin is known to kill some types of cancer cells (Mini *et al*., 2004) it has been reported to show anticancer effect (Moore and Moore, 2003 and Baek *et al.,* 2008) and it also provides relief in arthritis and respiratory ailments (Mazzone and Geraghty, 1999). It is a counter irritant and an analgesic agent (Fusco and Giacovazzo, 1997). The common properties of chilli are Vitamin C, A, B and B_6. It also contains high percentage of potassium, magnesium and iron. Capsaicin has become a promising molecule for the development of a new generation of analgesic-anti-inflammatory agents targeting the nociceptive primary afferent neurons (Szolcsanyi, 2004). Capsaicin has also been reported to show protective effects against cholesterol and obesity (Kempaiah *et al.,* 2005).

The amount of capsaicinoids in a chilli pepper pod depends on the genetic makeup of the plant and the environment where it is grown (Harvell and Bosland 1997, Zewdie and Bosland 2000). The capsaicinoids have evolved in chilli peppers as a defense mechanism against mammalian predators (Tewksbury and Nabhan, 2001); nevertheless, this trait is an important fruit quality attribute and one of the most important reasons chilli peppers are consumed.

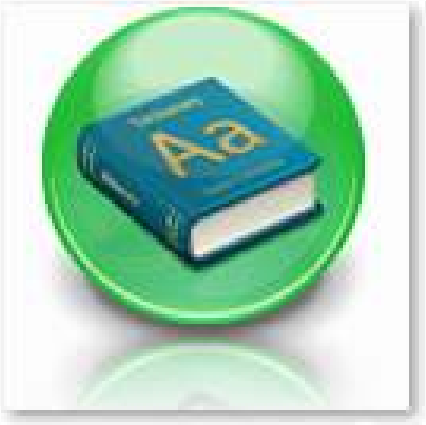
Bhut jolokia plant is location specific hence the plants of the same genotypes grown under different environmental condition vary from one another in various aspects which proves to be a boon to bring about improvement for efficient breeding works. The Nagaland government had passed the Nagaland Geographical Indication of Goods (Registration and

Protection) Act in 1999, to provide some safety net to Naga farmers in the cultivation of the King Chilli. Nagaland Government has obtained the GI rights for this product in 2008.

Systematic scientific exploration and evaluation of this crop may not only help in improving yield and quality attributes of the crop, but also in solving some critical problems of pest and diseases and other stress factors. The available landraces may have immense potential to serve as the basic raw material required for development of improved varieties.

Keeping in mind that Naga King Chilli is a potential crop for North Eastern region of India for domestic and export purpose, an attempt has been made to collect the available landraces of Naga King Chilli and the present investigation entitled **"Genetic variability, diversity and phenotypic stability of Naga King Chilli (*Capsicum chinense Jacq.*)"** was undertaken with the following objectives;

1. To study the different landraces of Naga King Chilli based on qualitative characters.
2. To study the extent of variability among the different landraces.
3. To find out the extent of diversity among the landraces.
4. To select the stable landrace with respect to yield parameters.



CHAPTER - II

LITERATURE REVIEW

LITERATURE REVIEW

2.1. GENETIC VARIABILITY

Nandpuri *et al*. (1971) in a study in chilli recorded high variability for yield per plant, 100 seed weight, fruit size, number of branches, plant height, days to flowering and days to maturity.

Rajput *et al*. (1983) observed high degree of genetic variability in plant height, number of branches, number of fruits and fruit length. They also reported that number of fruits exhibited highest magnitude of GCV and PCV followed by fruit weight and yield.

Meshram (1987) recorded a wide range of genetic variations for a number of characters such as number of primary branches, fruit length, number of fruits per plant and dry fruit yield per plant. He also recorded highest GCV for number of primary branches followed by number of fruits per plant while the PCV was highest for the number of fruits per plant followed by dry yield of fruit and number of primary branches.

Arumugam and Pappiah (1989) observed high variability for yield per plant, plant height, fresh fruit weight per plant and number of fruits per plant. They also recorded high GCV value for yield per plant followed by plant height and number of fruits per plant.

Alam (1990) in a study involving 9 local chilli cultivars of Assam observed high genotypic variability for plant height, number of primary and secondary branches, days to first flowering, flowers per plant, fruits per plant, fruiting percentage, fruit length, fruit diameter, fruit weight, seeds per fruit, leaf area index, harvest index and yield.

Bijendra and Rajput (1992) evaluated 6 varieties of chilli for 14 yield components including yield per hectare, and the data obtained were used to calculate genotypic and phenotypic correlations between characters. Result indicated that selection for high yielding genotypes should be based on the number of secondary branches, days to 50% flowering, fruit length, fruit weight, number of fruits/plant and dry matter percentage.

Pitchaimuthu and Pappiah (1992) evaluated fourteen F_6 families, produced from F_5 generation of the cross Acc. 1683 XK2, for major economic characters on an individual plant

basis to establish the nature and extend of genetic variability. Very high genotypic variability was found for number of fruits, dry and fresh weight of fruit and plant height. A close association between estimates of phenotypic and genotypic co-efficient of variation for several characters in most of the families indicated low environment influence. However, length and girth of fruit and earliness were highly sensitive to environmental factors.

Pandey and Dobhal (1993) in a study involving 30 diverse genotypes of chilli collected from Meghalaya, Assam, Nagaland and Tripura observed a high degree of variation among the genotypes for plant height, leaves per plant, branches per plant, days to flower, fruits per plant, fruit length, fruit diameter and dry yield per plant.

Ali (1994) studied yield correlations in 12 *Capsicum annum* genotypes and found out that yield was significantly correlated with fruit numbers/plant, seed number/fruit and number of seeds/25 fruits. Dry fruit weight was significantly correlated with fresh weight and weight of the pedicel and pericarp.

Sharma and Roy (1995) studied variability, heritability and yield correlation on 8 yield-related traits in 20 chilli genotypes collected from different regions of the hills of Assam. Path coefficient analysis revealed the importance of fruit diameter, fruit length and days to 50% flowering as selection criteria for improving chilli genotypes.

Rani and Singh (1996) studied genetic variability of various characters in 73 chillies (C. annum L.) genotypes and observed significant differences for all characters indicating the diverse genetic nature of base population.

Warade and Dhumal (1996) evaluated 60 chilli (*Capsicum annum*) genotypes for correlation among 12 yield-related characters and found that yield/plant was positively correlated with plant height, plant spread, fruit weight, seeds/fruit, days to 50% fruit set, fruit length and fruit girth, and negatively correlated with days to 50% flowering and maturity. It was also observed that heritability values were generally high, indicating good scope for improvement through selection.

Deka and Shadeque (1997) studied character association in sweet pepper *Capsicum annum* cv. California Wonder and found that the number of branches per plant had a strong positive association with yield per plant. Path analysis revealed that branches per plant, fruits

per plant and fruit size had high magnitudes of positive direct effects on yield. Fruits per plant and fruit size also had positive indirect effects via branches per plant. Thus, branches per plant, fruit per plant and fruit size appeared to provide reliable criteria for selection in sweet pepper.

Roy *et al*. (1997) evaluated 23 genotypes of chilli (*C. annum* L.) for yield and reported that genetic variation among genotypes and genotypes environment interactions were highly significant. `

Singh and Singh (1998) noted considerable genetic variability for plant height, days to 50% flowering, number of fruits per plant, length of the fruit, fresh weight of fruit, dry weight of fruit and fruit yield in 30 genotypes of chilli.

Nayeema *et al*. (1998) in a study involving 72 genotypes of hot peppers (*Capsicum annum* L.) revealed the existence of considerable amount of genetic variability for all the different characters studied and especially for fruit yield.

Devi and Arumugam (1999) studied on genotypic correlations and path analyses in 30 F_1 *Capsicum annum* hybrids to determine the effect of different characters on yield. A positive and significant correlation was observed between dry fruit yield/plant and the number of fruits/plant, capsaicin content and plant height. The number of secondary branches and fruit shape index were positively but not significantly related to dry fruit yield/plant. In path analysis, the number of fruits/plant and had the highest positive effect on dry fruit yield/plant. Plant height exhibited a negative direct effect, but influenced yield indirectly through number of fruits/plant, fruit shape index, number of secondary branches, capsaicin content and number of seeds/fruit. These characters were primary yield determinants in *Capsicum annum.*

Munshi *et al*. (2000) conducted an experiment on 30 germplasm of chilli to study the association between yield and yield attributes. They observed that yield per plant was significantly and positively correlated with number of fruits per plant and fruit weight. Significant negative association of days to first harvest with number of fruits per plant and yield associated characters.

Munshi and Behera (2000) in a study involving 30 germplasm lines indicated the existence of considerable amount of genetic variability for all the characters studied except fruit girth.

Dipendra and Gautam (2002) studied genetic variability among 52 chilli (*Capsicum* spp.) cultivars and lines with regard to yield and yield components. Significant variation was observed in all characters. Fruit drop percentage, fresh fruit yield per plant, and dry fruit yield per plant showed high genotypic and phenotypic co-efficient of variation. Heritability estimates were moderate to high for all characters except the number of primary branches. The highest genetic advance along with high heritability was recorded for fruit drop percentage, followed by fresh fruit yield per plant, leaf area index and fruit length, indicating the importance of these traits in selection for high yield.

Leaya and Khader (2002) studied 12 yield components in 37 genotypes, subjected to yield correlation and path coefficient analysis. The results suggested that selection for mean fruit weight, fruits/plant, crop duration, and early flowering and yielding might lead to increase in yield.

Rathod *et al*. (2002) conducted an experiment on variability parameters in 8 components in 13 chilli cultivars and observed the existence of considerable variability among various components. The number of fruits per plant, fresh red per plant and plant height recorded high genotypic coefficient of variation.

Deepu *et al*. (2004) studied fifty six Capsicum accessions, consisting of 48 hot peppers (*C. annuum*), 2 bell peppers (*C. annuum* var. *grossum*) accession each of *C. chinense*, C. *frutescens* and *C. practemissum* (*C. baccatum* var. *practermissum*), 2 accessions of *C. baccatum* sub sp. *pendulum* and one accession of *C. baccatum* sub sp. *baccatum* x *C. baccatum* sub sp. *pendulum* (*C. baccatum* var. *Pendulum*). Results of correlation and path analysis indicated that selection for fruit number, fruit length and fruit width as well as plant height and canopy length might increase yields. In the case of hot pepper, recovery ratio and 1000-seed Weight should also be included in the selection criteria.

Singh and Singh (2004) conducted the association studies with 10 selected local chilli cultivars/lines in Arunachal Pradesh and revealed the importance of correlation among yield

per plant, number of fruits per plant, fruit diameter and plant height in determining high fruit yield in chilli. The path co-efficient analysis brought out the number of fruits per plant, fruit weight and fruit diameter as major yield components, which might be considered as selection indices for improvement of chilli.

Mini and Khader (2004) studied genetic variability, heritability and genetic advance in 25 genotypes of wax-type chilli. Analysis of variance revealed significant difference among genotypes for all traits. High values of genotypic (GCV) and phenotypic coefficient of variation (PVC) were recorded for green fruit yield per plant, number of fruits per plant and average fruit Weight, indicating more scope for their improvement through selection. High heritability coupled with high genetic advance was observed for 100-seed weight, fruit length, average fruit weight, number of fruits per plant, green fruit yield per plant, fruiting span and number of secondary branches, indicating that selection based on these traits would be ideal.

Mishra *et al*. (2004) studied on genetic variability including mean, genotypic and phenotypic variances, coefficients of variation, heritability, genetic advance and genetic gain in 22 genotypes of Capsicum (*Capsicum annum*) in the mid-hills of Uttaranchal, India. Significant differences among the genotypes were observed for all characters studied. The cultivars Pepper Paprika, Sel l-2 and Sel 1-3 were promising with more than one desirable trait. High phenotypic and genotypic co-efficient of variation, heritability and genetic gain were observed for ascorbic acid content, number of fruits per plant, fruit yield per plant, seed yield per fruit and fruit length.

Sreelathakumary and Rajamony (2004) evaluated 15 accessions of hot chilli for plant height, stem girth, leaf area, days to first flowering, fruits per plant, fruit length, fruit girth, fruit weight and yield per plant. Correlation analysis showed that yield had highly significant and positive correlation with fruits per plant, fruit length, fruit girth and fruit Weight. Path analysis revealed that fruits per plant, fruit weight and fruit girth had positive direct effects on yield. Fruit length had a negative direct effect on yield, but its indirect effect through fruits per plant, fruit girth and fruit Weight was high and positive. These results suggest that selection for fruits per plant, fruit weight, fruit length and fruit girth might lead to an increase in the yield of hot chilli.

Sreelathakumary and Rajamony (2004) evaluated thirty five chilli (*Capsicum annum* L.) genotypes to assess genetic variability, heritability and genetic advance. Higher phenotypic and genotypic coefficients of variation were observed for leaf area, fruits per plant, fruit weight, fruit length, fruit girth and yield per plant. High heritability coupled with high genetic advance observed for these characters imply the potential for crop improvement through selection.

Nazir *et al*. (2005) studied variability in 21 diverse genotypes of Sweet Pepper (*Capsicum annum* var. grossum) during the 2003 summer season. Among the genotypes SP-628 recorded the highest fruit followed by SP-634 and California Wonder. A wide range of variation was also observed in most of the characters. The highest phenotypic and genotypic co-efficient of variability were observed in weight per fruit, while other traits exhibited moderate to high phenotypic and genotypic coefficients of variability. All the traits exhibited high heritability and high heritability coupled with high genetic gain was observed in plant height, plant spread, flesh thickness, number of fruits per plant, weight per fruit and seed yield per plant indicating that these characters had additive gene effect and therefore they are more reliable for effective selection.

Singh *et al*. (2005) evaluated nine local chilli cultivars along with one control cultivar for yield and yield attributes. Significant differences in respect to days to flowering, days to maturity, days to ripening, fruit diameter, fruit per plant, seeds per fruit, plant height, number of branches per plant, yield per plant, fruit and stalk ratio and capsaicin content were observed. It was inferred that the local chilli cultivars MM-4 and HM-1 which gave significant superior performance as compared to other cultivars including the improved control cultivar, may be recommended for growing extensively in Pasighat areas to maximize chilli production.

Varkey *et al*. (2005) studied genetic variability and heritability for 12 charactersin 45 genotypes of chilli (*Capsicum annum*). Mean squares due to genotypes were significant for all characters, except days to flower, indicating the existence of variability among genotypes. High genotypic and phenotypic coefficients of variation were observed for number of fruits per plant and fresh fruit yield per plant. High heritability coupled with high genetic advance

was recorded for number of fruits per plant, number of seeds per fruit and weight per plant. These traits can be exploited in breeding programmers to improve yield in chilli.

Ahmed *et al*. (2006) evaluated twenty five diverse germplasm lines of Paprika for 13 characters. Analysis of variance revealed highly significant difference among genotypes for all characters. There was an inherent association among characters, as indicated by the higher value of the genotypic correlation co-efficient compared with the corresponding phenotypic correlation coefficients. Correlation analysis revealed that fruit length, fruit girth, fruit weight, seed weight per fruit and pungency had significant positive correlation with fruit yield. Path analysis revealed that fruit weight, seed weight per fruit, flesh-to-seed ratio, number of fruits per plant, flesh thickness and days to 50% flowering had appreciable direct effects on fruit yield.

Bendale *et al*. (2006) evaluated 30 chilli genotypes to estimate variability, heritability and genetic advance. A wide range of variation was observed for all the characters studied. The magnitude of phenotypic coefficient of variation (PVC) was higher than the genotypic coefficient of variation (GCV). High heritability (broad sense) was the characteristic observation for all the characters except crop duration. High heritability coupled with high genetic advance was found for 100 fruit weight, yield per plant, dry weight of plant, seed per fruit and fruit yield per plant indicating the presence of additive gene action for these characters and therefore, the characters can be improved through selection. Low genetic advance was recorded for primary branches per plant, fruit breadth, fruit length and dry weight of root.

Karad *et al*. (2006) studied variability for various yield and yield contributing characters in chillies, collected from NBPGR, New Delhi and found out that they exhibited a good amount of variability for dry fruit weight, fresh fruit weight, fruit per plant and number of branches per plant. The heritability (bs) was very high for almost all the characters studied. However, the genotypic correlations were greater in magnitude than phenotypic ones. The dry fruit yield was significantly and positively associated with fresh fruit weight, fruits per plant, plant spread, plant height and number of secondary branches per plant. The path coefficient analysis revealed the fresh fruit weight as the most important component in determining the yield and had a direct effect on yield. The fresh weight of fruits, fruits per plant were found to

be an important yield indicator in chillies and can react upon these characters for making direct selections.

Smitha and Basavaraja (2006) in their studies in variability and correlation in chilli (*Capsicum annuum* L.) showed that fruit yield had highly significant and positive association with number of fruits per plant and pedicel length.

Shirshat *et al*. (2007) estimated genetic variability were analyzed in seventy two germplasm lines and three commercial cultivars. The analysis of variance and other genetic parameter indicated considerable genetic variability for different characters among the genotypes. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters indicating the influence of environment on these characters. Heritability estimates in respect of fruit length, number of seeds per fruit, weight of seeds per fruit were high. Moderate genetic advance was observed for the characters like number of fruits per plant, number of seeds per fruit. Heritability was high in these characters except for number of fruits per plant. In case of attributes like fruit length, number of seeds per fruit and weight of seeds per fruit, the genetic advance was low to moderate coupled with high heritability. Yield per plant, the complex trait, which is dependent on several component characters showed moderate heritability with low genetic advance.

Chatterjee *et al*. (2007) evaluated sixty diverse genotypes of chilli during 2005. Correlation studies indicated number of fruits per plant, number of branches per plant, plant height and 1000 seed weight to have significant positive association with dry fruit yield per plant. Path analysis studies revealed that the number of fruits per plant had a high positive direct effect on dry fruit yield per plant. Days to maturity and plant height exerted positive direct effect on dry fruit yield and be considered while breeding for improved dry fruit yield in chilli.

Kaur *et al*. (2007) conducted an experiment on genetic variability, heritability and genetic advance with respect to different traits in thirty three chilli genotypes. Study indicated a lot of variability for various characters. Number of fruits per plant, chlorophyll content, fruit weight, number of seeds per fruit and fruit yield exhibited high heritability along with high genetic advance. They suggested that whenever an improvement in chilli crop is to be made, the selection should be based on high fruit number, more seeds per fruit and high yield as

these characters exhibit high heritability along with high genetic advance. Similarly, to improve quality character of chilli the selection should be based on the chlorophyll content and high capsaicin content only.

Krishna *et al*. (2007) studied character association and path analysis in eighty genotypically diverse indigenous and exotic genotypes of chilli for 13 important characters and found that the phenotypic and genotypic association of fruit yield was significantly positive with all the characters except days to first flowering and ten fruit weight. Early fruit yield and late fruit yield per plant were found highly significant and positively correlated with total fruit yield. The genotypic and phenotypic path coefficient revealed that the total green chilli had high direct positive effect from early and late fruit yield.

Pawandeep *et al*. (2007) evaluated 40 cultivars and local landraces of chilli (*Capsicum annum*) and found that the phenotypic coefficient of variation (PVC) was higher than the genetic coefficient of variation (GCV) for most traits. The genetic correlation was higher than the phenotypic correlation for more traits, indicating the inherent relationship among them. Total yield showed positive and significant phenotypic and genetic correlation with fruit height, fruit breadth and fruits per plant, fruit weight, capsaicin content and oleoresin content had high positive direct effects on yield.

Sarkar *et al*. (2009) evaluated forty-nine genotypes of chilli to study the genetic variability as well as association for 12 growth and fruit characters. There was significant variation among the genotypes. Fruit yield (g)/plant, number of fruits/plant, fruit length (cm), placenta length (cm), fruit weight (g), number of seeds/fruit and plant height (cm) showed high values of GCV and PCV. High heritability in broad sense coupled with high GA in % grand mean was recorded for fruit yield/plant, number of fruits/plant, fruit length, days to 50% flowering and plant height indicating such characters were controlled by additive gene action The phenotypic path-coefficient analysis revealed that number of fruits/plant, fruit weight and 1000 seed weight had positive and high direct effect on fruit yield indicating their reliability as selection criteria to improve yield of chilli.

Singh *et al*. (2009) evaluated thirty genotypes of chilli pepper (*Capsicum annum* L.) to study the extent of genetic variability, determine the association between different characters, understand direct and indirect effects of component traits on fresh and dry yield, and identify

desirable genotypes. Sufficient variability was observed in days to 50% flowering, fruit length, fruit diameter, average fruit weight, number of seeds per fruit, 100-seed weight, number of total fruits per plant, plant height. High phenotypic (PCV) and genotypic coefficients of variation (GCV) were observed for average fresh and dry fruit weight, fruit length and diameter, seed weight per fruit. Moderate PCV and GCV were recorded for plant height, number of seeds per fruit, 100-seed weight. High heritability coupled with high genetic advance was noted for marketable fresh and dry yield per plant, average fruit weight, numbers of marketable fruit, fruit diameter. Correlation and path analysis studies indicated that average fruit weight and fruit length contributed to marketable fresh yield. Average dry fruit Weight, seed Weight per fruit played a predominant role for predicting dry yield.

Sharma *et al*. (2010) in an investigation on genetic variability including mean, genotypic and phenotypic variances, coefficient of variation, heritability, and genetic advance on genetically diverse twenty three genotypes of bell pepper and observed significant differences among the genotypes for all the traits. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for fruit yield per plant indicating that these traits had wide genetic variability and would respond better to selection. High heritability and high genetic advance were recorded for average fruit weight, fruit yield per plant, fruit diameter indicating the role of additive gene action for the inheritance of these traits. At genotypic levels, the traits fruit length, fruit diameter and number of fruits per plant revealed significant positive correlation with fruit yield per plant. Number of fruits per plants exhibited the highest positive direct effect followed by average fruit yield.

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Abu *et al.* (2013) studied correlation among quantitative characters in genotypes of aromatic pepper grown over years. Results of the correlation analysis showed significant positive correlations among traits, however some were negatively correlated.

Tembhurnel and Rao (2013) studied on Path analysis in chilli (*Capsicum annuum* L.) and found out that the number of fruits per plant and fresh fruit weight fruit were the two factors that exerted the greatest influence both directly and indirectly upon the dry fruit yield.

Mishra *et al*. (2015) investigated on Genetic analysis of agro-economic traits in chilli (*Capsicum annuum*) and found out that significant differences among genotypes was exhibited for all of the traits indicating wide range of variability in the material. The estimate of phenotypic coefficient of variation was higher than the genotypic coefficient of variation for almost all the traits. The magnitude of genotypic correlation was higher than the phenotypic correlation for all the characters.

2.2. GENETIC DIVERGENCE

Gill *et al*. (1973) reported that genetic diversity of parents was positively related to heterosis in F_1 chillies. Khadi (1983) also reported non-significant heterosis in the hybrids whose parents were in the same cluster. However, Shifriss and Sacks (1980) reported that heterosis was not related to diversity.

Singh and Singh (1976) grouped 45 strains of chilli into 10 clusters. The clustering pattern revealed that the strain belonging to a particular geographical location generally tended to be in the same cluster. They observed maximum contribution of number of branches, fruit thickness, number of fruits per plant and yield per plant towards the total

divergence whereas the characters plant height, days to 50 per cent flowering, days to maturity and fruit length contributed less.

Following Tocher's method, the 50 varieties of chilli were grouped into 7 clusters by Sundaram *et al*. (1980). They found no relationship between genetic and geographic diversity in chilli. The relative contribution of characters towards total divergence revealed that the number of branches and number of fruits per plant were the chief contributors towards genetic divergence.

Mehra and Peter (1980) grouped 27 chilli genotypes into 9 clusters based on D^2 values. They found maximum contribution (88.03%) of fruits per plant towards the diversity. The plant height contributed very little (0.28%) towards diversity whereas days to first fruit set, days to first fruit harvest, plant height, primary branches per plant, long and medium styled flowers (%), short and pseudostyled flowers (%), fresh weight of pods, dry weight of pods, seed weight of pods, pedicel to fruit ratio and locules per fruit were either negligible or nil.

Thirty three genotypes studied were grouped into 11 clusters by Varalaxmi and Haribabu (1991). Out of the 10 characters studied, fruits per plant, leaf area index, fruit weight and total yield were reported to be the chief contributors towards genetic divergence. They also found no firm relationship between genetic divergence and geographical distances.

Pandey and Dobhal (1993) in a study found out that the genotypes were clustered into 7 groups based on genetic diversity and intra and inter genetic divergence values. They suggested that variability was limited to a few extreme types and geographic and genetic diversity were not related.

Warade *et al*. (1997) grouped 60 cultivars of chilli obtained from different eco-geographical regions into 9 clusters and observed maximum diversity because of maximum cluster distances. The clustering pattern also revealed that geographic diversity did not seem to have direct association with genetic diversity. A comparison of cluster means for different characters indicated considerable differences between clusters for all the characters (Sundaram *et al*., 1980; Gill *et al*., 1982; Varalakshmi and Haribabu, 1991).

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

Karat *et al.* (2002) analysed the genetic divergence studies in forty chilli (*Capsicum annuum*) genotypes of indigenous and exotic origin. Diversity analysis revealed good amount of variation among the genotypes studied. The 40 genotypes were grouped into eight clusters. The variance of cluster means revealed that fresh fruit weight and fruits per plant had the highest contribution towards divergence. Prabhudeva (2003) grouped 36 genotypes into 11 clusters with D^2 values ranging between 34.02 to 102.13. He concluded that genetic diversity was not an index of geographical diversity by clustering pattern. In his study, maximum contribution of characters towards diversity was in fruits per plant followed by ten fruit weight and plant height. He observed maximum diversity i.e., inter cluster distance between cluster I and II, suggesting that the genotypes belonging to these clusters form ideal pairs for developing hybrids.

Senapati *et al.* (2003) analysed the genetic divergence in chilli using Mahalanobis's D^2 statistic, 11 characters were studied in a collection of 20 diverse chilli genotypes. Based on D^2 values, the genotypes were clustered in six groups. Four characters, namely fresh fruit weight, fruit girth, fruit length and fruit number per plant were the chief contributors towards genetic divergence.

Manju and Sreelathakumary (2004) investigated the genetic diversity for plant height, days to first flowering, pollen viability, fruits per plant, fruit weight, seeds per fruit, number of harvests, ascorbic acid content, mosaic incidence and yield per plant. Analysis of variance showed significant differences among accessions for all characters studied. Cluster analysis classified the accessions into 6 clusters. Among the characters, fruits per plant and yield per plant contributed maximum divergence in *Capsicum chinense*.

Saritha *et al*. (2005) in an evaluation on the genetic divergence as a function of combining ability in forty five hybrids Chilli which were produced in a Line x Tester design involving 5 lines. The hybrids along with their parents and a commercial control (Namdhan

Seeds 1101) observed significant variance among females for plant height, fresh fruit yield per plant, dry fruit yield per plant and ascorbic acid content and among males for plant height, Barlett's Index and ascorbic acid content. Variance for Line x Tester interaction was significant.

Sudre *et al.* (2005) investigated on Genetic divergence between 'chilli and sweet pepper accessions using multivariate techniques among 56 accessions of chilli and sweet pepper (*Capsicum sp.).* There were significant differences among accessions for all descriptors evaluated. General agreement among all multivariate techniques used was observed and it was possible to separate the accessions in eight distinct groups, indicating that there is genetic variability for the evaluated traits.

Dutonde *et al*. (2008) made a study on enetic diversity in 40 genotypes of chilli for various characters in which substantial differences for all the characters were revealed. The accessions were grouped into 7 clusters with Cluster-I comprising of 17 genotypes followed by Cluster IV (11) and Cluster III (8). The maximum intercluster distance (D=104.98) was observed between Cluster-IV and Cluster-VII. Intercrossing among the genotypes belonging to Cluster-II, IV and VII was suggested to develop high yielding varieties with other desirable characters.

Gogate *et al.* (2006) made genetic divergence studies in Chilli (*Capsicum annuum* var *longum* (D.C.) Sendt) and found out that the analysis of variance indicated existence of large variability among the genotypes for all the characters. Total of 11 clusters were made based on D^2 values. The genotypes were distributed randomly irrespective of geographic origin. The grouping of genotype did not show any relationship between genetic divergence and geographic diversity.

Smitha and Basavaraja (2006) investigated the genetic divergence analysis in 40 genotypes of chilli (*C. Annuum)* using Mahalanobis D^2 statistics. The genotypes were grouped into 8 clusters (A-H). The maximum relative contribution to the total divergence was recorded 8 characters studied confirming the existence of ample amount of divergence in the genotypes with respect to the traits.

55 accessions of chilli were evaluated for genetic divergence by Vani *et al.* (2007) where plant height and yield per plant showed maximum contributions towards diversity D^2 analysis grouped all the genotypes into 14 clusters with 10 solitary clusters. Cluster mean analysis showed that solitary clusters were having high mean values for yield per plant, average fruit weight, seeds per fruit and fruit length.

Jarret *et al.* (2007) made a study on diversity of fruit quality characteristics in 40 genotypes of *Capsicum fruitescens L.* They were analyzed for fruit quality parameters and found out that these data demonstrate an approximate 4 to 14-fold range in values for the characteristics examined, suggesting the presence of sufficient variability for these traits within this species to support the development of germplasm enhanced for specific or multiple fruit quality attributes.

Thul *et al.* (2009) estimated the phenotypic divergence in a collection of *Capsicum species* for yield related traits among the 24 accessions belonging to a collection of six species of *Capsicum* from different geoclimatic regions which was quantified by multivariate analysis from 12 quantitative and qualitative traits. Based on their values, all 24 accessions were grouped into six clusters. The three characteristics that played the greatest role in differentiation were fruit diameter, number of fruits per plant, and leaf diameter, which can be utilized as conventional/morphological markers for the improvement of chilli yield and obtaining good segregants in chilli breeding programs.

Sudre *et al*. (2010) using the Ward-MLM procedure estimated genetic divergence in fifty six (Capsicum spp) accessions based on 25 descriptors, 14 of which were morphological and 11 agronomic. Five groups, G1, G2, G3, G4 and G5 were established by the criteria of psudo-F and pseudo-t 2. The results showed that there was no association between the clusters formed and geographic location where the accessions were collected.

Fifty germplasms of chilli were evaluated to assess the genetic diversity during rabi season by Singh and Singh (2010). The result indicated that all the fifty genotypes were grouped in four and three clusters in first year and second year, respectively. Highest intra-cluster D^2 values (468.96) and genetic distance (21.85) in first year was estimated for cluster III followed by cluster II (427.41 and 20.67) and cluster I (202.64 and 14.24). Maximum inter-cluster D^2 values (984.71) and genetic distance (31.38) were recorded between cluster II

and III followed by cluster I and III (816.43 and 28.57), cluster III and IV (725.44 and 26.93), cluster II and IV (562.34 and 23.71), cluster I and II (546.70 and 23.38) and cluster I and IV (490.66 and 22.10). In second year cluster I had intra-cluster D^2 values and distance of 121.00 and 11.00, respectively. Maximum inter-cluster D^2 values (824.91) and genetic distance (28.72) were recorded between cluster II and III, followed by cluster I and II (747.37 and 27.34) and cluster I and III (169.00 and 13.00).

Kumar *et al*. (2010) made a study of genetic diversity in 25 chilli genotypes for various characters which revealed substantial differences for all the traits. Based on D^2 values, the genotypes were clustered into eight constellations. Intercrossing among the genotypes belonging to cluster III, IV and I was suggested to develop high yielding varieties with other desirable characters or may be used as potential donors for future hybridization programme to develop better chilli variety with good fruit yield.

Pandit *et al.* (2010) studied on genetic divergence through multivariate analysis in chilli (*Capsicum annuum* L.) germplasms and found out that based on the divergence (D^2 values) between any two genotypes, a logical grouping of the genotypes with low D^2 value could be arrived by Tocher's method.

Datta and Jana (2011) studied genetic divergence in chilli (*Capsicum spp.*) under sub Himalayan tracts of West Bengal where 65 genotypes were. The clustering pattern revealed that there was no association of species and geographical distribution for the formation of cluster in genetic divergence.

Joshi *et al.* (2013) in their experiment on assessment of genetic diversity in *Capsicum* spp. by using morphological and molecular tools found that all the exotic genotypes and genotypes from northern part of India clustered together while, two genotypes of southern part of India fell into separate cluster. Genetic diversity was also estimated at molecular level with the help of capsicum specific SSR markers.

Nazia Peeraullee and V.M. Ranghoo-Sanmukhiya, (2013) studied on the genetic diversity of five chilli (*Capsicum annuum* L.) varieties in Mauritius was evaluated using morphological and molecular techniques. Primer OPW04 showed the highest degree of

polymorphic bands. Overall, RAPD markers can be used to differentiate between the local chilli varieties

An experiment was conducted by Janaki *et al.* (2015) to analyze the genetic diversity among 63 genotypes for ten quantitative and six qualitative characters in chilli. The maximum contribution towards genetic divergence was shown by fruit diameter (44.14%) followed by yellow carotenoids (16.90%), red carotenoids (10.45%), ascorbic acid (10.19%) and capsaicin (9.17%).

Rego *et al*. (2015) worked to estimate the genetic diversity among accessions of *Capsicum* spp. and to calculate the relative importance and the correlation among them. The most explicative variables were fruit set/plant (29.57%), days to flowering (17.78%) and yield (12.62%). The physical fruit traits, in general, were positively correlated among them and with leaf length and width. They were negatively correlated with total soluble solids, acidity, fruit dry matter content, as with fruit set/plant and days to fructification.

2.3. PHENOTYPIC STABILITY

Peter J. Stoffella *et al.* (1995) grew Bell pepper *(Capsicum annuum* L.) cultivars in nine Florida environments to evaluate phenotypic stability of marketable fruit yield (t/ha^{-1}) and mean fruit size (g/fruit). A stable cultivar excelled for a particular trait when grown in either favorable or unfavorable environments. `Ssupersweet 860', `Whopper Improved', and `Ranger' were stable for mean marketable fruit weights and fruit size, and `Ssupersweet 860' and `Whopper Improved' were stable for mean fruit size. Bell pepper cultivars were differentiated for phenotypic stability of yield and fruit size or adaptability to diverse environments.

Chowdhury *et al.* (2001) made an investigation on phenotypic stability in Thirteen chilli (*Capsicum annum* L.) genotypes to determine the Genotype x Environment (GE) interaction and stability parameters for fruit yield, days to 50% flowering, fruit length and circumference, plant height and number of primary branches per plant. The pooled analysis of variance revealed significant differences among the genotypes for days to 50% flowering, plant height and fruit yield. The linear component of GE interaction was significant for days to 50% flowering and plant height.

Senapati and Sarkar (2002) studied the adaptability and genetic stability of 20 chilli cultivars and found out that Genotype x Environment interactions were significant for fruit yield, number and weight; dry chilli recovery percentage; and plant height. The linear and non-linear components equally contributed to the Genotype x Environment interactions in plant height, fruit weight, dry chilli recovery percentage and fruit yield. The linear component was significant against the non-linear component in fruit number only. Local cultivars were stable for all the characters examined.

Nehru *et al.* (2003) made a stability analysis for fruit yield and other metrical characters in sixteen chilli (*C. annuum*) genotypes for stability of genotypes for canopy (CAN), height (HT), fruits per plant (FP), and fruit yield per plant (FY). The ANOVA for stability revealed the significance of genotype x environment (linear) as well as pooled deviation components, indicating that it is rather difficult to predict the performance of genotypes over years.

Samnotrar *et al.* (2006) evaluated twenty-five genotypes of chilli from different parts of India for their stability for quality traits (capsaicin content and coloring matter) which showed highly significant mean squares for both quality traits indicated wide variability amongst the genotypes. The environment component was significant for colouring matter and non-significant for capsaicin content. The highly significant effect of genotype x environment for both quality traits indicated differential response of genotypes to various environments.

Anand *et al.* (2006) analysed chilli (*Capsicum sp*.) varieties for fruit yield stability which were subjected to the Additive Main effects and Multiplicative Interaction (AMMI) analysis. It revealed significant V X E interaction, which could be attributed to differential ranking of the genotypes across the environments. The V X E interaction was further partitioned into PCA axes, of which the first PCA axis captured 79.6% of the total G XE variance. Biplot analysis indicated that parents and the progeny from the cross have general adaptability with high mean yield and PCA scores nearer to zero..

Srividhya and Ponnuswami (2010) studied on G × E interaction and stability of yield in paprika genotypes (*Capsicum annuum* var *longum*) in Tamil Nadu. The result indicated that all the genotypes exhibited sufficient Genotype × Environment interactions for all the traits studied.

Datta and Jana (2011) analysed the stability of 15 chilli genotypes for different seasons and found that pooled analysis of variance revealed the presence of significant genetic variability among the genotypes.

Abu *et al.* (2013) studied on Genotypic stability among quantitative characters in genotypes of aromatic pepper grown over years and found out that the analysis of variance of the data collected showed significant differences among genotypes. The Genotype x Year (g x y) interaction was significant for most of the traits.

Tembhurnel and Rao (2013) studied on Stability analysis in chilli (*Capsicum annuum* L.) in twenty cytoplasmic genetic male sterility (CGMS) based F_1 hybrids, three promising genotypes and a check which were evaluated in three different environments for stability analysis. The correlation and path coefficient analysis were studied in 75 genotypes for 18 and 12 different quantitative characters, respectively. Variance due to Genotypes × Environment interactions were significant for all the characters except number of fruits per plant and fresh fruit weight per plant.

Vitria Puspitasari Rahadi *et al.* (2013) studied on nonparametric stability analysis of yield for nine chilli pepper *(Capsicum annuum* L.*)* genotypes in eight environments to identify promising high yield and stability of chilli pepper. Based on the ranking frequency stability of the nonparametric method, the genotypes with the highest frequency of static stability ranking were genotypes IPB002003, IPB002046, IPB009019 and Tit Super, whereas IPB009002 and Tombak were categorized as those of dynamic stability. Genotype IPB120005 and IPB019015 were less adaptable in the multiple environments tested. It shows that the genotypes were specific in certain environments. IPB120005 had high yield and specific location in Boyolali in dry season and IPB019015 genotype was specific in Bogor in wet season.

Sharma *et al.* (2014) investigated on twenty genotypes of chilli (*Capsicum annuum* L.) for stability studies for quality traits in four different environments created by planting material at two different dates of planting and each date of planting with two doses of N-fertilizer and found out that significant mean squares for quality traits indicated wide genotypic variability among the genotypes.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation entitled **"Genetic variability, diversity and phenotypic stability of Naga King Chilli (*Capsicum chinense* Jacq.)"** was conducted under three environmental conditions viz.

1. Under the Polyhouse Condition of Central Institute of Horticulture, Medziphema, Nagaland which was designated as Environment I.
2. Under open field condition located in the Experimental Farm of Genetics and Plant Breeding Department School of Agricultural Sciences and Rural Development (SASRD), Medziphema Campus, Nagaland University which was designated as Environment II.
3. Under farmers' field condition near bamboo groove located on the hill slope land of SASRD farm which was designated as Environment III.

The investigation was conducted for two growing seasons i.e. March to December, 2014 and 2015. Details of the materials used and procedures followed during the course of investigation are described as under.

3.1. General information:-

3.1.1. Site of work:-

Each experimental units were located in Medziphema situated at 29° 45' 43" N latitudes and 93° 53" 04" E longitudes at an elevation of 304.80 meters above mean sea level. The experimental lay out for all the three environmental conditions is presented in Fig: 1.

3.1.2. Climatic condition:-

The sites of the experimental areas fall under sub-tropical climate with high humidity and moderate temperature with medium to high rainfall. The temperature ranges from 12° C during winter to 32° C during summer. The average annual rainfall varies from 2000 to 2500 mm. The meteorological datas taken during the periods of investigation (2014 and 2015) are presented in Table 1, Table 2, Fig 2 and Fig 3 respectively.

3.1.3. Soil condition

The soil is acidic in nature with pH varying from 4.5 - 6.2. The organic matter content is low which varied from 1.2 - 2.9 %. N.P.K availability was 100.35 Kg, 204.5 Kg and 196.68 Kg/hectare respectively. Under polyhouse, the organic matter content is low with an average of 1.51%. N.P.K availability was 92.22 Kg, 221.00 Kg and 285.14 Kg/hectare respectively.

3.2. Experimental details

3.2.1. Source of planting material

The experimental materials in the present study comprise of various landraces of Naga King Chilli which were collected from different growing locations of Nagaland. The particulars of the landraces are presented in Table 3.

3.2.2. Nursery raising

In both the seasons, a raised bed of l m x 5 m size was prepared with due care. Well decomposed cow dung was applied at the rate of 5 kg/m^2. Sowing was done during the last week of February in both the growing seasons. Before sowing the seeds were soaked in 0.3 % potassium nitrate overnight and allowed to dry under room condition for improvement of germination percentage. Treated seeds were sown in lines under shade and the lines were covered with fine FYM and sand. Light irrigation was given immediately. The nursery beds were irrigated at regular intervals and weeding was done as and when necessary after sowing of seeds.

3.2.3. Field preparation

The experimental areas were prepared as follows during the two seasons

Under the polyhouse (Environment I), plots measuring 3 m x 2.25 m were made and pits were dug before transplantation in the month of April. Under the Experimental open field condition (Environment II), the land was ploughed by tractor drawn disc plough in the month of March, which was followed by two harrowing with the help of tractor drawn disc harrow. After thorough preparation of soil, plots were made and the pits were dug and kept for solarization. In the farmer's field condition, the jungle was cleared in the month of January and the slashed debris were left for drying. Burning, cleaning and preparation of the plots were carried out in the month of April before the onset of monsoon.

3.2.4. Experimental techniques and design

The experiments under all the Environments were laid out in Randomized Block Design with three (3) replications. The total experimental area was 312 sq. metres each (32 m x 9.75 m). The whole area was then divided length wise into three blocks representing three (3) replications with l m apart. Each of these blocks was divided into eight (8) equal plots of 3 m x 2.25 m size with a spacing of 75 cms plant to plant and row to row respectively. The detail plan and layout of the experiment is given in Fig 3 and the codes such as Cl, C2, C3 etc. were used to designate the respective landraces.

Table 3: Particulars of landraces.

Code	Place of collection	District
C1	Mangkolemba	Mokokchung
C2	Mon	Mon
C3	Tsiepama	Dimapur
C4	Razhaphema	Dimapur
C5	Medziphema	Dimapur
C6	Jaluki 1	Peren
C7	Jaluki 2	Peren
C8	Thekrejuma	Kohima

3.2.5. Manuring

Naga King Chilli requires adequate nutrient supply for its optimum production. In Environment I and Environment II farm yard manure was applied in pits @ 5 tonnes/ha during field preparation and in the Environment III, the pits were filled with ashes of bamboo and other burned debris mixed with soil.

3.2.6. Transplanting of seedlings

One week before transplanting, irrigation was stopped in order to facilitate hardening of seedlings making them hardy to tolerate transplanting shock. The seedlings were transplanted on the first week of May just before the onset of monsoon in all the three environments.

3.2.7. Aftercare and Intercultural operations

With a view to minimize the interference of weeds with crops, attention was given to weed control, The first weeding was done after 30 days of transplanting by simply scrapping the soil and hand weeding with very light earthing up. The second intercultural operation was done similarly after 50 days. In the subsequent months very few weeding was done accompanied by light hoeing.

As a precautionary measure, in all the environmental conditions imidacloprid 65 EC @ 0.25ml per liter was sprayed twice at 25 days interval one during the nursery stage and one after transplanting to prevent the crops from the attack of major sucking pests like aphids and jassids. For the crops under Environment I and II, during the vegetative stage, a routine preventive measure was taken against fruit rot (*Colletorricum capsici*) by spraying Captef WP (2 gm per litre). All throughout the experimental period, irrigation was provided at alternate days interval for the crops under Environment I, in Environment II irrigation was provided as and when dry spells prevailed and in Environment III monsoon rain was the only source of irrigation throughout the experimental period.

3.2.8. Harvesting

The fruits were harvested at different dates according to their stages of maturity. Attainment of proper size and change in colour was considered as the harvest stage.

3.3. Observations recorded and sampling procedure

Data were collected from five tagged individual plants of each landrace for different characters in each of the experimental plots.

3.3.1. Qualitative characters

Qualitative characters, viz., Stem colour, plant growth habit, branching habit, leaf size (at full foliage stage), leaf shape, leaf colour, leaf pubescence, pigmentation at node, corolla colour, anther colour, ripe fruit colour, fruit shape, fruit shape at pedicel attachment, blossom end fruit shape, fruit surface, seed colour and biotic stress susceptibility were recorded for each landrace.

3.3.2. Days to first flowering

The total number of days from the date of sowing to the date on which the first flowering started in each plot was recorded based on visual observation and average was calculated.

3.3.3. Plant height (cm)

The height of the plants from the base to the terminal apex was measured in centimeter in each sampling plant and the average was calculated. The observation was recorded when the first fruit begins to ripe in at least 50% of plants.

3.3.4. Days to 50% fruiting

The total number of days from the date of sowing to the date when 50% of the plants bear mature fruits was recorded and average was calculated.

3.3.5. Number of fruits per plant

Total number of fruits per plant was obtained by summing up the number of fruits harvested at different dates plus the number of dropped fruits from each sampling plant.

3.3.6. Fresh fruit weight (gm)

Weight of five randomly selected fresh fruits was measured from each sampling plant and the average was calculated.

3.3.7. Fruit length (cm)

Length of five randomly selected fruits from each sampling plant was taken after second harvest stage and their average was calculated.

3.3.8. Fruit width (cm)

Fruit width of five selected fruits was measured with the help of vernier calipers at the top, middle and lower portions of fruits at the second harvest stage and their average was calculated.

3.3.9. Number of fruits per cluster

The total number of fruits present in each cluster was recorded and average was calculated.

3.3.10. Number of seeds per fruit

Number of seeds in five randomly selected fruits from each sampling plant was counted and the average was calculated.

3.3.11. Dry fruit weight

Five randomly selected fruits were dried in oven at 50°C for 12 hours and their dried weight was taken and average was calculated.

3.3.12. 1000 seed weight (gm)

Weight of 100 random mature and dried seeds from each sampling plant was measured and the product was multiplied by 10 to obtain 1000 seed weight.

3.3.13. Fruit yield per plant (gm)

The total yield per plant was calculated by multiplying the average fruit weight (fresh) with total number of fruits harvested per plant.

3.4. Statistical analysis

The mean values of the observations recorded on each plot for different characters were subjected to the following statistical and biometrical analysis.

3.4.1. Analysis of variance

The analysis of variance for RBD was done according to Panse and Sukhatme (1958). In this method analysis of variance is worked out by using the mean performance of the genotypes.

Table 5: Pooled ANOVA for RBD was tabulated as follows

Source of variation	Degree of freedom (df)	Sum of square (SS)	Mean square (MS)	Variance ratio
Year	(y-1)	SSy	MSy	MSy/MSe
Replication within year	y(r-1)	SSr	MSr	MSr/MSe
Genotype	(g-1)	SSg	MSg	MSg/MSe
Year x Genotype	(y-1)(g-1)	SSyg	MSyg	MSyg/Mse
Pooled Error	(r-l) (g-1)	SSe	MSe	

Total		(yrg-1)	TSS

Where,

y: Number of years

r: Number of replications

g: Number of genotypes under study

SSr: Sum of square for replications

SSg: Sum of square for genotypes

SSe: Sum of square for error

TSS: Total sum of square

MSr: Mean square due to replication

MSg: Mean square due to genotypes

MSe: Mean square due to error.

F-test for significance was done using the mean square due to genotype against the mean square due to error. In order to test whether there is significant difference between any of the two genotypes, the Critical Difference (C.D.) for each of the character was calculated.

C.D. = S.Ed x t 0.05 or t 0.0lat error degree of freedom

S.Ed.= $\sqrt{2MSe/r}$

Where,

S.Ed = Standard error of the difference between two treatment means

MSe = Error mean square

r = number of replications

3.4.2. Estimation of genotypic and phenotypic variance (Fisher, 1918)

3.4.2.1. Genotypic variance ($\sigma^2 g$)

$\sigma^2 g$ = Msg-Mse/r

Where,

MSg = Mean square due to genotype

MSe = Mean square due to error

r = Number of replication

3.4.2.2. Phenotypic variance ($\sigma^2 p$)

$$\sigma^2 p = \sigma^2 g + \sigma^2 e$$

Where,

$\sigma^2 g$ = Genotypic variance

$\sigma^2 e$ = Environmental variance

3.4.3. Coefficient of variation

The phenotypic and genotypic coefficients of variations were calculated following the method given by Burton (1952).

3.4.3.1. Genotypic coefficient of variation (GCV %)

$$GCV = \frac{\sqrt{\sigma^2 g}}{Mean} \times 100$$

3.4.3.2. Phenotypic coefficient of variation (PVC %)

$$PCV = \frac{\sqrt{\sigma^2 p}}{Mean} \times 100$$

Where,

σ^2 g = Genotypic variance

σ^2 p = Phenotypic variance

3.4.4. Heritability

Heritability in broad sense ($h^2 bs$) was calculated according to the formula suggested by Allard (1960). According to this method heritability in broad sense is computed as the ratio of genotypic variance (σ^2 g) to the phenotypic variance (σ^2 p) and expressed in percentage.

$$h^2 bs = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

σ^2 g = Genotypic variance

σ^2 p = Phenotypic variance

3.4.5. Genetic advance (GA)

The expected genetic advance was calculated by using the formula suggested by Johnson, Robinson and Comstock (1958). The genetic advance as percent of mean to facilitate the comparison between different characters under study.

$GA = k\sigma p\, h^2bs$

Where,

k = Selection differential at 5% selection intensity, the value is 2.06.

σp = Phenotypic standard deviation

h^2bs = Heritability in broad sense (%)

The genetic advance as percentage of mean was calculated by dividing the value of estimated genetic advance by mean (X) and then expressed in percentage.

$$GA\ (\%\ of\ mean) = \frac{GA}{X} \times 100$$

3.4.6. Correlation studies

The correlation coefficient at genotypic and phenotypic levels was determined according to the formula given by Johanson *et al.* (1955) as follows:

3.4.6.1. Genotypic correlation coefficient between character x and y

$$rg_{xy} = \frac{Cov.xy\ (g)}{\sqrt{var.x(g)\ X\ var.y(g)}}$$

3.4.6.2. Phenotypic correlation coefficient between character x and y

$$rp_{xy} = \frac{Cov.xy\ (p)}{\sqrt{var.x(p)\ X\ var.y(p)}}$$

Where,

Cov.xy (g) and Cov.xy (p) denotes genotypic and phenotypic co-variance for the characters x and y respectively.

Var. x (g) and Var. x (p) denotes genotypic and phenotypic variance for the character x.

Var. y (g) and Var. y (p) denotes genotypic and phenotypic variance for the character y.

The calculated genotypic and phenotypic correlation coefficients were tested for 't'.ss

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$ at (n-2) degree of freedom

Where,

n = number of genotypes

The calculated t value was compared with t-value at 5 % or at 1 % probability level with (n-2) degree of freedom for its significance.

3.5. Path coefficient analysis

The path coefficient analysis was worked out by the formula applied by Dewey and Lu (1959). In general form, path coefficient is determined from the equation.

$$\sum_{j=1}^{n-1} riNr_{ij}p_{jN} = r_{iN} \quad \ldots..(1)$$

Where,

N is the character taken as the effect and all the characters as possible cause, r and p are the correlations and the path coefficients respectively, I and j are column and rows indices respectively and N is the total number of characters considered for analysis.

The path coefficients were obtained by solving a set of simultaneous equations of the formula:

$$r_{ny} = P_{ny} + r_{n1}P_{1y} + r_{n2}P_{2y} + \ldots\ldots\ldots\ldots r_{n(n-1)}P_{(n-1)y}$$

Where,

r_{ny}= correlation between one component character and grain yield.

P_{ny} = path coefficient between the character and grain yield.

r_{n1} , $r_{n2}\ldots..r_{n(n-1)}$= correlation between character and each of the other yield components in return.

In matrix notation, equation (1) can be written as:

$$\begin{vmatrix} r_{11N} \\ r_{21N} \end{vmatrix} = \begin{vmatrix} r_{11}\ r_{12}\ r_{13}\ldots\ldots r_{1(n-1)} \\ r_{21}\ r_{22}\ r_{23}\ldots\ldots r_{2(n-1)} \end{vmatrix} = \begin{vmatrix} P_{11N} \\ P_{21N} \end{vmatrix}$$

$$\begin{vmatrix} r_{(n-1)N} \end{vmatrix} \quad \begin{vmatrix} r_{(n-1)1}\ r_{(n-1)2}\ r_{(n-1)(n-1)} \cdots\cdots r_{2(n-1)} \end{vmatrix} \quad \begin{vmatrix} P_{(n-1)N} \end{vmatrix}$$

Or,

$r_{iN} = (r_{ij})\ (r_{jN})$

$P_{jN} = (r_{ij})^{-1}\ (r_{iN})$

To determine the values of inverse matrix $(r_{ij})^{-1}$, original square matrix was transformed in rows and columns. The factors of the elements were then determined and divided by the determinant of the entire original matrix with the value of the matrix, P_{jN} was calculated.

Indirect effects for a particular character through other characters were obtained by multiplication of direct path and particular correlation coefficients between those characters respectively.

Indirect effects = r_{ij} x P_{iy}

Where,

r_{iy} = correlation between the i^{th} and and dependent character.

P_{ij} = correlation between the i^{th} and j^{th} characters

P_{iy} = Direct path of i^{th} character on dependent character

Residual effect (x) is given by:

$$P_x^2 = 1 - \sum_{i=1}^{p} r_{iy} P_{iy}$$

Where,

P = Number of characters

r_{iy} = correlation between the i^{th} character and yield (dependent character)

P_{iy} = Direct effect of the i^{th} character on yield.

3.6. Genetic divergence

Genetic divergence among the genotypes of experiment was analyzed by using Mahalanobis D^2 statistics (Rao, 1952). D^2- statistics is a measure of genetic distance among groups or varieties based on multiple characters. Genetic diversity plays an important role in plant breeding because hybrids between lines of diverse origin generally display a greater

heterosis than those between closely related parents. Genetic diversity arises due to geographical separation or due to genetic barriers to crossability. The purpose of D^2- statistics is to identify genotypes which can be grouped together as one genetic group. If there are 'p' characters measured on each individual, and 'ds' are the difference between means of two groups, then D^2- statistics (Mahalanalobis, l928) is defined as:

$pD^2 = b_l d_l + b_2 d_2 + \text{---------} + b_p d_p$____ (1)

Where,

The b_i values are to be estimated such that the F ratio of variance 'between groups' and 'within groups' is maximized. In terms of variances and covariances of the i^{th} and j^{th} traits of two groups, l and 3, the D^2 value is obtained as follows:

$pD^2 = W^{ij}(x^1 i - x^2 i)(x^1 j - x^2 j)$

Where,

W^{ij} is the inverse of estimated variance- covariance matrix.

For each pair of mean deviation i.e. $Yi^l - Yi^l$ with i =1, 2, ---- P. is computed and the D^2 is calculated as the sum of these deviation i.e.

$D^2 = \sum (Yi^1 - Yi^2)^2$

	Traits				
Group	1	2	3	-------	P
1	Y_{11}	Y_{21}	Y_{31}	-------	Y_{p1}
2	Y_{12}	Y_{22}	Y_{32}	-------	Y_{p2}
-----	-----	-----	-----	-------	-----
Difference	$Y_{11} - Y_{12}$	$Y_{21} - Y_{22}$	$Y_{31} - Y_{32}$	-------	$Y_{p1} - Y_{p2}$

$D^2 = (Y_{11}-Y_{12})^2 + (Y_{21}-Y_{22})^2 + \text{-------} (Y_{p1}-Y_{p2})^2$

$= \sum(Yi^1 - Yi^2)^2$

Similarly, the D^2 values for all the other combination of group pairs\, 1 and 3, l and 4, 2 and 3, etc are calculated. The D^2 values obtained for a pair of group is taken as the calculated value of X^2 for p degrees of freedom, where p is the number of characters considered.

Each character is ranked on the basis of di =Y_{ij} - Y_{ik} values. Rank one is given to the highest mean difference, where p is the number of characters. These ranks are given in the parenthesis in the calculation of D^2 values for all the contribution of pairs.

Percent contribution is calculated taking pq = 100.

3.6. 1. Tocher's Method of Cluster Grouping:

A table is made with each group heading a column and changing their group in the same column in order of their distances. First column is headed by group or variety l. In this column, the group or variety nearest to the group or variety 1 is placed next row below and so on for the 3^{rd}, 4^{th}, ---- p^{th} rows of the same column. Second column is headed by group 2 and the group nearest to the group 2 is placed in the 2^{nd} row and so on. In this ways all the columns and rows are filled by groups with D^2 statistics values in parenthesis. The groups belonging to the same are now grouped into different clusters according to D^2 values.

The average D^2 value in the first row is arbitrarily taken as the maximum permissible value for being placed in the same cluster. The first two are automatically of the same cluster. When the third is added, the average D^2 value due to addition of the third and fourth group from the previous average should not exceed the permissible limit set above. If the increase in the average D^2 value over the previous combination is less than the permissible value, it is excluded in the cluster, otherwise stays out. The rest of the group is then considered for making a second cluster. Any pair which shows least distances between them is taken and the same procedure is followed for the inclusion of other group.

3.7. Pooled analysis of variance and phenotypic stability:

The mean data over replication of each genotype for each environment were subjected to pooled analysis of variance in order to study the Genotype X environment interaction and phenotypic stability, following the model of Eberhart and Russell (1966).

a) Model: The model, as developed by Eberhart and Russell (1966) is presented below:

$Y_{ij}=m+\beta_i I_j+\delta_{ij}$(i=l,2 ……..t and j=1,2 ……..s),

Where,

Y_{ij} = Mean i^{th} genotype in j^{th} environment.

m = Mean of all the genotypes over all the environment.

β_i = Regression coefficient i^{th} genotype over environment.

I_j = The environment index which is defined as the deviation of all the genotype at a given (j^{th}) environment from the overall mean.

$$= \frac{\sum_j Yij}{t} - \frac{\sum_i \sum_j Yij}{ts}$$

with, $\sum_j Ij = 0$ and

δ_{ij} = The deviation from regression of the i^{th} variety at j^{th} environment.

b) Analysis of variance:

The analysis of variance for stability analysis was done according to Eberhart and Russell's (1966) model as given in Table 6.

c) Calculation of pooled error: Pooled error mean square was calculated as

$$\sum_{j=1}^{n} \frac{ej}{n}$$

Where,

ej = error MS for the j^{th} environment obtained from the separate analysis of variance for individual.

d) Stability parameters: The three stability parameters were calculated as follows:

Mean (mi) = Mean of the i^{th} genotype over all the environment.

Regression co-efficient (bi) = $\sum_j Yij\ Ij / \sum_j I^2 j$

where,

$\sum_j Yij\ Ij$ = the sum of products and

$\sum_j I^2 j$ = the sum ofsquare

Deviation mean square (S^2_{di}) = $\frac{\sum_j \delta^2 ij}{s-2} - \frac{s^2}{r}$

Where, $\sum_j \delta^2_{ij} = \sum y^2_{ij} - \frac{Y_i^2}{t} - \frac{(\sum Y_{ij} I_j)^2}{\sum I_j^2}$

S^2_e = The estimate of pooled error

and $I_j = \frac{\sum Y_{ij}}{g} - \frac{\sum\sum Y_{ij}}{ge}$

To test the significance of difference of 'bi' value for unity, the procedure given by Gomez (1968) was followed:

$t = \frac{b-1}{Sb}$

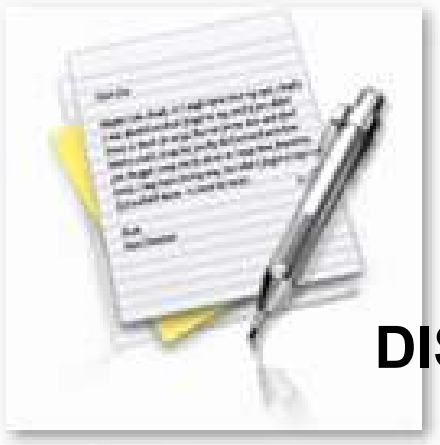
b = regression co-efficient

Sb = standard deviation of 'b' calculated as

$$\sqrt{\frac{MS\ due\ to\ pooled\ error}{\sum_j I_j^2}}$$

Table 6: Pooled analysis of variance for stability.

Source	Degree of freedom	Sum of squares
Total	ge -1	$\sum_i \sum_j Y_{ij}^2$ - CF
Genotype	g - 1	$\frac{\sum Y_i^2}{e}$ - CF
Env.+(genotype x Env.)	g(e -1)	$\sum_i \sum_j Y_{ij}^2 - \frac{Y_i^2}{e}$
Env. (linear)	1	$\frac{(\sum Y_{ij} I_j)^2}{\frac{g}{\sum I_j^2}}$
Genotype + Env.(linear)	(g – 1)	$\sum[\frac{\sum Y_{ij} I_j^2}{\sum I_j^2}] - [\frac{\frac{(\sum Y_{ij} I_j^2)}{g}}{\sum I_j^2}]$
Pooled Deviation	g(e -2)	$\sum\sum \zeta_{ij}^2$
Genotype 1	(e -2)	$[\sum Y_{ij}^2 - \frac{Y_i^2}{e}] - [\frac{(\sum Y_{ij} I_j)^2}{\sum I_j^2}]$
Genotype g	(e -2)	
Pooled error	ge(r-1)	



CHAPTER - IV

RESULTS AND DISCUSSIONS

EXPERIMENTAL FINDINGS

The result obtained through the statistical and biometrical analysis of the data of the present investigation is presented in this chapter.

4.1. Observations on qualitative characters

Seventeen qualitative characters were not subjected to statistical analysis but were studied based on phenotypic observations during the growing season. The result of the study is tabulated in Table 4.

4.1.1. Stem colour

From the observations made, it was revealed that all the landraces had light green stem colour with dark green spots except for C6 which had dark green stem colour with light green spots.

4.1.2. Plant growth habit

Plant growth habit was intermediate for all the landraces except for C6 and C8 which showed postrate plant growth habit and C3 with erect plant growth habit.

4.1.3. Leaf size

From the observations made all the landraces showed large leaf size.

4.1.4. Branching habit

Branching habit was intermediate for landraces C3, C5, C7 and C8. C1 and C6 showed dense type of branching habit while C2 and C4 showed sparse type of branching habit.

4.1.5. Leaf shape

Based on the observations, all the landraces showed ovate leaf shape.

4.1.6. Leaf colour

All the landraces showed dark green leaf colour except for C2 and C7 which showed green leaf colour.

4.1.7. Leaf pubescence

All the landraces showed intermediate leaf pubescence except for C2 and C7 which showed dense leaf pubescence.

4.1.8. Corolla colour

All the landraces showed yellowish white corolla colour according to observations recorded.

4.1.9. Pigmentation at node

Pigmentation at node was present in landraces C3, C6, C7 and C8 whereas C1, C2, C4 and C5 showed absence of pigmentation at node.

4.1.10. Anther colour

All the landraces showed purple type of anther colour according to observations recorded.

4.1.11. Fruit shape at pedicel attachment

All the landraces showed varied type of fruit shape at pedicel attachment. C1, C3, and C6 showed obtuse type of fruit shape at pedicel attachment. C2, C4, C5 and C8 showed truncate type of fruit shape at pedicel attachment while C7 showed cordate type of fruit shape at pedicel attachment.

4.1.12. Ripe fruit colour

C6 exhibited brown type of ripe fruit colour while C1, C3, C4, C5 showed red ripe fruit colour. C7 and C8 showed dark red ripe fruit colour. C2 exhibited light red ripe fruit colour according to the observations recorded.

4.1.13. Blossom end fruit shape

Landraces C1, C2 and C5 exhibited blunt type of blossom end fruit shape while C3, C4, C6, C7 and C8 showed pointed type of blossom end fruit shape.

4.1.14. Fruit shape

Fruit shape was companulate for C1, C3, C4, C5 and C6. Triangular type of fruit shape was exhibited by C2 and C8 while C7 exhibited elongate type of fruit shape.

4.1.15. Biotic stress susceptibility

Biotic stress susceptibility was very high for all the landraces except for landraces C5 and C6 which showed high biotic stress susceptibility.

4.1.16. Fruit surface

Landraces C1, C2, C5, C7 and C8 showed wrinkled type of fruit surface while C3, C4 and C6 showed semi wrinkled type of fruit surface.

4.1.17. Seed colour

According to observations recorded all the landraces exhibited yellowish type of seed colour.

4.2. Analysis of variance

Pooled Analysis of variance of the mean value revealed significant difference among the landraces for all the traits except fruit width and dry fruit weight. The analysis of variance for all the traits studied is presented in Table 7.

4.3. Mean performance

The mean performance of all the 8 landraces and range of variation for yield and yield related traits are presented in Table 8 and Fig 4-7.

4.3.1. Days to first flowering

Significant variations among the landraces were observed with regard to number of days required for first flowering. The landrace C1 produced first flowering earliest in 152.83 days. On the other hand the highest number of days (158.83) to produce first flowering was taken by landrace C5.The general mean observed was 155.65 days.

4.3.2. Plant height

The landraces exhibited significant difference in respect of plant height. The highest plant height was recorded in landrace C6 (165.47 cm) while landrace C8 (125.64 cm) recorded lowest plant height. General mean was recorded 138.03 cm for plant height.

4.3.3. Days to 50% fruiting

Differences in days to 50% fruiting were observed among the landraces. The landrace C7 produced fruiting earliest in 189.83 days while the highest number of days (196.50) to fruiting was taken by the landrace C2. The general mean observed was 194.42 days.

4.3.4. Number of fruits per plant

The character exhibited highly significant differences among the landraces studied in the investigation. The highest number of fruits per plant was recorded in landrace C6 (138.25), while the lowest number of fruits per plant recorded was 41.36 in landrace C5. The general mean recorded was 74.47.

4.3.5. Fresh Fruit weight

Differences in fresh fruit weight among the landraces were recorded. The highest fresh fruit weight recorded was 6.10 gm in landrace C6, while the lowest fresh fruit weight recorded was 4.94 gm in landrace C5. The general mean recorded was 5.36 gm.

4.3.6. Fruit length

Highly significant differences for fruit length among the landraces were recorded in the study. The longest fruit length recorded was 6.33 cm in landrace C6 and lowest fruit length recorded is 5.11 cm in landrace C2. The general mean recorded was 5.48 cm.

4.3.7. Fruit width

In the studied landraces, no significant differences were recorded in respect to fruit width. The highest fruit width was recorded in landrace C2 (2.89 cm), while the lowest fruit width was 2.65 cm in landrace C5. The general mean recorded was 2.74 cm.

4.3.8. Number of fruits per cluster

Highly significant differences for number of fruits per cluster among the landraces were recorded in the study. The highest number of fruits per cluster recorded was 3.07 in landrace C6 and lowest number of fruits per cluster recorded was 2.04 in landrace C5. The general mean recorded was 2.62.

4.3.9 Number of seeds per fruit

The landraces exhibited highly significant differences in respect of number of seeds per fruit. The number of seeds per fruit was recorded highest in landrace C7 (46.03), while the

lowest number of seeds per fruit recorded was in landrace C6 (32.28). The general mean recorded was 38.72.

4.3.10. Dry fruit weight

In the studied landraces, no significant differences were recorded in respect to dry fruit weight. The highest dry fruit weight was recorded in landrace C2 (0.85), while the lowest fruit width was 0.63 in landrace C7. The general mean recorded was 0.75.

4.3.11. 1000 seed weight

Highly significant differences for 1000 seed weight among the landrace were recorded. The highest 1000 seed weight recorded was 5.21 gm in landrace C1 while the lowest 1000 seed weight recorded was 4.27 gm in landrace C3. The general mean recorded was 4.62 gm.

4.3.12. Fruit yield per plant

Significant difference was observed for fruit yield per plant. The fruit yield per plant was recorded highest in landrace C6 (578.61 gm), while the lowest fruit yield per plant was recorded in landrace C5 (217.12 gm). The general mean recorded was 369.23 gm.

4.4. Estimation of genetic parameters

Different genetic parameters viz. genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2bs) and genetic (GA) advance as a percentage of mean were calculated for all the twelve characters under study and the results are presented in Table 9.

The estimation of GCV when compared among different characters showed highest GCV (53.40%) for number of fruits per plant followed by fruit yield per plant (39.09%) and number of seeds per fruit (18.43%). Low estimates of GCV were exhibited by fruit width (3.48%), days to first flowering (1.72%) and days to 50% fruiting (1.59%).

In case of PCV, the estimate of PCV was recorded to be highest (66.36%) for number of fruits per plant followed by fruit yield per plant (50.00%) and dry fruit weight (22.36%). Days to 50% fruiting (2.16%) recorded the lowest PCV followed by days to first flowering (2.29%) and fruit width (7.45%).

The heritability (broad sense) estimates ranged from 9.08% to 82.16%. The highest heritability in broad sense was observed for 1000 seed weight (82.16%) followed by plant height (80.48%) and number of seeds per fruit (73.30%). Dry fruit weight showed least estimates of heritability (9.08%) followed by fruit width (21.87%) and fresh fruit weight (32.29%).

Genetic Advance (GA) as percentage of mean for different characters showed a wide variation. It was highest for number of fruits per plant (65.92%) followed by plant height (32.11%) and fruit yield per plant (23.25%). Low genetic advance was estimated for dry fruit weight (0.03%), fruit width (0.09%) followed by fresh fruit weight (0.44%).

4.5. Correlation studies

The genotypic and phenotypic correlation coefficient among all the twelve characters are presented in Table 10.

4.5.1 Correlation between yield and yield attributing characters

At genotypic level, fruit yield per plant showed positive and significant correlation with number of fruits per plant (0.874), fresh fruit weight (0.973), fruit length (0.727) and number of fruits per cluster (0.772).

While at phenotypic level, fruit yield per plant exhibited a positive and significant correlation association with number of fruits per plant (0.623).

4.5.2. Correlation between component characters

4.5.2.1 Days to first flowering

Days to first flowering showed significant negative genotypic correlation with fruit yield per plant (-0.984) while there was no significant positive correlation was observed with respect to other characters.

4.5.2.2. Plant height

Plant height showed significant positive genotypic correlation with number of fruits per plant (0.665) and fresh fruit weight (0.782), while there was no significant negative genotypic correlation observed with any of the characters. At phenotypic level, plant height did not show any significant positive and negative correlation with the rest of the characters.

4.5.2.3. Days to 50% fruiting

At genotypic level, days to fruiting showed significant positive correlation with dry fruit weight (0.665), whereas significant negative correlation was exhibited with fruit length (-0.845). At phenotypic level, no significant correlation was observed.

4.5.2.4. Number of fruits per plant

At genotypic level, number of fruits per plant showed significant positive correlation with fruits per cluster (0.827), dry fruit weight (0.839) and fruit yield per plant (0.874). No significant negative correlation was exhibited by number of fruits per plant. At phenotypic level, number of fruits per plant showed significant positive correlation with fruit yield per plant (0.623) but showed no significant negative correlation.

4.5.2.5. Fresh fruit weight

Fresh fruit weight showed significant positive correlation with fruit length (0.790) and fruit yield (0.973) at genotypic level. Significant negative correlation was exhibited with number of seeds per fruit (-0.739). There was no significant positive and negative correlation exhibited by fresh fruit weight with any of the other characters at phenotypic level.

4.5.2.6. Fruit length

At genotypic level, fruit length showed significant positive correlation with number of fruits per cluster (0.815) and fruit yield per plant (0.727) while significant negative genotypic correlation was observed with number of seeds per fruit (-0.682). There was no significant positive and negative correlation exhibited by fruit length with any of the other characters at phenotypic level.

4.5.2.7. Fruit width

Fruit weight did not exhibit any significant positive and negative correlation with the rest of the characters both at genotypic and phenotypic level.

4.5.2.8. Number of fruits per cluster

At genotypic level, number of fruits per cluster showed significant positive correlation with dry fruit weight (0.759) and fruit yield per plant (0.772). There was no significant negative correlation observed. At phenotypic level, number of fruits per cluster did not showed any positive and negative correlation with any of the other characters.

4.5.2.9. Number of seeds per fruit

Number of seeds per fruit did not exhibit any significant positive and negative correlation with the rest of the characters at phenotypic level. Significant negative correlation was exhibited by number of seeds per fruit with dry fruit weight (-0.830) at genotypic level.

4.5.2.10. Dry fruit weight

Dry fruit weight did not exhibit any significant positive and negative correlation with the rest of the characters both at genotypic and phenotypic level.

4.5.2.11. 1000 seed weight

1000 seed weight did not exhibit any significant positive and negative correlation with the rest of the characters both at genotypic and phenotypic level.

4.6. Path coefficient analysis

Path coefficient analysis was carried out to separate the direct and indirect effects of different yield contributing characters on yield at genotypic level (Table 11). The result of various causes influencing yield are described below:

4.6.1. Direct effect

Fresh fruit weight (22.624) contributed maximum positive direct effect on fruit yield per plant followed by plant height (17.944) and 1000 seed weight (11.038). Negative direct effect on yield was contributed by dry fruit weight (-0.051).

4.6.2. Indirect effect:

4.6.2.1. Fruit yield per plant vs Days to first flowering

Days to first flowering showed indirect positive effect on fruit yield per plant via number of seeds per fruit (1.194), number of fruits per cluster (1.740), days to 50% fruiting (0.880), while negative indirect effect were shown via 1000 seed weight (-1.028), number of fruits per plant (-0.625) and fruit width (-0.557).

4.6.2.2. Fruit yield per plant vs Plant height

Plant height showed indirect positive effect on fruit yield per plant via fruit length (10.354), number of seeds per fruit (6.788), days to 50% fruiting (4.895), while negative indirect effect were shown via fresh fruit weight (-19.229), 1000 seed weight (-12.944) and number of fruits per plant (-7.135).

4.6.2.3. Fruit yield per plant vs Days to 50% fruiting

Days to 50% fruiting showed indirect positive effect on fruit yield per plant via plant height (4.895), number of fruits per cluster (3.019), number of seeds per fruit (2.953), while negative indirect effect were shown via 1000 seed weight (-4.179), fresh fruit weight (-3.630) and number of fruits per plant (-3.587).

4.6.2.4. Fruit yield per plant vs number of fruits per plant

Number of fruits per plant showed indirect positive effect on fruit yield per plant via fresh fruit weight (7.829), 1000 seed weight (6.549), fruit width (1.959), while negative indirect effect were shown via plant height (-7.135), fruit length (-5.148) and number of seeds per fruit (-3.724).

4.6.2.5. Fruit yield per plant vs number of fresh fruit weight

Fresh fruit weight showed indirect positive effect on fruit yield per plant via 1000 seed weight (13.274), number of fruits per plant (7.829), fruit width (3.401), while negative indirect effect were shown via plant height (-19.229), fruit length (-11.645) and number of seeds per fruit (-6.085).

4.6.2.6. Fruit yield per plant vs fruit length

Fruit length showed indirect positive effect on fruit yield per plant via plant height (10.354), number of seeds per fruit (3.110), number of fruits per cluster (2.697), while negative indirect effect were shown via fresh fruit weight (-11.645), number of seeds per fruit (-3.110) and number of fruits per plant (-5.148).

4.6.2.7. Fruit yield per plant vs fruit width

Fruit width showed indirect positive effect on fruit yield per plant via fresh fruit weight (3.401), 1000 seed weight (3.114), number of fruits per plant (1.959), while negative indirect effect were shown via plant height (-3.870), number of fruits per cluster (-2.099) and number of seeds per fruit (-2.023).

4.6.2.8. Fruit yield per plant vs number of fruits per cluster

Number of fruits per cluster showed indirect positive effect on fruit yield per plant via plant height (3.994), number of seeds per fruit (3.875), days to 50% fruiting (3.019), while

negative indirect effect were shown via 1000 seed weight (-4.165), fresh fruit weight (-3.093) and number of seeds per fruit (-3.070).

4.6.2.9. Fruit yield per plant vs number of seeds per fruit

Number of seeds per fruit showed indirect positive effect on fruit yield per plant via plant height (6.788), number of fruits per cluster (3.875), fruit length (3.110), while negative indirect effect were shown via fresh fruit weight (-6.085), 1000 seed weight (-6.064) and number of fruits per plant (-3.724).

4.6.2.10. Fruit yield per plant vs dry fruit weight

Dry fruit weight showed indirect positive effect on fruit yield per plant via plant height (1.011), fruit length (0.672), number of fruits per cluster (0.520), while negative indirect effect were shown via fresh fruit weight (-1.882), 1000 seed weight (-1.044) and fruit width (-0.312).

4.6.2.11. Fruit yield per plant vs 1000 seed weight

1000 seed weight showed indirect positive effect on fruit yield per plant via fresh weight (13.274), number of fruits per plant (6.549), fruit width (3.114), while negative indirect effect were shown via plant height (-12.944), fruit length (-7.410) and number of seeds per fruit (-6.064).

4.6.3. Residual effects

The estimated residual factor was 0.032.

4.7. D^2 analysis:

The study of D^2 (genetic divergence) of 8 landraces was done through Mahalanobis D^2 statistic as described by Rao (1952). All the landraces were grouped into 3 different clusters (Table 12). Cluster 1 has 3 landraces, Cluster 2 has 4 landraces and cluster 3 has 1 landrace. The estimates of intra and inter cluster distances have been presented in Table 13. The intra cluster distance ranged from 23.26 to 51.43. The inter cluster distance was observed to be 51.43 between cluster I and cluster II indicating that these two clusters were genetically diverse.

The mean performances of all the characters are presented in Table 14 and Fig 8-11. All the three Clusters showed highest mean value for fruit yield per plant and days to 50%

fruiting. Cluster I showed lowest mean value for dry fruit weight and number of fruits per cluster. Cluster II showed lowest mean value for dry fruit weight and number of fruits per cluster. Cluster III showed lowest mean value for dry fruit weight and fruit width. Among the different characters studied, 1000 seed weight, fresh fruit weight, number of seeds per fruit and number of fruits per cluster contributed maximum towards divergence (Table 15 and Fig 12).

4.8. Stability Analysis (Eberhart and Russell, 1966)

The pooled analysis of variance for Genotype X Environment interaction presented in the Table 16, clearly indicated that the landraces differed significantly for all the characters. The significant influence of additive environment was also indicated for all the characters. The Genotype X Environment interactions were significant for all the characters except days to first flowering, plant height and number of fruits per plant. For all the other parameters except days to first flowering, plant height and number of fruits per plant, both linear and nonlinear components contributed to the (GE) interaction variance as evident from significant Genotype X Environment (linear) and pooled deviation mean squares. For the three characters viz. days to first flowering, plant height and number of fruits per plant, the pooled deviation contributed of the non-linear components towards Genotype X Environment interaction variances.

4.8.1. Stability parameters:

Owing to the presence of significant Genotype X Environment interactions for different characters, the stability parameters as proposed by Eberhart and Russell (1966) viz. mean performance (mi), regression coefficient on environmental indices (bi) and deviation mean squares (S^2di) for each individual landrace were estimated for all the characters and are presented in the Table 17 to 32 and Fig 14 to 25. The landraces with high or low mean as per the requirement for the characters, regression coefficient approaching unity and low deviation mean squares approaching zero were considered as average stable landraces. Similarly, landraces with regression coefficient (bi) less than one and landraces with regression coefficient (bi) more than one were considered as ‘above average’ and. ‘below average’ stable respectively.

4.8.1.1. Days to first flowering:

With regards to days to first flowering, landraces with mean value less than 118.64 were considered as desirable one. For days to first flowering, C1 and C7 exhibited below average stability whereas C2 exhibited average stability.

4.8.1.2. Plant height:

For plant height, landraces with mean value less than 116.53 cm was considered as desirable. C7 exhibited average stability for shorter plant height. C1 exhibited below average stability and landraces C3 and C8 exhibited above average stability.

4.8.1.3. Days to 50% fruiting:

For, days to 50% fruiting, mean values less than 154.88 was considered as desirable. For lower days to 50% fruiting no landraces exhibited above average stability. For this character, C1 and C7 exhibited below average stability and only C5 exhibited average stability.

4.8.1.4. Number of fruits per plant:

For number of fruits per plant, landraces with mean performance, more than 60.26 were considered. C6 and C7 exhibited below average stability and average stability respectively.

4.8.1.5. Fresh fruit weight:

For Fresh fruit weight, the landraces with a mean performance of more than 5.39 grams was considered. For this character, only C2 and C4 exhibited below average stability and average stability, while C6 and C7 above average stability.

4.8.1.6. Fruit length:

For fruit length, landraces with a mean performance of more than 5.52 cm were considered. C3, C4 and C8 exhibited below average stability, C6 exhibited above average stability. None of the landraces exhibited average stability.

4.8.1.7. Fruit width:

For fruit width, landraces with mean value more than 2.78 were considered. C1, C2 and C7 exhibited below average stability, C6 exhibited average stability and none of the landraces exhibited above average stability.

4.8.1.8. Number of fruits per cluster:

With regards to number of fruits per cluster, landraces with a mean performance more than 2.06 was considered. C1 and C6 exhibited below average stability for this character. C2 and C4 exhibited above average stability. None of the varieties exhibited average stability for this character.

4.8.1.9. Number of seeds per fruit:

For number of seeds per fruit, landraces with a mean performance of less than 44.03 was considered as desirable. C6 and C8 exhibited below average stability and C5 exhibited average stability. None of the varieties exhibited above average stability.

4.8.1.10. Dry fruit weight:

With regard to dry fruit weight, landraces with a mean performance of more than 0.86 was considered. C3 and C4 exhibited average stability and below average stability for this character. C2, C6 and C8 exhibited above average stability.

4.8.1.11. 1000 seed weight:

For 1000 seed weight, landraces with a mean performance of less than 4.81 was considered as desirable. C6 and C8 exhibited average stability and C2, C3 and C7 exhibited below average stability. None of the varieties exhibited above average stability.

4.8.1.12. Fruit yield per plant (gm):

For fruit yield per plant, landraces with mean value more than 320.58 grams was considered as desirable. Only C2 and C6 landraces exhibited below average stability for fruit yield per plant and none of the landraces showed average stability and above average stability.

From all these results, it could be seen that, C5 exhibited average stability for days to 50% fruiting and number of seeds per fruit, C6 exhibited average stability for fruit width and 1000 seed weight and C7 exhibited average stability for plant height and number of fruits per plant. C2 exhibited above average stability number of fruits per cluster and dry fruit weight, C6 exhibited above average stability for fruit length and dry fruit weight and C8 exhibited above average stability for plant height and dry fruit weight. C1 exhibited below average stability for days to first flowering, plant height, days to 50% fruiting, fruit width and number of fruits per cluster. C2 exhibited below average stability for fresh fruit weight, fruit width, 1000 seed weight and fruit yield per plant. C6 exhibited below average stability for number of fruits per plant, number of fruits per cluster, number of seeds per fruit and fruit yield per plant. C7 exhibited below average stability for days to first flowering, days to 50% fruiting, fruit width and 1000 seed weight.

DISCUSSION

Collection of diverse landrace/germplasm and their systematic evaluation assume considerable importance in any crop improvement programme. In Naga King Chili, a wide diversity of plant and fruit character is quite evident, which holds potential for developing high yielding varieties with desirable characters through appropriate breeding methods. Some needful variation created in nature may not only be important to support the present day crop improvement programme, but they will also be needed to face some unprecedented challenges of biotic and abiotic stresses in future. There is every chance of losing some useful genetic resources if efforts are not made from time to time for collection, evaluation and maintenance of locally adapted landraces germplasm materials.

5.1. Qualitative characters

The landraces in the present investigation showed variability for plant growth habit, branching habit, fruit shape at pedicel attachment, ripe fruit colour and fruit shape.

It is necessary to carry out breeding experiments in order to determine whether the qualitative variation among the landraces has significant influence on yield. In addition, the qualitative variants aid the morphological characters thereby helping the breeder for easy identification of the genotypes.

The existence of genetic variability among landraces for the characters to be improved is the most important and basic factor for successful selection in a breeding programme. Since selection operates on phenotypic variability present in the population, hence estimation of phenotypic and genotypic variability is a prelude in any systematic breeding programme. Thus, the first objective of the present investigation was to attain first hand information regarding extent of variability, interrelationship of yield and its components and causal relationship which would be helpful in formulating effective breeding programme in Naga King Chilli.

Since the entries included in the present study are from different districts of Nagaland with varied climatic conditions the findings may be of general application and should give directions for the improvement of Naga King Chilli.

5.2. Genetic variability and related parameters

Presence of genetic variability (may be natural or induced) is the first pre- requisite for success of any breeding programme. Hence, it is essential for the breeder to assess the genotypic variation and genetic value of the material under investigation by estimating the genotypic variance, genotypic coefficient of variation, heritability, genetic advance etc. Again, the genotypic components are accessed from the phenotypic value, which reflect both genetic (heritable) and non-genetic (non-heritable) influence. Thus, it is important to estimate genotype variance and phenotypic variance and genotypic co-efficient of variation and phenotypic co-efficient of variation to have a clear idea about the genetic worth of the breeding material.

The analysis of variance indicated significant difference for all the traits under study except days to 50% fruiting, fruit width and dry weight. A wide range of variability and coefficient of variation in chilli has also been found for yield and its components have also been reported by Sharma *et al.* (2009) and Padhar and Zaveri (2010).

5.3. Genotypic and phenotypic coefficient of variation

The estimates of genotypic and phenotypic coefficient of variation for different characters revealed that phenotypic coefficient of variation (PCV) were found to be higher than genotypic coefficient of variation (GCV). This indicates the influence of environment for the expression of these characters. In this context, Diwaker Kumar *et al.* (2012) reported that in chilli, phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV).

5.4. Comparison between genotypic and phenotypic coefficient of variation

A comparison of the genotypic coefficients of variation of characters with their corresponding phenotypic coefficient of variation revealed that the difference between genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was found to be narrow for days to first flowering, plant height, days to 50% fruiting, fruit length and 1000 seed weight. This is in agreement with the findings of Vijaya *et al.* (2014). The results suggest that these traits are least effected by environment and selection for these traits based on phenotypic expression would be rewarding. For the rest of the characters, the estimate of phenotypic coefficient of variation (PCV) was found to be higher than genotypic

coefficient of variation (GCV). This indicates that the variation is more due to environmental factors. Selection based on phenotypes in these traits may mislead, as their expression depends more on environmental factors. Similar observations were reported in chilli by Krishna *et al*. (2007). The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for number of fruits per plant, number of seeds per fruit and fruit yield per plant indicating that these traits have wide genetic variability and would respond better to selection. This finding is similar with the findings of Bharadwaza *et al.* (2015).

5.5. Heritability and genetic advance

The effectiveness of selection for any characters does not depend on the amount of variability alone. It is of great interest to the breeder to determine how much of the phenotypic variability, which is present in a particular generation, is heritable. In the present study, most of the characters exhibited moderate to high estimates of heritability except for days to first flowering, days to 50% fruiting, fresh fruit weight, fruit width and dry fruit weight. The high estimates of heritability was observed for 1000 seed weight (82.16), plant height (80.48), number of seeds per fruit (73.30), fruit length (68.96), number of fruits per plant (64.76), number of fruits per cluster (64.22) and fruit yield per plant (61.13). High estimates of heritability in broad sense indicate that substantial improvement can be made using standard selection. The results further confirmed the findings of earlier researchers for number of seeds per fruit (Singh and Singh 2012), fruit length (Padhar and Zaveri 2010; Singh and Singh 2012), plant height (Ibraham *et al*., 2001; Bhadwarj *et al*., 2007; Sharma *et al*., 20l0), number of fruits per plant (Nasimento *et al.,* 2012; Sreelathakumary and Rasamony 2004; Shirshat *et al*., 2007; Sharma *et al*., 2010), fruit yield per plant (Sreelathakumary and Rajamony 2004; Shirshat *et al*., 2007; Sharma *et al*., 2010). The high estimate of heritability for plant height was against the finding of Ajjapplavara and Channagoudra 2009.

Heritability value alone may not provide clear predictability of the breeding value. Heritability estimates along with genetic advance are usually more useful than heritability alone in predicting the resultant effect of selecting the best individual (Johnson *et al*., 1955). This is because a character may have very high heritability but very less phenotypic variation thus giving low values of genetic advance. High genetic advance with high heritability was observed in number of fruits per plant which is in agreement with the earlier finding of Smitha

and Basvaraja (2007); Kumari *et al.* (2010) and Vijaya *et al.* (2014). High heritability with moderate genetic advance was observed in plant height and fruit yield per plant which implied equal importance of additive and non additive gene action. These results are in consonance with the findings of Sharma *et al.* (2009) for average fruit weight. Similar results were also recorded by Rani *et al*. (1996) and Krishna *et al*. (2007). High heritability with low genetic advance were observed in fruit length, number of fruits per cluster and 1000 seed weight which may be attributed to the non-additive gene effects and these traits can be improved through hybridization and use of hybrid vigour (Panse, 1957). Low heritability coupled with low genetic advance was observed in dry fruit weight which indicates the role of non-additive genes for these traits, suggesting that their improvement could be achieved through heterosis breeding.

5.6. Correlation studies

The knowledge of interrelationship among various plant characters has an important bearing on formulating of effective breeding strategy. To improve complex traits like yield which is influenced by a number of component characters, it is necessary for the breeder to have a clear idea about the degree and direction of association of yield with these components and also among the components. Hence after getting information regarding the phenotypic variability present in the material, it was considered important while to study the interrelationships of different characters and the associations were worked out at genotypic and phenotypic level.

Fruit yield per plant had a significant positive genotypic and phenotypic correlation with number of fruits per plant, thus indicating that selection for these traits will lead to the simultaneous improvement of fruit yield per plant. This is in conformity with Diwaker Kumar *et al.* (2012) and Santosh Kumari (2013). At genotypic level, plant height exhibited significant positive correlation with number of fruits per plant and fresh fruit weight. A positive significant correlation was also exhibited by number of fruits per plant with number of fruits per cluster and dry fruit weight. Fresh fruit weight exhibited significant positive genotypic correlation with fruit length and fruit yield per plant. Fruit length exhibited significant positive genotypic correlation with number of fruits per cluster and fruit yield per plant. Number of fruits per cluster exhibited positive correlation with dry fruit weight and fruit yield per plant at genotypic level. Similar results were found out by Gupta *et al.* (2009); Sharma *et al.* (2009);

Padhar and Zaveri (2010); Singh and Singh (2012); Diwaker Kumar *et al.* (2012) and Santosh Kumari (2013).

The information with regard to estimates of genotypic and phenotypic coefficient of variation, heritability and genetic advance together with estimates of correlation suggest a greater possibility of inclusion of plant height and number of fruits per plant in the breeding programme for desired improvement of both the characters as well as for the improvement of their correlated characters.

5.7. Path coefficient analysis

Yield is a complex character influenced by several genetic factors interacting with environment. Success of any breeding programme for its improvement depends on the efficiency of selection. For a successful selection, it is necessary to study the nature of association of the characters in question, with other relevant traits. Path coefficient provides a better index for selection rather than mere correlation coefficient by separating the correlation coefficient of yield and its components into direct and indirect effects (Jha *et al.,* 1996).

A number of variables are included in correlation studies; the indirect association becomes complex and important. Hence path coefficient analysis has been found useful in finding out direct and indirect cause of correlation (Nayak *et al.,* 2001). Wright (1921) developed a technique known as path coefficient analysis by which, extent of direct and indirect effects of the correlation variable components can be understood.

In the present investigation the correlation with yield were further partitioned into direct and indirect effects to establish the cause and effect relationship between the yield and its component characters. The path analysis (Table 11) revealed that fresh fruit weight (22.624) contributed maximum positive direct effect on fruit yield per plant followed by plant height (17.944) and 1000 seed weight (11.038). Fresh fruit weight exerted positive direct effect and also exhibited significant positive correlation with yield indicating a true relationship between the traits. This suggested that the direct relation for fresh fruit weight would likely be effective in increasing the fruit yield per plant. The residual effect estimated was 0.032 indicating that the traits under study are 96.8% sufficient to account for variability but there might be a few more pertinent characters other than those studied in the present investigation and thus solicits inclusion of some more characters. The present study suggested

that while selection, emphasis should be given for fresh fruit weight for improvement of the fruit yield per plant.

5.8. D^2 Analysis

Analysis of variance revealed significant variation among the 8 landraces for all the characters. Several measures of distance have been proposed to suit various objectives of which Mahalanobis's generalized distance (Mahalanobis 1936; Rao, 1952) had occupied a unique place in plant breeding. The computations from distance matrix gave non-hierarchical clustering among the 8 Naga King Chilli landraces and they were grouped into three clusters (Table 12). Cluster II was the largest one comprising of four landraces followed by cluster I with 3 landraces and cluster III with 1 landrace, indicating heterogeneity among the landraces. This was supported by Yatung *et al.* (2014) in a study of genetic diversity in 30 chilli genotypes and they were grouped into 6 clusters. Hasan *et al.* (2014) studied 54 chilli genotypes which were fallen into seven clusters. The selection of genotypes for hybridization should be based on genetic divergence rather than geographical diversity.

Intra and inter cluster distances (D values) are shown in Table 13. The inter-cluster distances were larger than the intra-cluster distances. The inter cluster D^2 values were found to be 51.43 between Cluster I and II, indicating wide genetic diversity between these two clusters. This is in conformity with Kumar *et al.* (2010). Thus the cross between the landraces from cluster I and II can be used in Naga King Chilli breeding programmes to achieve maximum heterosis. Landraces from these two clusters if involved in hybridization may result in a wide spectrum of segregating populations as genetic diversity is very. The selection of diverge genotypes from a cluster would produce a broad spectrum of variability for morphological and quality traits studied which may enable further selection and improvement. The intra cluster divergence was found to be 23.26 in Cluster I, while Cluster II showed zero intra cluster distance even though there were four landraces, which signifies that the landraces were similar in their genetic makeup. Cluster III showed zero intra cluster distance due to containing of only one landrace. Similar findings were reported by Yatung *et al.* (2014) and Hasan *et al.* (2014).

Difference in cluster means existed for almost all the characters studied and are presented in Table 14. Cluster III had highest mean values for different characters viz fruit

yield per plant (g) followed by plant height (cm), number of fruits per plant, fruit length (cm), fresh fruit weight (g), number of fruits per cluster, fruit width (cm) and dry fruit weight (cm). Therefore the landrace fallen in cluster III have the genetic potentiality to contribute better for yield maximization of Naga King Chilli landraces. The landraces in cluster III exhibited lowest number of days to first flowering while those in cluster II exhibited highest. Days to 50% fruiting was recorded highest in Cluster I and lowest in Cluster II. Highest number of seeds per fruit was observed in Cluster I and lowest was in cluster III and highest 1000 seed weight was recorded for cluster II and lowest for cluster III. The results indicated that selection of landraces having high values for a particular trait can made and they can be utilized in the hybridization programme for improvement of that particular character. . Similar finding was made by Lahbib *et al.* (2013). The maximum relative contribution to the total divergence was made by 1000 seed weight (42.86%), fresh fruit weight and number of seeds per fruit (14.29%) each, number of fruits per cluster (10.71%) and plant height, days to 50% fruiting and dry fruit weight each contributing 3.57% respectively (Table 15). Similar results were observed by Farhad *et al.* (2010) and Bandla *et al.* (2013).

5.9. Stability Analysis

Considering the differential response of landraces to varying environmental conditions the landraces included in the present investigation was assessed for their phenotypic stability. The analysis of variance for stability is presented in Table 16. The mean square values from the pooled analysis of variance indicated highly significant variation due to landraces for all the traits. This revealed the presence of genetic variability in the breeding material under investigation. Highly significant environmental variance represented adequate heterogeneity between the environments and their suitability for evaluating the landraces for all the component characters. The additive environmental variance was found to be of considerable magnitude as indicated by the significant variance due to environment (linear) for all the characters. The pooled deviation is significant for days to first flowering, plant height, days to 50% fruiting and number of fruits per plant indicating that the unpredictable portion formed the major part of the G × E interaction that the landraces tested differed considerably in their stability for these characters. Significant variance due to Genotype X Environment (linear) interaction was observed for all the characters except days to first flowering, plant height and number of fruits per plant which suggest that the landraces possessed considerable variation

among them and also additive environmental variation interacted significantly with for all the characters under study. This is in conformity with findings as reported by Srividhya and Ponnuswami (2010) for fruit weight, yield per plant and dry fruit weight.

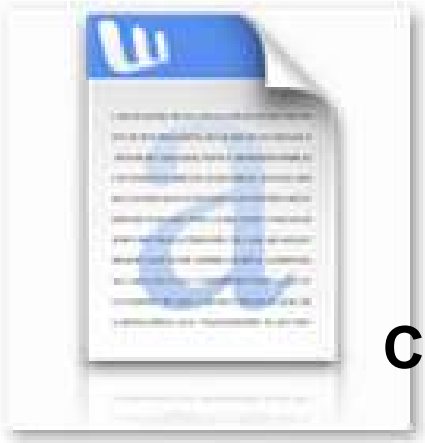
Owing to the presence of sufficient GE interaction the population was screened for phenotypic stability by estimating the stability parameters proposed by Eberhart and Russell (1966), viz. mean over environments (mi), regression co- efficient (bi) and deviation mean squares (S^2di). According to Eberhart and Russell (1966), a variety with high or low mean as per the requirement for the characters, unit regression co-efficient and low deviation mean square is considered as average stable genotype which will perform consistently over environments. A variety fulfilling the above mentioned conditions for mean and deviation mean square but regression co-efficient less than one is above average stable variety which will be specifically suitable under low yielding or under stress environments exhibiting its actual genetic potentiality. While variety with regression coefficient more than one is below average stable which will give much higher performance than its actual genetic potentiality under high yielding or favorable environment but would perform much lower under stress environmental conditions.

From the stability analysis, it was revealed that all the landraces except C5 were below average stable for all the 12 characters under study. C2 and C6 exhibited below average stability for fruit yield per plant. C5 exhibited average stability for days to 50% fruiting and number of seeds per fruit; C6 exhibited average stability for fruit width and 1000 seed weight and C7 exhibited average stability for plant height and number of fruits per plant. C2, C3 and C8 exhibited average stability for days to first flowering, dry fruit weight and 1000 seed weight respectively.

C2 exhibited above average stability for number of fruits per cluster and dry fruit weight while C3 exhibited above average stability for plant height. C4 exhibited above average stability for number of fruits per cluster. C6 exhibited above average stability for fresh fruit weight, fruit length and dry fruit weight. C7 exhibited above average stability for fresh fruit weight while C8 showed above average stability for plant height and dry fruit weight. The stability in yielding ability result from genetic homeostasis (Lerner, 1954) in which component character may respond differently to fluctuating environment but

component characters compensate in such a way as to give stability to the final characters (Thoday, 1958; Grafius,l956). In the present study, below average stability was exhibited by C2 and C6 for fruit yield per plant, thus indicating than these landraces will give much higher performance than its actual genetic potentiality under high yielding or favorable environment but would perform much lower under stress environmental conditions.

On the basis of all the stability parameters, C5, C6 and C7 with average stability for most of the characters for yield potential were found to be best. These genotypes may be used in various breeding programmes adaptable to a wide range of environments.



CHAPTER - V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present investigation was designed to study the genetic variability, diversity and phenotypic stability of the eight Naga King Chilli landraces in two growing seasons during kharif 2014 and 2015. Besides fruit yield per plant, observations were recorded on days to first flowering, plant height, days to 50% fruiting, number of fruits per plant, fresh fruit weight, fruit length, fruit width, number of fruits per cluster, number of seeds per fruit, Dry fruit weight and 1000-seed weight.

The important findings of the investigation are summarized below:

1. The analysis of variance indicated significant difference for all the traits under study except days to 50% fruiting, fruit width and dry weight. This revealed the presence of genetic variability in the breeding material under investigation.

2. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for number of fruits per plant, number of seeds per fruit and fruit yield per plant indicating that these traits had wide genetic variability and would respond better to selection.

3. The heritability estimates was highest for 1000 seed weight followed by plant height and number of seeds per fruit. High genetic advance with high heritability was observed in number of fruits per plant. For fruit yield per plant high heritability with moderate genetic advance was observed. Fruit yield per plant had a significant positive genotypic and phenotypic correlation with number of fruits per plant, thus indicating that selection for these traits will lead to the simultaneous improvement of fruit yield per plant. Path analysis suggested that the direct relation for fresh fruit weight would likely be effective in increasing the fruit yield per plant.

4. The 8 Naga King Chilli landraces were grouped into three clusters. Cluster II was the largest one comprising of four landraces followed by cluster I with 3 landraces and cluster III with 1 landrace. High genetic divergence was found between Cluster I and II, indicating wide genetic diversity between these two clusters. The

maximum relative contribution to the total divergence was made by 1000 seed weight, fresh fruit weight and number of seeds per fruit.

5. The mean square values from the pooled analysis of variance indicated highly significant variation due to landraces for all the traits. Significant variance due to Genotype X Environment (linear) interaction was observed for all the characters except days to first flowering, plant height and number of fruits per plant. On the basis of all the stability parameters, C5, C6 and C7 with average stability for most of the characters for yield potential were found to be best. These landraces may be used in various breeding programmes adaptable to a wide range of environments.

Apart from the results summarized above, there are two more findings as cited below.

Firstly, out of the three environments, the fruits which were harvested from environment I, i.e. polyhouse environmental condition, were found to be more pungent (for all the landraces) than the other two environments i.e. open field of experimental field condition and farmer's field condition. This result is cited as a feedback from the customers who bought the chillies for consumption when the chillies were sold for departmental revenue programme. This result can be explained as; the Chilli plants becomes more, or less, pungent under different environmental stress. Two types of stresses that affect the pungency of peppers are high average temperature outside and insufficient watering. Particularly, the root temperature must be sufficiently high (20–22°C). The key factor affecting fruit setting in *Capsicum* is night temperature, which ideally should be between 18.33-26.67°C (Purkayastha J *et al.,* 2012). The irrigations given to the growing plants were provided at alternate days. This type of environmental condition was prevalent in the polyhouse condition, which may have fulfilled the above given condition.

Secondly, the shelf life of the fruits harvested from the polyhouse was longer as compared to the fruits harvested from the other two environmental conditions. It was observed that the fruits harvested from the polyhouse had a shelf life of 24-28 days, whereas the shelf life of the fruits harvested from open field condition was found to be between 5-10 days.

These results can be put into investigation in future programme and analyzed for further documentation and improvement of the Naga King chilli.

REFERENCES

REFERENCES

Abu, Ngozi E, Uguru, M I and Obi I U. 2013. Genotypic stability and correlation among quantitative characters in genotypes of aromatic pepper grown over years. *Academic Journals* **12(20)**: 2792-2801.

Achal S, Lal S D and Pant C C. 1986. Variability studies in chilli. *Progressive Horticulture* **18 (3-4)**: 270-272.

Adhikari Bhaskar Mani and Pradhan Nancy. 2014. Study on functional properties of selected chilli varieties grown in Kathmandu, Nepal. *The Journal of Microbiology, Biotechnology and Food Sciences*.3(6): 488-490.

Ahmed N, Bhat M A, Tanki M I and Singh A K. 2006. Correlation and path coefficient analysis in paprika (*Capsicum annum* L). *Indian Journal of Horticulture* **63(1)**: 92-95.

Ajjapplavara P S and Channagoudra R F. 2009. Studies on variability, heritability and genetic advance in chilli (*Capsicum annuum* L.). *Asian Journal of Horticulture* **4(1)**: 99-101.

Alam S. 1990. Studied on the growth, development, yield and quality aspects of few local chillies (*Capsicum annum* L., *Capsicum frutescens* L.) cultivars of Assam. *M.Sc. Thesis, Assam Agri. Univ., Jorhat.*

Ali S A. 1994. Correlation of yield characters with yield in different chilli genotypes. *Bharti Krishi Anusandhan Palrika* **8(1)**: 81-83.

Alonso R A, Moya C, Cabrera A, Ponce P, Quiroga R, Rosales M A and Zuart J L. 2008. *In situ* evaluation of the genetic variability of wild chilli (*Capsicum* spp.) in the *Frailesca* region of Chiapas state, Mexico. *Cultivos Tropicales* **29(2)**: 49-55.

Amar Chandra, Verma B K and Satpute R G. 1990. Evaluation of selected chilli lines (*Capsicum annuum* L.). *Vegetable Science* **17(1)**: 105-107.

Anand G, Subraman N and Gopakumar B. 2006. AMMI analysis for fruit yield stability of Chilli (*Capsicum annuum* L.). *Journal of Plantation Crops* **34(3)**: 239-242.

Anonymous. 2009. Patent rights of Naga Chilli, Nagaland Post, 18th March, 2009.

Arumugam T and Pappiah C N. (1989). Variability studies in chilli (*Capsicum annum* L.). *South Indian Hort*. **37(3)**: 135-137.

Baek D, Villen J, Shin C, Camargo F D, Gygi S P, Bartel D P. 2008. The impact of microRNAs on protein output. *Nature* **455(7209)**: 64-71.

Bahrami Rad M, Hassani M E, Mohammadi A, Lessan S H and Ghazi Zade S. 2009. Evaluation of genetic diversity in *capsicum* spp. as revealed by RAPD markers. *ISHS Acta Hortic.* **829(40**): 275-278.

Balvir Kaur and Daljit Singh. 2007. Genetic variability in chilli (*Capsicum annuum* L.). *Haryana Journal of Horticultural Sciences* **36(3/4)**: 305-306.

Bandla Srinivas, Beena Thomas, Sreenivas Gogineni. 2013. Genetic Divergence for Yield and its Component Traits in Chilli (*Capsicum frutescens* L.) accessions of Kerala. *International Journal of Science and Research (IJSR) ISSN (Online)* **4(4)**: 442-446.

Baseerat Afroza, Khan S H, Chattoo M A, Mufti S, Kouser Parveen and Mukhdoomi M I. 2013. Variability studies for quality traits in sweet pepper (*Capsicum annuum* L.). *Asian Journal of Horticulture* **8(1)**: 358-360.

Basu K S and De A K. 2003. The Capsicum. Medicinal and aromatic plants-industrial profiles. (London: Taylor and Francis)

Bendale V W, Palsuledesia M R, Bhave S G, Sawant S S and Desai S S. 2006. Genetic evaluation of some economic traits in chilli (*Capsicum annum* L.). *Crop Research (Hisar)* **31(3)**: 401-403.

Bhadragoudar M R, Patil C G. 2011. Assessment of genetic diversity among *Capsicum annuum* L. genotypes using RAPD markers. *African Journal of Biotechnology* **10(76)**: 17477-17483.

Bhagowati R R and Changkija S. 2009. Genetic variability and traditional practices in Naga King Chilli Landraces of Nagaland. *Asian Agri-History* **13(3)**: 171-180.

Bharadwaj D N, Singh H and Yadav R K. 2007. Genetic variability and association of component characters for yield in chilli (*Capsicum annum* L.). *Progressive Agric*. **7(1-2)**: 72-74.

Bharadwaza R K, Prasad V M and Srinivas M. 2015. Variability and correlation studies in chilli (*Capsicum annuum* L.) at Allahabad agro-climatic conditions. *Environment and Ecology* **33(4A)**: 1626-1629.

Bijendra Singh and Rajput C B S. 1992. Component analysis in chillies. *Progressive Horticulture* **24(1-2)**: 32-37.

Bosland P W. 1994. Chiles: history, cultivation, and uses. *Progress in new Crops (Janick J, ed.). ASHS Press, Arlington, Virginia, USA.* pp. 479-487.

Bosland P W. 1996. Capsicums: innovative uses of an ancient crop. *Progress in new crop*. *ASHS Press, Arlington, VA*. pp. 479-487.

Bozokalfa M K and Essiyok D. 2010. Genetic diversity in pepper (*Capsicum annuum* L.) accessions as revealed by agronomic traits. *Ege Üniversitesi Ziraat Fakültesi Dergisi* **47(2)**: 123-134.

Chatterjee B, Reddy V C, Ramana J V, Sankar C R and Rao C P. 2007. Correlation and Path analysis in Chilli (*Capsicum annum* L.). *The Andhra Agfa. J*. **54(1342)**: 36-39.

Chattopadhyay Arup, Sharangi Amit Baran, Dai Nuka, Dutta Subrata. 2011. Diversity of genetic resources and genetic association analyses of green and dry chillies of eastern India. *Chilean Journal of Agricultural Research*.71(3): 350-356.

Cheema D S, Jindal S K and Dhaliwal M S. 2010. Evaluation of chilli hybrids developed by using genetic male sterility. *Haryana Journal of Horticultural Sciences* **39(3/4)**: 321-325.

Chowdhury D, Sarma K C and Sarma R. 2001. Phenotypic stability in chilli (*Capsicum annum* L.). *Journal of the Agricultural Science Society of North-East India* **14(1)**: 11-14.

Datta S and Jana J C. 2010. Genetic variability, heritability and correlation in chilli genotypes under Terai zone of West Bengal. *SAARC Journal of Agriculture* **8(1)**: 33-45.

Datta S and Jana J C. 2011. Performance of chilli (*Capsicum annum*) genotypes under terai agroclimatic region of West Bengal. *Indian Journal of Agricultural Sciences* **81(6)**: 567-570.

Deepu Mathew, Doijode S D and Reddy K M. 2004. Correlation and path coefficient analysis in five species of capsicum. *Capsicum & Eggplant Newsletter* **23**: 57-60.

Deka P C and Shadeque A. 1997. Correlation and path coefficient analysis in Sweet Pepper. *Horticultural Journal* **10(1)**: 59-63.

Devi D S and Arumugam R. 1999. Correlation and path coefficient analysis in chilli (*Capsicum annum* L.). *Crop Research (Hisar)* **17(1)**: 90-93.

Dewey D R and Lu K H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* **51**: 515-518.

Dhall R K**.** 2008**.** Breeding for quality traits in chilli: A review. *Journal of Research* **3(4)**: 156-160.

Dipendra Gogoi and Gautam B P. 2002. Variability, heritability and genetic advance in chilli (*Capsicum* spp). *Agricultural Science Digest* **22(2)**: 102-104.

Diwaker Kumar, Vijay Bahadur, Rangare S B and Devi Singh. 2012. Genetic variability, heritability and correlation studies in chilli (*Capsicum annuum* L.). *Hort. Flora Research Spectrum* **1(3)**: 248-252.

Dutonde S N, Bhalekar M N, Patil B T, Kshirsagar D B and Dhumal S S. 2008. Genetic diversity in chilli (*Capsicum annuum* L.). *Agri. Sci. Digest* **28(1)**: 45-47.

Eberhart S A and Russel W A. 1966. Stability parameters for comparing varieties. *Crop Sci.,* **6**: 36-40.

FAO 2007. (Food and Agriculture Organization of the United Nations), FAO Production Yearbook, Rome, Italy. pp. 333.

Farhad M, Hasanuzzaman M, Biswas B K, Arifuzzaman M and Islam M M. 2010. Genetic divergence in chilli. *Bangladesh Res. Pub. J*. **3(3)**: 1045- 1051.

Faria P N, Laia G A, Cardoso K A, Finger F L and Cecon P R. 2013. Genetic variability of pepper (*Capsicum chinense* Jacq.) samples from a germplasm bank: a case study. *Revista de Ciências Agrárias (Portugal)* **36(1)**: 17-22.

Fusco B M and Giacovazzo M. 1997. Peppers and pain. The promise of capsaicin. *Drugs* **53**: 909-914.

George F Antonious, Terry Berke and Robert L Jarret. 2009. Pungency in *Capsicum chinense*: Variation among countries of origin**.** *Journal of Environmental Science and Health, Part B: Pesticides, Food Contaminants, and Agricultural Wastes* **44(2)**: 179-184.

Gill H S, Thahur P C, Asawa B M and Thakur T C. 1973. Correlation analysis in sweet pepper. *Indian Journal of Agricultural Sciences* **43**: 918-927.

Gogate S M, Patel R K, Patel M J and Patel J A. 2006. Genetic divergence in chilli (*Capsicum annuum* var. *longum* (D.C.) Sendt.). *Vegetable Science* **33(1)**: 21-25.

Grafius J E. 1956. Components of yield in oats a geometrical interpretation. *Agron. J.,* **48**: 419-423.

Gupta A M, Daljeet Singh and Ajay Kumar. 2009. Genetic variability, genetic advance and correlation in chilli (*Capsicum annuum*). *Indian Journal of Agricultural Sciences* **79(3)**: 221-223.

Ha S H, Kim J B, Park J S, Lee S W and Cho K J. 2007. A comparison of the caretenoid accumulation in *Capsicum* varieties that show different ripening colours: deletion of the capsanthin-capsorubin synthase gene is not a prerequisite for the formation of a yellow pepper. *J. Exp. Botany* **58**: 3135-3144.

Hardy Eshbaugh W. 1975. Genetic and Biochemical Systematic Studies of Chili Peppers (*Capsicum*- Solanaceae). *Bulletin of the Torrey Botanical Club* **102(6)**: 396-403.

Harvell K P and Bosland P W. 1997. The environment produces a significant effect on pungency of chilles (*Capsicum annuum* L.). *Horticultural Science* **32**: 1292.

Hasan M J, Kulsum M U, Ullah M Z, Manzur Hossain M and Eleyash Mahmud M. 2014. Genetic diversity of some chili (*Capsicum annuum* L.) genotypes**.** *International Journal of Agricultural Research, Innovation and Technology* **4(1)**: 32-35.

He JianWen, Yang WenPeng, Han ShiYu, Yang Hong and Yang LiuQi. 2009. Molecular genetic diversity of local pepper varieties in Guizhou. *Guizhou Agricultural Sciences* **8**:15-18.

Ibrahim M, Ganiger V M and Yenejerappa S T. 200l. Genetic variability, heritability, genetic advance and correlation studies in chilli. *Karnataka J. Agfa. Sci*. **14(3)**: 784-787.

Indira P, Rajalekshmi V S and Peter K V. 2007. All about Capsicum spices. *Indian Spices* **34**: 10-20.

Jadhav M G and Dhtunal S A. 1994. Genetic studies of some quantitative characters in chilli. *Journal of Maharashtra Agricultural Universities* **19(1)**: 62-64.

Janaki M, Ramana C V, Naidu L N and Rao M P. 2015. Assessment of genetic divergence through multivariate analysis in chilli (*Capsicum annuum* L.). *Electronic Journal of Plant Breeding* **6(4)**: 981-991.

Jha S K, Awasthi L P and Maurya P M. 1996. Nature of association among some quantitative traits in wild rice. *Indian Journal of Genetics and Plant Breeding* **58(3)**: 307-311.

Jiang XiangHui, She ChaoWen, Xu Dong, Zhang QingHua and Zhao Wang. 2010. Morphology comparison and RAPD genetic diversity analysis of seven varieties of *Capsicum frutescens*. *Southwest China Journal of Agricultural Sciences* **23(3)**: 810-813.

Johnson H W, Robinson H E and Comstock R S. 1955. Estimates of genetic and environmental variability in soyabean. *Agronomy Journal* **47**: 314-318.

Joshi S, Sarma C, Jangid C and Vijayakumarswamy H V. 2013. Assessment of genetic diversity in *Capsicum* spp. by using morphological and molecular tools. *Journal of Research ANGRAU* **41(2)**: 26-32

Kalita J. 2007. Bhut Jolokia-the hottest of all species. *Spice India* **20**: 9-12.

Karad S R, Navale P A and Kadam D E. 2006. Variability and path coefficient analysis in chilli (*Capsicum annum* L.). *International Journal of Agricultural Sciences* **2(1)**: 90-92.

Karad S R, Raikar G R and Navale P A. 2002. Genetic divergence in chilli. *J. Maharashtra Agril. Univ.* **27(2)**: 143-145.

Kellen C Martins, Sergio Alessandro M Souza, Telma Nair S Pereira, Rosana Rodrigues, Messias G Pereira and Maura Da Cunha. 2013. Palynological characterization and genetic divergence between accessions of chilli and sweet peppers. *Hortic. Bras*. **31(4)**: 568-573

Kempaiah R K, Manjunatha H and Srinivasan K. 2005. Protective Effect of Dietary Capsaicin on Induced Oxidation of Low-Density Lipoprotein in Rats. *Journal of Molecular and Cellular Biochemistry.* **275**: 7-13.

Kohli U K and Chatterjee R. 2000. Variability studies in bell pepper (*Capsicum annuum* L.). *Haryana Journal of Horticultural Sciences* **29(1/2)**: 77-79.

Krishna C U, Madalageri M B, Patil M P, Mulage R and Kotikal Y K. 2007. Variability studies in green chilli (*Capsicum annum* L.). *Karnataka J Agric*. *Sci*. **20(1)**: 102-104.

Kumar D B M, Anand K and Mallikarjunaiah H. 2010. Genetic divergence in chilli accessions. *Electron. J. Plant Breed*. **1(5)**: 1363-1366.

Kumari S S, Jyothi K U, Srihari D, Sankar A S and Sankar C R. 2010. Variability and genetic divergence in paprika (*Capsicum annuum* L.). *Journal of Spices and Aromatic Crops* **19(1/2)**: 71-75.

Kumari S S, Srihari D, Shankar C R, Reddy V C and Sanker A S. 2014. Genetic divergence and combining ability studies for exploitation of heterosis in paprika (*Capsicum annuum* L). *International Journal of Agricultural Science and Research (IJASR)* **4(2)**: 59-66.

Lahbib K, Bnejdi F and Gazzah M E. 2013. Selection of pepper parent from a collection of *Capsicum annuum* landraces based on genetic diversity. *J. Plant Breed. and Crop Sci.* **5(5)**: 68-72.

Leaya Lose and Khader K M A. 2002. Correlation and path coefficient analysis in chilli (*Capsicum annum* L.). *Capsicum & Eggplant Newsletter* **21**: 56-59.

Lerner I M. 1954. Genetic homeostasis. *John Wiley and sons, New York.*

Madhu Sharma, Yudhvir Singh and Jamwal R S. 2009. Variability studies for various metric traits in chilli. *Haryana Journal of Horticultural Sciences* **38(3/4)**: 284-287.

Mahalanobis P C. 1936. On the generalized distance in statistics. *Proc. Natl. Inst. Sci. India.* **12**: 49-55.

Manju P R and Sreelathakumary I. 2004. Genetic divergence in hot chili. *Capsicum and Eggplant Newsletter* **23**: 69-72.

Marcin Kozak**,** Jan Bocianowski**,** Alina Liersch**,** Małgorzata Tartanus**,** Iwona Bartkowiak-Broda, Fernando A Piotto and Ricardo A Azevedo. 2011. Genetic divergence is not the same as phenotypic divergence. *Molecular Breeding* **28(2)**: 277-280.

Mathur D R S, Das S C and Malhotra R C. 2000. Hottest chilli variety in India. *Current Science* **79**: 287-288.

Mazzone S B and Geraghty D P. 1999. Respiratory actions of tachykinins in the nucleus of the solitary tract: effect of neonatal capsaicin pretreatment. *Br. J. Pharmacol.* **126(6)**: 1132-1139.

McLeod M J, Eshbaugh W H and Guttman, S I. 1979. A preliminary biochemical systematic study of the genus *Capsicum*-Solanaceae. In: Hawkes JG, Lester RN and Skelding AD (Eds.). *The biology and taxonomy of the Solanaceae. Academic Press, London*. pp. 701-713.

McLeod M J, Guttman S I and Eshbaugh W H. 1982. Early evolution of chilli peppers (*Capsicum*). *Econ. Bot*. **36**: 361-368.

Meghvansi M K, Siddiqui S, Md. Haneef Khan, Gupta V K, Vairale M G, Gogoi H K and Singh L. 2010. Naga chilli: A potential source of capsaicinoids with broad-spectrum ethnopharmacological applications. *Journal of Ethnopharmacology* **132(1)**: 1-14.

Mehra C S and Peter K. 1980. Genetic divergence in chilli. *Indian Journal of Agricultural Sciences* **50**: 477-481.

Meshram L D. 1987. Genetic variability and correlation in chilli. *PK V Res. S.* **11(2)**: 104-106.

Mini S and Khader K M A. 2004. Variability, heritability and genetic advance in wax type chilli (*Capsicum annum* L.). *Capsicum & Eggplant Newsletter* **23**: 49-52.

Mishra A C, Singh R V and Ram H H. 2004. Studies on genetic variability in Capsicum (*Capsicum annum* L.) under mid hills of Uttaranchal. *Capsicum& Eggplant Newsletter* **23**: 41-44.

Mishra T S, Chaturvedi and Tripathi A N.2015. Genetic analysis of agro-economic traits in chillies (*Capsicum annuum*). *Progressive Horticulture* **47(2)**: 322-332.

Montesano V, Negro D, Bitonte D, Montemurro F, Lisi A de and Sarli G. 2014. Characterization of a *Capsicum annuum* L. of a germplasm collection. *International Journal of Agri. Science* **4(12)**: 499-508.

Moore D J and Moore D M. 2003. Synergistic *Capsicum*-Tea Mixtures with Anticancer Activity. *Journal of Pharmacology and Pharmacotherapeutics* **55(7)**: 987-994.

Moreira S O, Goncalves L S A, Rodrigues R, Sudre C P, Amaral Junior A T do and Medeiros A M. 2013. Correlations and path analysis under multicollinearity in recombinant lines of chili pepper (*Capsicum annuum* L.). *Revista Brasileira de Ciencias Agrarias* **8(1)**: 15-20.

Mubarak. 2002. Evaluation of chilli (*Capsicum annuum* L.) germplasm for productivity, its component traits and resistance to some biotic stresses, *M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.*

Munshi A D and Behera T K. 2000. Genetic variability, heritability and genetic advance for some traits in chilli (*Capsicum annum* L.). *Vegetable Science* **27(1)**: 39-41.

Munshi A D, Behra T K and Gyanendra Singh. 2000. Correlation and path coefficient analysis in chilli. *Indian Journal of Horticulture* **57(2)**: 157-159.

Nandpuri K S, Gupta V P and Thakur P C. 1971. Variability studied in chillies. *I Res. Punjab Agric. Univ.* **8(3)**: 311-315.

Nascimento N F F, Rego E R, Nascimento M F, Finger F L, Bruckner C H, Silva Neto J J and Rego M M. 2012. Heritability and variability of morphological traits in a segregating generation of ornamental pepper. *ISHS Acta Hortic.* **953(41)**: 299-304.

Nayak A R, Chaudhary D and Reddy J N. 2001. Correlation and path analysis in scented rice. *Indian Journal of Agricultural Research* **5(3)**: 186-189.

Nayeema J, Ahmad N and Tanki M I. 1998. Genetic variability in hot pepper (*Capsicum annum* L.). *Agric. Sci. Digest* **18(1)**: 23-26.

Nazia Peeraullee and Ranghoo Sanmukhiya V M. 2013. Assessment of Genetic Diversity in Local Chilli (*Capsicum annuum*) varieties in Mauritius. *International Journal of Agriculture and Biology* **15(5)**: 891-896.

Nazir G, Narayan R, Ahmed N and Hussain K. 2005. Genetic variability and selection parameters for yield attributes in sweet pepper (*Capsicum annuum* var *grossum*). *Environment and Ecology* **23 (Special 3)**: 527-531.

Nehru S D, Manjunath A and Rangaiah S. 2003. Genetic variability and stability for fruit yield and other metrical characters in chilli (*Capsicum annuum* L.). *Karnataka J. Agril. Sci*. **16(1)**: 44-47.

Ngomle S, Ambesh B S and Thapa A. 2014. Genotypic variation of chilli (*Capsicum annuum* L.) genotypes to bio-inoculation. *Environment and Ecology* **32(3)**: 1070-107

Nowaczyk P and Nowaczyk L. 2004. Genetic variation in *Capsicum frutescens* L. as a result of an SSD method modification. *Proceedings of the 17th EUCARPIA General Congress, Tulln, Austria, 8-11 September 2004.* pp. 455-458.

Padhar P R and Zaveri P P. 2010. Genetic studies in relation to selection criteria in chilli. *Research on Crops* **11(3)**: 722-727.

Pandeva R and Simeonova N. 1992. Preliminary study on the morphogenetic response of several pepper varieties. *VIIIth Eucarpia meeting on Genetics and Breeding on Capsicum and eggplant,* Italy, 7-10 September 1992: 238-242.

Pandey G and Dobhal V K. 1993. Multivariate analysis chilli (*Capsicum annum* L.). *I Spices Aromatic Crop* **2(1-2)**: 71-74.

Pandey J, Singh J, Verma A, Singh A K, Rai M, Pandey A K and Kumar S. 2009 Variability in quality components of rils in chilli (*Capsicum annuum* L.). *ISHS Acta Hortic.* **830(24)**: 179-182.

Pandit M K, Muthukumar P and Mukhopadhyay T P. 2010. Study of genetic divergence through multivariate analysis in chilli (*Capsicum annuum* L.) germplasms. *J. Inter. Academicia* **14(3)**: 298-301.

Panse V G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian Genetics* **17**: 318-328.

Patel P N, Fougat R S and Sasidharan N. 2009. Studies on genetic variability, correlation and path analysis in chillies (*Capsicum annuum* L.). *Research on Crops* **10(3)**: 626-631.

Pawandeep S, Daljeet S and Ajay K. 2007. Genetic variability, heritability and genetic advances in chilli (*Capsicum annuum*). *Indian J. Agril. Sci*. **77(7)**: 459- 461.

Pessoa A M dos S, Rego E R, Barroso P A and Rego M M. 2015. Genetic diversity and importance of morpho-agronomic traits in a segregating F_2 population of ornamental pepper. *ISHS Acta Hortic.* **1087(23)**: 195-200.

Peter J Stoffella, Salvador J Locascio, Teresa K Howe, Steve M Olson, Kenneth D Shuler and Charles S Vavrina. 1995. Yield and Fruit Size Stability Differs among Bell Pepper Cultivars**.** *Journal of the American Society for Horticultural Science* **120(2)**: 325-328.

Pickersgill B. 1969. The domestication of chilli peppers. pp. 443-450. *The domestication and exploitation of plants and animals,* eds. P J Ucko and G W Dimbleby. London: Duckworth.

Pickersgill B. 1988. The genus Capsicum: a multidisciplinary approach to the taxonomy of cultivated and wild plants. *Biologisches Zentralblatt* **107**: 381-389.

Pino J, Gonzalez M, Ceballos L, Centurion-Yah A R, Mtrujillo Aguirre J, Latournerie Moreno L and Sauri Duch E. 2007. Characterization of total capsaicinoids, colour and volatile compounds of Habanero chilli pepper (*Capsicum chinense* Jacq.) cultivars grown in Yucatan. *Food Chemistry* **104**: 1682-1686

Pitchaimuthu M and Pappiah C M. 1992. Studies on variability in chilli (*Capsicum annum* L.). *South Indian Horticulture* **40(2)**: 109-110.

Prabhudeva S A. 2003. Studies on variability, genetic diversity and heterosis in chilli (*Capsicum annuum* L.). *M.Sc. thesis, University of Agricultural Sciences, Dharwad*.

Prajapati D B, Agalodiya A V, Jaiman R K and Patel D G. 2012. Genetics for fruit yield and its attributes under various environments in spice chilli (*Capsicum annum* L.). *Environment and Ecology* **30(3)**: 505-511.

Purkayastha J, Alam S I, Gogoi H K, Singh L and Veer V. 2012. Molecular characterization of 'Bhut Jolokia' the hottest chilli. *Journal of Biosciences* **37(4)**: 757-768.

Rajput J C, Palve S B Jarnadagni B M and Salvi M. 1983. Variability, heritability, genetic advance and correlation studies in chilli. *Indian Cocoa Arecanut Species J.* **6(4)**: 100-103.

Ramaktunar P V, Sri Ramachandramurthy N and Durgaprasad H M K. 1981. Genetic variability, correlation and discriminate function in chilli. *Indian J Agric. Sci*. **51(10)**: 723-725.

Ramalho do Rego E, Cortez dos Santos R M, Monteiro do Rego M, do Nascimento N F F, Nascimento M F and Bairral M A. 2012. Quantitative and multicategoric descriptors for phenotypic variability in a segregating generation of ornamental peppers. *ISHS Acta Hortic.* **937**: 289-296.

Rangaiah S and Manjunath A. Enhancement of genetic variability in chilli (*Capsicum annuum* L.) following hybridization, mutation and hybridization with mutation. 2000. *Centennial conference on spices and aromatic plants, Spices and aromatic plants:*

challenges and opportunities in the new century. Contributory papers. Calicut, Kerala, India, 20-23 September, 2000 pp. 17-22.

Rani P U and Singh D P. 1996. Variability, heritability and genetic advance in chilli (*Capsicum annum* L.). *J. Res. APAIL* **24(1)**: 1-8.

Rao C R. 1952. Advanced statistical methods in Biometrical Research. *John Wiley and Sons, New York.* pp. 357-365.

Rathod R P, Deshmukh D T, Sable N H and Rathod N G. 2002. Genetic variability studies in chilli (*Capsicum annuum* L.). *J. Soils and Crops.* **12**: 210-212.

Rego E R, Rego M M and Farias-Filho L P. 2011. Genetic diversity in pepper (*Capsicum* spp.) by RAPD marker. *ISHS Acta Hortic.* **918(44)**: 341-347.

Rego E R, Rego M M, Finger F L, Nascimento N F F, Nascimento M F and Cortez dos Santos R M. 2013. Phenotypic variability and importance of characters in a F_2 segregating generation of ornamental chili (*Capsicum annuum*). *ISHS Acta Hortic.* **1000(1000)**: 493-498.

Rego M M, Sapucay M J L C, Rego E.R and Araujo E R. 2015. Analysis of divergence and correlation of quantitative traits in ornamental pepper (*Capsicum* spp.). *ISHS Acta Hortic.* **1087**: 389-394.

Renata Cristina Alvares, Edesio Fialho dos Reis and Jefferson Fernando Naves Pinto. 2012. Genetic divergence in pepper genotypes from southwest Goias. *Agrotec* **36(5)**: 498-506.

Robert L Jarret, Elizabeth Baldwin, Brian Perkins, Rod Bushway and Kelly Guthrie. 2007. Diversity of Fruit Quality Characteristics in *Capsicum frutescens*. *Hort. Science February* **42(1)**: 16-19.

Rokib Hasan, Mahmudul Huque A K M, Kamal Hossain M and Nazmul Alam. 2015. Assessment of genetic divergence in Chilli (*Capsicum annuum* L.) genotypes. *Plant Gene and Trait* **6(3)**: 1-5.

Roy A, Sharma R N and Paul S R. 1997. Phenotypic stability for yield in chilli (*Capsicum annum* L.). *PKI/Res*. *J*. **21(2)**: 240-241.

Samnotra R K, Sidhu A S and Khurana D S. 2006. Stability studies for quality traits in chilli (*Capsicum annuum* L.). *Environment and Ecology* **24(Special 3)**: 570-574.

Sanatombi K and Sharma G J. 2008. *In vitro* propagation of *Capsicum chinense* Jacq. *Biologia Plantarium* **52(3)**: 517-520.

Santosh Kumari. 2013. Genetic variability studies in bell pepper (*Capsicum annuum* L.). *Asian Journal of Horticulture* **8(1)**: 280-284.

Saritha J K, Kulkarni R S, Rao A M and Manjunath A. 2005. Genetic divergence as a function of combining ability in chilli (*Capsicum annuum* L.). *Indian Journal of Genetics & Plant Breeding* **65(4)**: 331-332.

Sarkar S, Murmu D, Chattopadhyay A and Hazra P. 2009. Genetic variability, correlation and path analysis of some morphological characters in chilli. *Journal of Crop and Weed* **5(1)**:157-161.

Sarnia R N and Roy A. 1995. Variation and character association in chilli (*Capsicum annum* L.). *Annals of Agricultural Research* **16(2)**: 179-183.

Semeredi A A B and Berar V. 2015. Researches concerning the yield traits variability of some paprika cultivars. *Journal of Horticulture, Forestry and Biotechnology* **19(2)**: 152-156.

Senapati B K and Sarkar G. 2002. Genotype-environment interaction and stability for yield and yield components in chilli (*Capsicum annuum* L.). Vegetable Sciences **29**: 146-148.

Senapati B K, Sahu F K and Sarkar G. 2003. Genetic divergence in chilli. *Crop Res. Hisar*. **26(2)**: 314-317.

Shah Lal S D and Panth C C. 1986. Variability studies in chilli. *Prog. Hort.* **18**: 270-272.

Shapturenko M N, Tarutina L A, Mishin L A, Kilchevsky A V and Khotyleva L V. 2014. DNA divergence as a criterion of a sweet pepper (*Capsicum annuum* L.) selection for heterosis. *Russian Journal of Genetics* **50(2)**: 123-130.

Sharma I J, Samnotra R K, Vijay Kumar and Balbir Dhotra. 2014. Stability studies for quality traits in chilli (*Capsicum annuum* L.) under sub tropical areas. *Asian Journal of Soil Science* **9(12)**: 192-195.

Sharma P N, Kaur M, Sharma O P, Sharma P and Pathania A. 2005. Morphological, Pathological and Molecular Variability in *Colletotrichum capsici*, the Cause of Fruit Rot of Chillies in the Subtropical Region of North-western India. *Journal of Phytopathology* **153**: 232-237

Sharma R N and Roy A. 1995. Variation and character association in chilli (*Capsicum annuum* L.*). Ann. Agric. Res.* **1**: 179-183.

Sharma V K, Semwal C S and Uniyal S P. 2009. Genetic variability and character association analysis in bell pepper under rainfed mid hills situation of Uttarakhand. *Annals of Horticulture* **2(2)**:177-183.

Sharma V K, Semwal C S and Uniyal S P. 2010. Genetic variability and character association analysis in bell pepper (*Capsicum annum* L.). *Journal of Horticulture and Forestry* **2(3)**: 058-065.

Shirsat S S. 1994. Genetic variability and divergence studies in chilli (*Capsicum annuum* L.) *M.Sc. Thesis, University of Agricultural Sciences. Dharwad, Karnataka (India).*

Shirshat S S, Giritammannavar V A and Patil S J. 2007. Analysis of genetic variability for Quantitative Traits in Chilli. *Karnataka J. Agric. Sci*. **20(1)**: 29-32.

Singh A K and Chaudhary B R. 2010. Genetic architecture in the improvement of chilli (*Capsicum annuum* L.) crops. *Vegetos* **23(2)**: 132-136.

Singh M D and Singh N G. 2004. Correlation and path analysis studies in selected local chillies (*C. annum* L.). *Environment & Ecology* **22(4)**: 672-675.

Singh M D, Singh M B and Bhagirath T. 2005. Evaluation of selected local chilli (*Capsicum annum* L.) cultivars under Phasigat condition. *Environment & Ecology* **23(3)**: 607-611.

Singh R K and Singh D B. 2012. Genetic variability and characters association in chilli (*Capsicum annuum* L). *SAARC Journal of Agriculture* **10(1)**: 71-80.

Smitha R P and Basavaraja N. 2006. Variability and correlation studies in chilli (*Capsicum annuum* L.). *Karnataka Journal of Agricultural Sciences* **91(4)**: 888- 889.

Smitha R P and Basvaraja N. 2007. Variability and selection strategy for yield improvement in chilli. *Karnataka J. Agricultural Sciences* **20(1)**: 109-111.

Sreelathakumary I and Rajamony L. 2004. Genetic divergence in chilli (*Capsicum annuum* L.). *Indian J. Hort.* **61**: 137-139.

Srividhya S and Ponnuswami V. 2010. G×E interaction and stability of yield in paprika genotypes (*Capsicum annuum* var *longum*) in Tamil Nadu. *Electronic Journal of Plant Breeding* **1(3)**: 297-300.

Subashri S and Natarajan S. 2000. Genetic variability insegregating progenies of chilli (*Capsicum annuum* L.). *South Indian Horticulture* **48(1/6)**: 36-39.

Sudre C P, Goncalves L S A, Rodriques R, Do Amaral Junior A T, Riva-Souza E M and Bento C S. 2010. Genetic variability in domesticated *Capsicum* spp assessed by morphological and agronomic data in mixed statistical analysis. *Genetic and Molecular Resources* **9(1)**: 283-294.

Sudre C P, Rodrigues R, Riva E M, Karasawa M, Amaral Júnior A T. 2005. Divergência genética entre acessos de pimenta e pimentão utilizando técnicas multivariadas. *Horticultura Brasileira* **23**: 22-27.

Sundaram A, Ramkrishnan A, Ranganathan C R. 1980. Genetic divergence in chilli. *Indian Journal of Agricultural Sciences* **50**: 391-398.

Suzuki K, Fujiwake H and Iwai K. 1980. Intercellular localization of capsaicin and its analogous, capsaicinoid in Capsicum fruit. I. Microscopic investigation of structure of the placenta of the *Capsicum annuum* var. *annuum* cv. Karyatsubusa. *Plant Cell Physiol.* **21**: 839-853.

Szolcsanyi J. 2004. Forty years in Capsaicin Research for Sensory Pharmacology and Physiology. *Neuropeptides* **38**: 377-384.

Tembhurnel B V and Rao. 2013. Stability analysis in chilli (*Capsicum annuum* L.). *Journal of Spices and Aromatic Crops* **22(2)**: 154-164.

Tewksbury J J and Nabhan G P. 2001. Directed deterrence by capsaicin in chillies. *Nature* **412**: 403-404.

Thoday J M. 1958. Homeostasis in a selection experiment. *Heredity* **12**: 401-415.

Thul S T, Lal R K, Shasany A K, Darokar M P, Gupta A K, Gupta M M, Verma R K, Khanuja S P S. 2009. Estimation of phenotypic divergence in a collection of *Capsicum* species for yield-related traits. *Euphytica* **168**:189-196.

Vani S K, Sridevi O and Salimath P M. 2007. Genetic divergence in chilli (*Capsicum annuum* L.). *Ann. Biol*. **23(2)**: 123-128.

Varalakshmi B and Haribabu K. 1991. Genetic Divergence, Heritability and Genetic Advance in Chilli. *Indian journal of Genetics* **51(2)**: 174-178.

Varkey J, Saiyed M P Patel J S and Patel D B. 2005. Genetic variability and heritability in chilli. *Journal of Maharashtra Agricultural Universities* **30(3)**: 346-347.

Verma S K, Negi K S, Muneem K C and Arya R R. 2008. Preliminary evaluation of chilli germplasm. *Pantnagar Journal of Research* **6(1)**: 81-85.

Vijaya H M, Gowda A P M, Nehru S D, Lingaiah H B and Umesha K. 2014. Variability, heritability and genetic advance for growth, yield and quality in chilli (*Capsicum annuum* L.). *Annals of Agri Bio Research* **19(2)**: 298-300.

Vijaya H M, Gowda A P M, Nehru S D, Lingaiah H B and Umesha K. 2014. Genetic diversity studies in chilli (*Capsicum annuum* L.) genotypes. *Environment and Ecology* **32(4)**: 1559-1562.

Vitria Puspitasari Rahadi, Muhamad Syukur, Sriani Sujiprihati and Rahmi Yunianti. 2013. Nonparametric stability analysis of yield for nine chili pepper *(Capsicum annuum* L.*)* genotypes in eight environments. *Agrivita* **35(2)**: 193-200.

Warade S D, Dhumal M M and Shinde K G. 1996. Correlation studies in chilli. *Journal of Maharashtra Agricultural Universities* **21(1)**: 55-57.

Warade S D, Dhumal M M and Shinde K G. 1997. Diversity studies in chilli. *Journal of Maharashtra Agricultural* Universities **22**: 109-112.

Yatung T, Dubey K R, Singh V and Upadhyay G. 2014. Genetic diversity of chilli (*Capsicum annuum* L.) genotypes of India based on morpho-chemical traits. *Aust. J. Crop Sci.* **8(1)**: 97-102.

Zehra Syed Berjes, Khan Shabir Hussain, Afroza Baseerat, Dar Zahoor Ahmad, Shikari Asif. 2015. Genetic divergence studies in chilli (*Capsicum annuum* L.) under temperate conditions. *Research on Crops* **16(3)**: 609-616.

Zewdie Y and Bosland P W. 2000. Evaluation of genotype, environment, and genotype-by environment interaction for capsaicinoids in *Capsicum annuum* L. *Euphytica* **111**: 185-190.