International Journal of Plant & Soil Science

18(6): 1-10, 2017; Article no.IJPSS.35427
ISSN: 2320-7035

Stability and Adaptability Patterns of Chilli Hybrids in Karnataka State

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RH and BRJ designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors VD and PH managed the collection and edition of literatures. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2017/35427
Editor(s):
(1) Faruk Toklu, Field Crops Department, Agricultural Faculty, Cukurova University, Turkey.
Reviewers:
(1) Desimir Knezevic, University of Pristina, Kosovska Mitrovica Lesak, Kosovo and Metohia, Serbia.
(2) Rasmia Sayed Sayed Darwesh, Central Lab. For Research and Development of Date Palm. Agriculture Research Centre, Egypt.
Complete Peer review History: http://www.sciencedomain.org/review-history/21042

Review Article

Received 12th July 2017
Accepted 8th September 2017
Published 18th September 2017

ABSTRACT

Chilli is an important vegetable and spice crop in India. It is most widely cultivated in India for its pungency and export-oriented quality. It is a climate dependent sensitive to various pest and disease infestation. The southern parts of the country emerged as novel diversity in the cultivated species the genus *Capsicum*. Investigations were carried out to assess the stability of many chilli hybrids using popular commercial checks across the nation. The results of these studies were meticulous and the popularity of hybrid chilli crop mostly depends on the yield and yield attributing factors. Breeding for most stable chilli hybrid needs genetic variation and the variance environmental factor plays a vital role in emergence of stable chilli hybrid. Considering all the edaphic factors and stability parameters the test hybrids were developed and evaluated at different environmental conditions. The test Hybrids, developed were subjected to various observations such as average fruit weight, fruit width, length, number of fruits per plant, etc., the best yielding genotype among different test hybrids, having higher yield level than the check and which were

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also stable for most of the characters as evident from their non-significant s^2di values were considered for their adaptability. The adaptability of these selected hybrids for specific location may help in identifying most promising hybrids for yield and its component traits and to assess its stability across the state.

Keywords: Capsicum annuum L.; stability; adaptability; genetic variation; fruit yield.

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is an important solanaceous commercial vegetable crop grown for variegated uses of its fruits both in green and ripe stages. This is grown in Asia, America and South Africa by small and marginal farmers as commercial spice crop. It is the second largest commodity after black pepper (*Piper nigrum* L.) in the international spice trade. Chilli has its unique place in Asian diet as a spice as well as vegetable. The area under Chilli in India is about 0.79 million ha with annual production of 13.04 m tones and productivity of 1.74 tonnes ha^{-1} [1].

The main objective of chilli breeding programme has been to develop cultivars that perform well over a broad spectrum of environment. Thus, assessment of the nature and extent of genotype x environment interaction and identification of phenotypically stable genotype, showing low genotype x environment interaction, become important. This requires the screening of promising genotypes in a set of environmental conditions. It has been found that the effectiveness of different cultivars/ genotypes of a crop usually varies from location to location and even more markedly, from season to season. The average response of cultivars/genotypes, thus, depends largely upon the absence or presence of genotype x environment interaction, coupled with high yield indicates that the genotypes are suitable for general adaptation in the range of environments considered. The cultivars/genotypes with high stability are generally low yielders and vice versa. A balance between these extremes is, therefore, set as goal of any breeding programs for a crop improvement. Especially in case of vegetable crops, which are often cultivated under varying agro-climatic and edaphic factors. In this contest review of work carried out by different research workers along with the specific research work carried out at UAS, GKVK Bengaluru were pooled together and submitted here with following objectives *viz,* To identify the cultivars, which are high yielding and stable in performance, across the environment, before they are released for commercial cultivation.

2. STABILITY OF CHILLI HYBRIDS

Stability analysis was carried out by employing the linear regression model proposed by Eberhart and Russell [2]. Although there are number of models available to characterize the hybrids for their G x E interactions, this model is widely used for its simplicity and reliability. An ideal hybrid is defined as the one possessing high mean performance with regression coefficient around unity (b_i=1) and deviation from regression (S^2d_i) close to zero. The linear regression is regarded as the measure of linear response of a particular hybrid to the changing environment. If the regression coefficient (b_i) is greater than unity, the hybrid is said to be highly sensitive to environmental fluctuations but adapted to high yielding environments. If regression coefficient (b_i) is equal to unity, it indicates the average sensitivity to environmental fluctuations and adaptable to all environments. If the regression coefficient (b_i) is less than unity, it indicates less sensitivity to environmental changes and if this is accomplished by a high mean value, then the hybrid is said to be better adapted for poor conditions. In the present study stability parameters such as mean (X), regression coefficient (b_i) and deviation from regression (S^2d_i), as suggested by Eberhart and Russell [2] were considered to discuss the stability of different hybrids for various characters under consideration and the same is presented character wise.

3. PLANT GROWTH CHARACTERS INFLUENCING STABILITY TRAIT OF CHILLI HYBRIDS

A genotype is considered stable in performance if it has high mean performance, unit regression coefficient, and least deviation from regression. Cultivar with a regression value above one is considered unstable with higher sensitivity to environmental change. [2]. It is good for specific adaptation in high yielding environment. Regression coefficient below one indicates that the cultivar is relatively stable with greater resistance to environmental change. The test

hybrid, CMS10A x Byadgikaddi exhibited higher mean with unit regression co-efficient (b_i>1) and the deviation non-significantly different from zero (S^2_{di} = 0) indicating specifically adapted to unfavorable environment for the productive traits viz., average fruit weight and fruit width. The selected hybrids studied for green fruit yield plant^{-1}, red fruit yield plant^{-1} and for number of fruits exhibited high mean with unit regression co-efficient (b_i>1) and the mean deviation was non-significantly different from zero (S^2_{di} = 0) indicating below average stability specifically adapted to unfavorable locations for the productive traits. Chowdhury et al. [3], Senapati and Sarkar [4], Nehru et al. [5] and Tembhurne and Rao [6] also obtained similar results for the said characters.

The test Hybrids, CMS 6A × Tiwari for the character average fruit weight and CMS 9A × LCA 206 for the character fruit width were well adapted to all environments. But, CMS10A × Byadagidabbi was poorly adapted to all the environments for the productive traits viz., red fruit yield, average fruits per plant and fruit width. The hybrid, CMS 10A × LCA 206 for green fruit yield, red fruit yield, average fruits per plant and average fruits length and CMS10A × Gouribidanur for green fruit yield, red fruit yield and average fruits per plant were specifically adopted to favorable and unfavorable environments respectively. Further, the test hybrids at a specific location indicated that the best yielding genotype among various test hybrids and higher yield level than the check hybrid and which was also stable for most of the edaphic characters as evident from their non-significant s^2di values was also opined by Raghavendra et al. [7].

A study conducted by Pandita et al. [8] involving thirty-six lines of chilli for different characters. They recorded maximum plant height in HC-255 and the maximum number of branches per plant in new strain 76 =/ 241-1 genotype. Sachan [9] evaluated 11 cultivars of chilli under Pantnagar conditions. He observed maximum plant height in chilli cultivar G-4 followed by LCV-312. Revanappa et al. [10] evaluated green chilli cultivars viz., Pusa Jwala, Nagavi, Kadrolli at Dharwad, Karnataka. Nagavi had the highest root weight and Pusa Jwala had the longer roots. Mohanty [11] evaluated eight chilli cultivars and reported that G-4 had maximum plant height (80.87 cm), highest branches per plant (17.33 cm) and shortest days to harvest (102.40 days).

The performance of 30 chilli genotypes indicated that maximum plant height in ACS-2000-03 (146.6 cm) and minimum in KA-2 (43 cm), primary branches per plant-recorded maximum in AC-510 (11.16) and minimum in LCA-206 (5.16) Gupta [12]. Maximum stem diameter was exhibited by AC 515-2(3.35 cm) and it was minimum in ACS 92-4 (1.37 cm). Pramila [13] studied 40 exotic and indigenous genotypes of chilli and found that Pant Sel-13, EC 519638, Pant Sel-20 were the taller than rest of the genotypes. The maximum number of primary branches per plant was recorded in Pant sel-13, where as maximum stem diameter was obtained in EC 519630 (2.38 cm) and it was minimum in PC-2064 (1.43). Sachan [9] obtained more number of fruits per plant in AC- 458 (128.9) and minimum in LCA-301 (12.3) among all the 11 genotypes. Singh et al. [14] studied 12 cultivars for eight characters, for a period of two years and found maximum number of fruits per plant in Pant C-1 followed by LCA-206 and G-4 as compared to Pusa Jwala (check).

Evaluation of 10 genotypes of *Capsicum annuum L.* under North Indian agro-climatic conditions exhibited highly significant differences for sixteen growth and yield characters. Among all the genotypes tested, AN-11 recorded the highest number of fruits per plant and maximum fruit weight was found in Hissar Sakti followed by HC Sel-6, Kumar et al. [15]. Khokhar et al. [16] evaluated four exotic chilli cultivars for number and weight of fruits per plant, fruit size, single fruit weight but a commercially grown local chilli cultivar Peshwar Selection produced maximum number of fruits per plant (268).

4. EFFECT OF YIELD AND YIELD ATTRIBUTES ON STABILITY OF CHILLI HYBRIDS

A study conducted by Pandita et al. [8] involving 36 lines of chilli in two years of study programme and found that a new strain 76=242-1 gave significantly more yield than HC-260 and HC-266. Natrajan et al. [17] studied the performance of six chilli cultures in semi dry conditions and obtained the maximum yield of dry chilli in culture CA-PM-27 (2.56 t per ha). Rani [18] evaluated 73 chilli genotypes and reported that the genotypes namely JCA-154, JCA-232, Guntur chilli and Dwale, gave 118.7, 85.1, 83.1 and 79.7 per cent increased yield over the standard check Pusa Jwala, respectively. Sachan [9] obtained the highest red ripen fruit yield per plant and per

hectare in Punjab Surkh and AC-458. They yielded 97.5 and 87.7 per cent more than the standard cultivar Pusa Jwala, respectively, whereas AC-458, Punjab Surkh and Utkal Ragini in descending order had highest yield of dry chilli per plant.

Study of 19 genotypes of *Capsicum annuum* L. under North Indian agro-climatic conditions. Among the tested genotypes, An-11 recorded highest fresh red ripen fruit yield per plant followed by Hissar Shakti, Punjab Shakti and HC Sel-6,Kumar et al. [15]. Mohanty [11] studied eight chilli cultivars and reported X-235 the most superior cultivar regarding green fruit yield of 144.36 q per ha. Gupta [12] studied the performance of 30 genotypes. He found that out of 30 genotypes, Pant Chilli-5, KA-2, Pant Chilli-3 and Pant Chilli-4 were top yielder than rest of the genotypes. Singh and Jain [19] reported that out of fifteen genotypes, the fruit yield per ha was found higher in Pant C-1(79.0 q per ha) followed by JCA- 283 (71.69 q per ha), HC-28 (70.64 q per ha) and RHRC- 16-5 (65.33 Q per ha) which was 75.6, 57.0, 57.71 and 45.02% higher over national check LCA-206, respectively.

Genetic variability, Heritability and Genetic advance Rani and Singh [20] conducted a field experiment at IIHR, Bengaluru to evaluate 73 chilli varieties. They determined fruit length, surface area and stem diameter with their interactions. The results showed that fruit length ranges from 2.99 to 14.73 cm (Avg. 8.35 cm), fruit diameter 0.69 to 2.43 cm (Avg. 1.22 cm), all of these characters exhibited high variability.

Evaluation of 30 germplasm lines of chillies. They observed considerable amount of genetic variability for all characters except fruit girth. The number of fruits per plant exhibited highest value of genotypic and phenotypic coefficient of variation. They also estimated high heritability in broad sense, genotypic coefficient of variation and genetic advance for fruit length, number of fruits per plant and yield per plant, Munshi et al. [21]. Mishra et al. [22] evaluated nine genotypes of chilli for fruit characters for 2 years. They found that phenotypic coefficient of variation (PCV) had slightly higher value as compared to the genotypic coefficient of variation (GCV) indicating the negligible effect of the environment on the fruit characters. They observed highest PCV and GCV for fruits per plant, followed by fruit length, dry weight of single fruit and red chilli yield per plant.

The study of seventeen genotypes of chilli (*Capsicum annuum*) and they observed that phenotypic and genotypic coefficients of variation were highest for fruit length (26.64cm and 26.21cm) followed by dry fruit yield (13.28 and 19.93), and number of branches per plant (19.46 and 15.10). They also observed that heritability was highest for plant height (98.12%) followed by fruit length (96.74%) and number of fruits per plant (96.18%) where as number of branches per plant, followed by fruit width and dry fruit yield per plant showed higher genetic advance as percentage of mean, Mohammed et al. [23]. Sree Latha Kumari and Rojamoni [24] evaluated 70 diverse genotypes of chilli and they observed higher phenotypic and genotypic coefficient of variation for fruits per plant, fruit weight, fruit length, fruit girth, yield and leaf area in both shade and open areas. They also reported higher heritability and genetic advance for these characters.

The evaluation of twelve chilli (*Capsicum annuum L.*) genotypes. They observed higher phenotypic coefficient of variation then genotypic coefficient of variation for all characters and high heritability for plant canopy, number of fruits per plant, days to 50% fruiting, plant height, days to 50% flowering and pod length. High genetic advance as percent of mean coupled with high heritability for the number of fruits per plant, plant canopy, pod length and plant height suggesting additive genetic variance for these characters. High heritability associated with low genetic advance as percent of mean was observed for days to 50% flowering and days to 50% fruiting indicating a non additive gene action, Verma et al. [25].

The variability study of 17 genotypes of chilli (*Capsicum annuum*). Observations were recorded for days to 50% flowering, plant height, number of branches per plant, number of fruits per plant, fruit length, fruit girth, 1000- seed weight, seed percentage, incidences of dieback and fruit rot (*Colletotrichum capsici*), and yield of red chilies per plant. The presence of variability amongst the genotype for all the characters was observed. High values of genotypic coefficient of variation were noted for fruit rot incidence percentage, number of fruits per plant, wet red chilli yield, fruit girth and number of branches per plant, showing large variation for these traits. Heritability estimates ranged from 27.60 to 92.10%. Nine characters showed high heritability (> 70%). The expected genetic advance ranged from 3.73 to 74.90. High heritability (92.70%)

was accompanied by high genetic advance (70%) in respect to number of fruits per plant, indicating prevalence of additive gene action, which offers good scope for further improvement as observed by Wasule et al. [26].

Genetic variability and heritability for 12 characters of 45 genotypes of chilli (*Capsicum annuum*). They reported that the mean squares due to genotypes were significant for all the characters, except days to flower, indicating the existence of variability among the 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 were recorded for number of fruits per plant, number of seeds per fruit and dry weight per plant. These traits can be exploited in breeding programmes to improve the yield in chilli, Verkey et al. [27].

The genetic variability and heritability study for 17 characters in relation to heat tolerance was assessed in different chilli genotypes during summer in Maharastra, India. In this study analysis of variance showed highly significant differences among the genotypes for all the characters. Yield of green fruits per hectare showed the maximum variability, followed by capsaicin content, ascorbic acid content, green fruits per plant, marketable yield of green fruits per plant and yield of green fruits per plant. High values of heritability and genetic advance were recorded for yield of green fruits per plant, marketable yield of green fruits per plant and fruit length, indicating the possibility of larger response to selection and greater chance for improvement of chilli, Dutonde et al. [28].

Evaluation of forty genotypes of chilli to estimate variability, heritability, genetic advance and correlation coefficient. Higher genotypic and phenotypic coefficients of variation were observed for fruits per plant, fruit weight, fruit length, fruit girth and yield. Heritability and genetic advance were also higher for these characters indicating the possibility of selection to these characters, Smitha and Basavaraja [29].

Evaluation of chilli hybrid genotypes for stability analysis for their yield and yield attributing traits **c**onsidering all these stability parameters the study revealed that fruit weight, fruit width, green fruit yield plant^{-1}, red fruit yield plant^{-1} and number of fruits were exhibited below average stability and these were specifically adapted to some unfavorable conditions at a specific location. This proved as the best yielding hybrid against the check and was also stable for most of the characters as evident from their non-significant s^2di values that was also opined by Raghavendra et al. [30].

Evaluation of forty cultivars and local landraces of chilli (*Capsicum annuum*)conducted by Pawandeep et al. [31] indicated that the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for most traits. High GCV accompanied by high heritability and genetic gain was recorded for coloring matter, ascorbic acid and dry matter, indicating that these traits could be improved by simple selection. Path analysis showed that number of fruits per plant, fruit weight, capsaicin content, fruit breadth, fruit length, and ascorbic acid content, and oleoresin content had high positive direct effects on yield.

5. QUALITATIVE AND QUANTITATIVE TRAITS FOR ADAPTABILITY OF CHILLI HYBRIDS

The study conducted by Sooch et al. [32] for mosaic response in 2-yr experiments, the resistance of 20 genotypes to chilli (pepper) mosaic viruses was assessed in 4 different edaphic and agro-climatic regions. The low disease severity index and the low regression coefficient, coupled with the non- significant deviation in S-119 and S-114, suggested a high degree of stability in these genotypes for resistance to both viruses. They also reported that resistance of 20 lines to tobacco leaf curl and chilli mosaic viruses was assessed over two years in four edaphic and agroclimatic regions in India. The low disease-severity index and the low regression coefficient, coupled with a nonsignificant deviation, in S119 and S114 suggested a degree of stability in these lines for resistance to both viruses. While, Roy et al. [33] evaluated some 23 genotypes of chilli (*Capsicum annum*) for yields at Diphu during 1993-96. Genetic variation among genotypes and genotype environment interactions were highly significant. DC24 and DC11 performed best under a wide range of environments and were recommended for future breeding programmes.

Evaluation of thirteen chilli genotypes, viz. Gossaigaon, Bijni, Goalpara, Dhupdhara, Chamata, Rangia, Mangaldoy, Bijoynagar, Borpeta Road, Kharupetia, Loharghat, Dharapur and Baihata in Guwahati, Assam, India, during 1994-96 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. None of the genotypes showed average stability for all the characters. However, Borpeta Road and Bijoynagar showed stable performance for fruit yield, while Mangaldoi showed stable performance for earliness in flowering was noticed by Chowdhury et al. [3].

The phenotypic stability for 7 quantitative traits (earliness, fruit length, fruit diameter, average fruit weight, number of fruits per plant, dry fruit yield per plant and capsaicin content) was evaluated using 55 chilli genotypes (45 hybrids and 10 parents) grown during summer 1995 under three environments in Bangalore, Karnataka, India. Analysis of variance revealed significant genotype x environment (G x E) interaction for these traits. The variance due to the linear component of G x E interaction was significant for dry fruit yield per plant. The non-linear component of G x E interaction was significant for all traits. In general, the hybrids showed higher production and stability than the parents as opined by Lohithaswa et al. [34].

The adaptability and genetic stability of 20 chilli cultivars and were evaluated in a field experiment conducted in Parganas, West Bengal, India during the summer of 1997-99. Genotype x environment interactions was 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, and dry chilli recovery percentage and fruit yield. The linear component was significant against the non-linear component in fruit number only. Kakdwip Local and Kalimpong Local were stable for all the characters examined. EC 12473-1 was stable for fruit yield, number and weight and dry chilli recovery percentage, and IC 119746 was stable for fruit yield, number and weight and plant height [4].

Studies on yield stability in chilli (*Capsicum annuum* L.) elite chilli cultivars from Sri Lanka (MI-2 and KA-2) were evaluated during *kharif* 1999 and 2000 in farmers' fields in southern India. Arka Lohit served as the control. The cultivars differed significantly in different environments for green fruit yield per plot, fruit length, fruit width and days to harvest. Genotype x environment interaction was not significant for any of the characters studied. Arka Lohit showed superiority in yield (382.5 kg per plot), followed by MI-2 (343.75 kg per plot) and KA-2 (291.88 kg per plot) during the year 2000. A similar trend was observed during the year 1999. Although MI-2 and KA-2 were determinate and highly suitable for fresh green fruit yield, KA-2 was highly suitable for favorable environments. On the other hand, MI-2 exhibited well yield potential, earliness, acceptable fruit type in the market, stability and was highly suitable for unfavorable environments. Hence, MI-2 is preferred by farmers and is recommended for cultivation under irrigated conditions [35].

The stability analysis for yield and quality characters in hot pepper (*Capsicum annuum* L.) Influenced by genotype x environment (linear) component was found non-significant for ascorbic acid content and fruit colour, while it was significant for fruit yield and capsaicin, with the linear component having a greater magnitude in most of the characters than the corresponding non-linear component. The magnitude of linear components and the corresponding non-linear components for fruit yield, ascorbic acid content, fruit colour and capsaicin were 76.480, 87.100, 0.440, 0.002 and 50.190, 28.210, 0.250, 0.002, respectively. Genotypes SC-106 and SC-114 besides having yield potential and superior ascorbic acid content, fruit colour and fruit pungency also exhibited stability. These genotypes would, therefore, be useful for commercial cultivation over a wide range of environments or as elite gene pool in future breeding programmes [36].

Evaluation of sixteen chilli (*Capsicum annuum*) genotypes were during 1995-96, 1996-97 and 1997-98 in Bangalore, Karnataka, India, for mean genotypic coefficient of variation (GCV), heritability in broad sense (h) and genetic advance over mean (GA) for 6 characters, i.e. canopy (CAN), height (HT), primary branches per plant (PB), fruits per plant (FP), fruit length (FL) and fruit yield per plant (FY); for correlations among the characters; and for stability of genotypes for CAN, HT, FP and FY. Correlations of FP with FY were high during all the 3 years. The GA and h values were high, while the GCV values were moderate and stable over years for 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. Ceylon was found to be the most stable genotype for yield [5].

Evaluation of twenty-five genotypes of chilli collected from different parts of India for their stability of quality traits (Capsaicin content and coloring matter) at three locations in Punjab (i.e. Ludhiana, Faridkot and Amritsar) during 2001-02 and 2002-03. Highly significant mean squares for both quality traits indicated wide variability amongst the genotypes. The environment component was significant for coloring 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. Genotype Punjab Lal had average stability for coloring matter and below average stability for capsaicin content. The genotypes Punjab Lal, HC-44, Phule Sai, G-4, CA-960 and Bireek-2 can be utilized in further quality breeding programmes [37].

The genotype x environment interaction of five parents and four F1 hybrids along with check in four diverse environments to study the genotype environment interaction and phenotypic stability for fruit yield and its components. Sufficient G x E interaction was exhibited by the genotypes for all the traits studied. Two genotypes Arka Abir, Arka Abir x Bydagi - kaddi were stable across environments because of their non-significant deviation from linearity. The hybrid Arka Abir x Bydagi - kaddi manifested above average performance accompanied by responsiveness around unity and was recognized for general adaptability. This hybrid could be utilized in alternate breeding programmes to tap high yielding potentiality with wider adaptability [38].

Evaluation of 25 hybrids chilli (*Capsicum annuum* L.) genotypes for Assessment of Stability Patterns in Some Selected chilli Hybrids in three locations, Out of three environments studied E3 was found to be the most suitable location for expression of many bio-physical characters. Significance of variance due to hybrid X environment (linear) was evident for green fruit yield. Variance due to environment (linear) was highly significant for all the traits across three environments indicating considerable differences among environments and their predominant effect in the expression of all the traits. The hybrid CMS10A X Byadgi-Kaddi exhibited higher mean with unit regression co- efficient and non-significant S2di different from zero indicating specifically adapted to unfavorable environment for average fruit weight and fruit width. The hybrids CMS10A X LCA-206 and CMS10A X Gouribidanur were found specifically adopted to favorable environments for green fruit yield, red fruit yield, average fruits/plant and average fruit length [7].

Study on phenotypic stability analysis in tomato *(lycopersicon esculentum* mill.) and evaluated nine varieties of tomato, were in randomized block design with three replications during *Rabi* season. The pooled analysis of variance indicated significant differences among the genotypes and G x E interactions for fruit yield, plant height, fruit girth and 10-fruits weight. It indicated that the genotypes were responded differentially to the changing of environments with respect to above four characters. However, significant mean squares due to environments were observed for all the eight characters, indicating the presence of variable environments in expression of all the traits. Reddy et al. [39] carried out stability analysis for grain yield in 45 hybrids over environments (years/location) to identify suitable and stable hybrids in maize. The results revealed significant G × E interaction which could be attributed to different rankings of the genotypes across environments [40].

An experiment to identify of stable variety and to characterize genotype and environment interaction for yield and quality attributes in eight tomato varieties. The pooled analysis of variation indicated the presence of differential reaction of genotypes for days to 50% of flowering and to ripening. The stability analysis revealed the suitability of Kashi Amrit and Kashi Anupam for different environments with higher yield. However, the majority of the traits exhibited the linear predictability across the environments.

A study conducted by Venugopal and Reddy [41] for the stability analysis on fruit yield and its attributing traits in 13 chilli varieties over three years (2004-06). Stability models (with R^2 as 75.4 to 97.5 %) developed individually for yield and yield attributing biometrical characters indicated that Arka Lohit (for red fruit yield (95.9 /ha (q)) and dry fruit yield (25.9 /ha (q)) followed by BC 25 were stable, as they possesses least equivalence values as compared to others. However, KA-2 and PANT-5 were identified as lines suitable for favourable environment and

LCA 206 was classified as above average varieties which will respond well to a poor environment [42].

Study conducted by Muhamad et al. [43] for non-parametric stability analysis of several chili pepper hybrids and results indicated that, according to stability parameters namely $SI^{(3)}$, RS, $NPi^{(1)}$, $NPi^{(2)}$, $NPi^{(3)}$ and $NPi^{(4)}$, Imperial was the most stable hybrid. However, the hybrid IPB CH3 was the most stable hybrid based on $SI^{(1)}$, $SI^{(2)}$ and TOP stability parameters. The results also revealed that based on the non-parametric stability test, the results could be classified into 2 groups, according to the agronomic and biological stabilities.

An evaluation study conducted by Datta and Jana [44] for fifteen chilli genotypes on their stability in the rabi (winter) season for two years under five fertility levels (0, 50, 100, 150 and 200% of RDF 100:50:50 Kg NPK/ ha). Pooled analysis of variance revealed highest fresh green fruit yield was also recorded in Ulka 686 (15.98 t/ha) and was specifically adopted under favorable condition. Jwalan CA-29 and CA-48 also recorded higher yield but these genotypes were not stable under changing environment, as their s^2d_i value was significant. Among the high yielding genotypes CA-47, NS-1701 performed better under favourable condition and the genotypes Tejaswini, DKC-8 and CA-30 performed better under adverse condition.

6. CONCLUSION

On an appropriate approach for improvement of yield the information regarding association between different yield component and their relative contribution to yield is very much essential in a breeding programme. The analysis of nature and magnitude of association among the characters for total yield. The expression of association among characters was influenced by G x E interaction and genetic background. Hence for understanding and underlying association the use of diverse environments assume great importance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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