# SUITABILITY OF LAM CHILLI (*Capsicum annuum* L.) LINES FOR DIFFERENT DATES OF SOWING IN BENGALURU REGION

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**GKVK, BENGALURU, 560 065**

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**PALB 6254**

***Thesis submitted to the***

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## MASTER OF SCIENCE (Agriculture)

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## GENETICS AND PLANT BREEDING

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*Affectionately dedicated to my beloved Mother*

# DEPARTMENT OF GENETICS AND PLANT BREEDING
# UNIVERSITY OF AGRICULTURAL SCIENCES
# GKVK, BENGALURU – 560 065

## CERTIFICATE

This is to certify that the thesis entitled **"SUITABILITY OF LAM CHILLI (*Capsicum annuum* L.) LINES FOR DIFFERENT DATES OF SOWING IN BENGALURU REGION"** submitted in partial fulfilment of the requirement for the degree **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING** to the University of Agricultural Sciences, GKVK, Bengaluru, is a bonafide record of research work done by **Mr. SRINATHAREDDY, S., I.D. No. PALB 6254,** during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru

August, 2018

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# SUITABILITY OF LAM CHILLI (*Capsicum annum* L.) LINES FOR DIFFERENT DATES OF SOWING IN BENGALURU REGION

**SRINATHAREDDY, S.**

## ABSTRACT

An investigation was carried out at three environments *viz.*, July, September, November for three dates of sowing at K-block, Department of Genetics and Plant Breeding, GKVK, UAS, Bengaluru. During November sowing apart from Bengaluru, sowing was taken at Siddalaghatta and Srinivaspuraduring 2017-18. Experiment was carried outto detect and quantify Genotype × Environment interaction and to identify LCA genotypes (Lam Chilli Accessions) suitable across different dates and locations of sowing. 17LCA varieties were evaluated along with four checks (KBCH-1,US 341,ArkaMeghana and ArkaHaritha) in a Randomized Complete Block Design withtwo réplications. Among the threeenvironmentssown for different dates Novembersowing and for different locations GKVK werefoundmostsuitable for expressingmost of all characters. Per cent variance contributed due to genotype was evident for most of the traits across both dates and locations of sowing. Per cent variance due to Genotype × Environment was highly significant for days to 50 per cent flowering across both dates and locations of sowing. Thisindicates considerable differences among genotypes and their interaction effect in the expression of all the traits.The genotypes, LCA 334, LCA 424 and LCA336for dates of sowing andthe genotypes, LCA 336, LCA 206 and LCA 235 for locations of sowing hadlowest estimate of ASV (AMMI Sability Value) and SI (Stability Index) for green fruit yield were widely adapted. The genotypes LCA 639 for July sowing, LCA 334 for September sowing and LCA 620 for November sowing were specifically adaptable. The genotypes US 341 for GKVK sowing, KBCH-1 for Siddalaghatta sowing and LCA 625 for Srinivaspur sowing were specifically adaptable.

August, 2018

**(JAYASHREE, M. K.)**
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**ಲ್ಯಾಮ್ ಮೆಣಸಿನಕಾಯಿ ಸಾಲುಗಳ ವಿಭಿನ್ನ ಬಿತ್ತನೆಯ ದಿನಾಂಕಗಳ ಸೂಕ್ತತೆಯ ಕುರಿತು ಬೆಂಗಳೂರು ಪ್ರದೇಶದಲ್ಲಿ ಕೈಗೊಂಡ ಅಧ್ಯಯನ**

**ಶ್ರೀನಾಥರೆಡ್ಡಿ, ಎಸ್.**

**ಪ್ರಬಂಧ ಸಾರಾಂಶ**

ಅನುವಂಶೀಯತೆ ಮತ್ತು ಸಸ್ಯತಳಿ ಅಭಿವೃದ್ಧಿ ಶಾಸ್ತ್ರ ವಿಭಾಗದ ಕೆ ಬ್ಲಾಕ್, ಕೃಷಿ ವಿಶ್ವ ವಿದ್ಯಾಲಯ, ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರಿನಲ್ಲಿ ಮೂರು ಪರಿಸರಗಳಾದ ಜುಲೈ, ಸೆಪ್ಟಂಬರ್ ಮತ್ತು ನವೆಂಬರ್ ತಿಂಗಳುಗಳಲ್ಲಿ ಮೂರು ವಿಭಿನ್ನ ಬಿತ್ತನೆಯ ದಿನಾಂಕಗಳ ಕುರಿತು ತನಿಖೆ ಕೈಗೊಳ್ಳಲಾಯಿತು. ನವೆಂಬರ್ ೨೦೧೭-೧೮ ರಲ್ಲಿ ಬೆಂಗಳೂರಿನಲ್ಲದೆ, ಶಿಡ್ಲಘಟ್ಟ ಮತ್ತು ಶ್ರೀನಿವಾಸಪುರ ಪ್ರದೇಶಗಳಲ್ಲಿ ಬಿತ್ತನೆಯನ್ನು ಮಾಡಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಲ್ಯಾಮ್ ಮೆಣಸಿನಕಾಯಿ ಬೆಳೆಯಲ್ಲಿ, ಪ್ರಭೇದಗಳ ಮತ್ತು ಪರಿಸರದ ಪರಸ್ಪರ ಕ್ರಿಯೆಯನ್ನು ಅಂದಾಜು ಮಾಡಲು ಮತ್ತು ಪ್ರಮಾಣೀಕರಿಸಲು ಹಾಗೂ ಬಿತ್ತನೆ ಮಾಡುವ ವಿಭಿನ್ನ ದಿನಾಂಕಗಳ ಮತ್ತು ಸ್ಥಳಗಳ ಸೂಕ್ತತೆಯನ್ನು ಕುರಿತು ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. ೧೭ ಎಲ್‌ಸಿಎ ಪ್ರಭೇದಗಳ ಜೊತೆಗೆ ನಾಲ್ಕು ಪರಿಶೀಲನೆಗಳೊಂದಿಗೆ (ಕೆಬಿಸಿಎಚ್-೧, ಯುಎಸ್-೩೪೧, ಅರ್ಕಾ ಮೇಘನಾ ಮತ್ತು ಅರ್ಕಾ ಹರಿತಾ) ಯಾದೃಚ್ಚಿಕ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ ಎರಡು ಪ್ರತಿಕೃತಿಗಳಲ್ಲಿ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ನವಂಬರ್ ತಿಂಗಳಿನಲ್ಲಿ ಬಿತ್ತನೆ ಮಾಡಿದ ಮೂರು ಪರಿಸರಗಳ ಮತ್ತು ಸ್ಥಳಗಳಲ್ಲಿ ಜಿಕೆವಿಕೆಯಲ್ಲಿ ಹೆಚ್ಚಿನ ಗುಣಲಕ್ಷಣಗಳನ್ನು ವ್ಯಕ್ತಪಡಿಸಲು ಸೂಕ್ತವೆನಿಸಿದೆ. ಪ್ರಭೇದಗಳ ಕುರಿತಾದ ಶೇಕಡವಾರು ಭಿನ್ನತೆಯು ಬಿತ್ತನೆ ಮಾಡುವ ದಿನಾಂಕ ಮತ್ತು ಸ್ಥಳಗಳೆರಡಕ್ಕೂ ಹೆಚ್ಚಿನ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಸ್ಪಷ್ಟವಾಗಿದೆ. ಪ್ರಭೇದ*ಪರಿಸರ ಪರಸ್ಪರ ಕ್ರಿಯೆಯ ಕುರಿತಾದ ಶೇಕಡಾವಾರು ಭಿನ್ನತೆಯು, ಶೇಕಡಾ ೫೦ ರಷ್ಟು ಹೂ ಬಿಡುವ ದಿನಗಳ ವಿಭಿನ್ನ ಬಿತ್ತನೆಯ ದಿನಾಂಕ ಮತ್ತು ಸ್ಥಳಗಳೆರಡರಲ್ಲೂ ಗಮನಾರ್ಹವಾಗಿದೆ. ಇದು ಪ್ರಭೇದಗಳಲ್ಲಿನ ಗಣನೀಯ ವ್ಯತ್ಯಾಸ ಮತ್ತು ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳ ಅಭಿವ್ಯಕ್ತಿಯಲ್ಲಿ, ಅವುಗಳ ಪರಸ್ಪರ ಪರಿಣಾಮವನ್ನು ಸೂಚಿಸುತ್ತದೆ. ಪ್ರಭೇದಗಳಾದ, ಎಲ್‌ಸಿಎ-೩೩೪, ಎಲ್‌ಸಿಎ-೪೨೪, ಮತ್ತು ಎಲ್‌ಸಿಎ-೩೩೬ ಗಳು ವಿಭಿನ್ನ ಬಿತ್ತನೆಯ ದಿನಾಂಕಗಳಿಗೆ ಮತ್ತು ಎಲ್‌ಸಿಎ-೩೩೬, ಎಲ್‌ಸಿಎ-೨೦೬ ಮತ್ತು ಎಲ್‌ಸಿಎ-೨೩೫ ಗಳು ವಿಭಿನ್ನ ಬಿತ್ತನೆಯ ಸ್ಥಳಗಳಲ್ಲಿ, ಹಸಿರುಕಾಯಿ ಇಳುವರಿಗಳಿಗೆ ಎಎಸ್‌ವಿ ಮತ್ತು ಎಸ್‌ಐಗಳು ಕಡಿಮೆ ಎಂದು ಅಂದಾಜಿಸಲ್ಪಟ್ಟು ವ್ಯಾಪಕ ಅಳವಡಿಕೆಯನ್ನು ಹೊಂದಿವೆ. ಪ್ರಭೇದಗಳಾದ ಎಲ್‌ಸಿಎ-೬೫೯ ಜುಲೈ ತಿಂಗಳಿನಲ್ಲಿ, ಎಲ್‌ಸಿಎ-೩೩೪ ಸೆಪ್ಟಂಬರ್ ತಿಂಗಳಲ್ಲಿ ಮತ್ತು ಎಲ್‌ಸಿಎ-೬೨೦ ಡಿಸೆಂಬರ ತಿಂಗಳುಗಳ ಬಿತ್ತನೆಗೆ ನಿರ್ದಿಷ್ಟವಾದ ಅಲವಡಿಕೆಯನ್ನು ಹೊಂದಿವೆ. ಪ್ರಭೇದಗಳಾದ ಯುಎಸ್-೩೪೧ ಜಿಕೆವಿಕೆಯಲ್ಲಿ, ಕೆಬಿಸಿಎಚ್-೧ ಶಿಡ್ಲಘಟ್ಟದಲ್ಲಿ ಮತ್ತು ಎಲ್‌ಸಿಎ-೬೨೫ ಶ್ರೀನಿವಾಸಪುರ ಸ್ಥಳಗಳಲ್ಲಿನ ಬಿತ್ತನೆಗೆ ನಿರ್ದಿಷ್ಟವಾಗಿ ಅಲವಡಿಕೆ ಹೊಂದಿವೆ.

ಆಗಸ್ಟ್, ೨೦೧೮

ಅನುವಂಶೀಯ ಮತ್ತು ಸಸ್ಯತಳಿ ಅಭಿವೃದ್ದಿ ಶಾಸ್ತ್ರ ವಿಭಾಗ | ಜಯಶ್ರೀ, ಎಂ. ಕೆ.
ಕೃಷಿ ವಿ.ವಿ., ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರು-೬೫ | (ಮುಖ್ಯ ಸಲಹೆಗಾರರು)

# Suitability of LAM chilli (*Capsicum annum* L.) lines for different dates of sowing in Bengaluru region*


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## Introduction

- Chilli (2n=24) is used as both green and red fruit is an indispensible spice cum condiment for Indian cuisine.
- India has an area of (0.79 m ha), production of (1.3 m t) and productivity of (1.7 t $ha^{-1}$). Karnataka has an area (0.09 m ha), production (0.11 m t), productivity (1.3 t $ha^{-1}$), however the productivity is lower than the national average (FAO, 2015)
- Cultivation of predominantly low yielding open pollinated varieties coupled with lack of stable high yielding hybrids are the chief causes for low productivity.
- Therefore, identification of LAM genotypes that can perform stable in different dates of sowing could enhance the productivity in Karnataka.
- Genotype × Environment (G × E) interaction, especially cross over type is the major cause for differential performance of genotypes across dates in target production environments.

## Objective

- To identify stable LAM genotypes across different dates of sowing in Bengaluru region.

## Material and methods

- The material for the study consisted of 17 genotypes and four checks *viz.,* KBCH-1, Arka Haritha, Arka Meghana and US 341.
- Seventeen genotypes were sown in two months interval July15, September 15 and November 15 and evaluated in two replicated randomized block design during 2017-18 at K block of Department of Genetics and Plant Breeding, GKVK, Bengaluru for the following dates.
- Each genotype was grown in a single row of 5m length consisting of 12 plants with a spacing of 0.40 m between plants within a row and 0.75m between row.


**Sampling and data collection**

- Five randomly sampled plants in each entry were chosen for recording of observations on green fruit yield $plant^{-1}$, plant height, red fruit yield $plant^{-1}$(cm), no. of fruits $plant^{-1}$, days to 50% flowering, first fruit maturity, fruit length(cm), fruit width (cm) and average fruit weight (g).

**Statistical Analysis**

- Genotype × dates of sowing interaction was detected using AMMI model (Gauch and Zobel, 1988).
- The patterns of suitability of genotypes across three dates of sowing was examined using Genotype + Genotype × Environment Biplot (Yan *et al.* 2000).
- AMMI stability value (ASV) and Yield Stability Index (YSI), the parameters of stability were estimated (Purchase *et al.* 2000).

## Results

- Mean squares attributable to genotype × dates of sowing were significant for green fruit yield $plant^{-1}$ (Table 1).
- The genotypes LCA 334, LCA 336 and LCA 424 were high yielding and stable across dates of sowing (Fig 1).
- The ranking of the genotypes based on ASV differed from that based on YSI (Table 2).
- The genotypes LCA 334, LCA 336, LCA 424 and LCA 206 in the order found stable across dates of sowing based on both ASV and YSI (Table 2).
- The genotypes LCA 639, LCA 333, LCA 620 and LCA 436 were located on the vertices on the polygon (Fig 2) .

Table 1 : AMMI ANOVA for green fruit yield $plant^{-1}$ (g) and number of fruits $plant^{-1}$

| Source of Variation | Degrees of freedom | Green fruit yield $plant^{-1}$ | |
|---|---|---|---|
| | | Mean Sum of Squares | % Variation |
| Genotypes (G) | 20 | 53441 | 67 |
| Dates of Sowing (DS) | 2 | 82913 | 10 |
| G X DS | 40 | 4312* | 10 |
| Block | 3 | 4677* | 1 |
| IPCA 1 | 21 | 5124** | 62.38 |
| IPCA 2 | 19 | 3415* | 37.61 |
| Pooled error (e) | 60 | 2867 | |

*Significance @ P= 0.05 **Significance @ P= 0.01

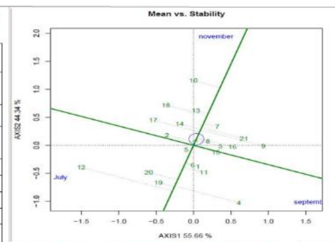


Fig. 1 : Average environment coordination (AEC) view of GGE bi-plot of green fruit yield $plant^{-1}$ for different dates of sowing.

Table 2 : Estimates of parameters of stability (ASV & YSI) of genotypes for different dates of sowing

| Sl. No | Genotype | Ranking based on green fruit yield and stability Indices | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | RANK | ASV | RANK | YSI | RANK |
| 1. | LCA 206 | 172.8 | 7 | 2.315321 | 4 | 11 | 5 |
| 2. | LCA 235 | 114 | 1 | 3.493617 | 10 | 11 | 4 |
| 3. | LCA 305 | 145.3 | 5 | 3.325987 | 8 | 13 | 6 |
| 4. | LCA 333 | 186 | 8 | 8.388003 | 19 | 27 | 13 |
| 5. | LCA 334 | 119.1 | 2 | 0.991954 | 1 | 3 | 1 |
| 6. | LCA 336 | 133.5 | 3 | 2.101317 | 3 | 6 | 2 |
| 7. | LCA 353 | 278 | 14 | 3.453605 | 9 | 23 | 11 |
| 8. | LCA 424 | 142.6 | 4 | 1.810705 | 2 | 6 | 3 |
| 9. | LCA 436 | 216.3 | 10 | 8.585162 | 20 | 30 | 14 |
| 10. | LCA 620 | 253.6 | 13 | 6.846652 | 18 | 31 | 16 |
| 11. | LCA 625 | 165.1 | 6 | 3.174958 | 7 | 13 | 7 |
| 12. | LCA 639 | 244.9 | 12 | 13.91039 | 21 | 33 | 18 |
| 13. | LCA 655 | 354.3 | 19 | 3.678798 | 11 | 30 | 15 |
| 14. | LCA 960 | 301.8 | 17 | 2.899902 | 6 | 23 | 12 |
| 15. | G3 | 297.4 | 16 | 2.867461 | 5 | 21 | 8 |
| 16. | G4 | 222.8 | 11 | 4.788684 | 12 | 23 | 10 |
| 17. | G5 | 196.7 | 9 | 5.720854 | 14 | 23 | 9 |
| 18. | KBCH- 1 | 448.1 | 21 | 5.551661 | 13 | 34 | 20 |
| 19. | Arka Meghana | 320.2 | 18 | 5.735572 | 15 | 33 | 19 |
| 20. | Arka Haritha | 292.2 | 15 | 6.09837 | 16 | 31 | 17 |
| 21. | US 341 | 406.9 | 20 | 6.212115 | 17 | 37 | 21 |

ASV - AMMI Stability Value ; YSI - Yield Stability Index

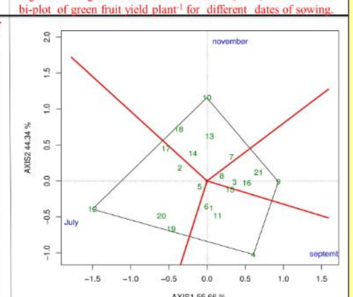


Fig. 2 : Polygon view of GGE bi-plot of green fruit yield $plant^{-1}$ for different dates of sowing

## Discussion

- Significant genotype × dates of sowing suggests differential performance of genotypes across different dates of sowing.
- Based on the estimates of ASV, YSI and GGE bi-plot, LCA 334 followed by LCA 336 and LCA 424 were stable across dates of sowing.
- LCA 639 is specifically suitable for July15 sowing, LCA 333 for September 15 sowing and LCA 620 for November 15 sowing.

## Summary

- The genotypes LCA 334, LCA336 and LCA 424 where stable and high yielder across dates of sowing.
- The identified lines for different dates of sowing can be used for raising the crop on such specified dates.


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## Advisory committee

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# ABBREVIATIONS

| | | |
|---|---|---|
| AMMI | – | Additive Main effect and Multiplicative Interaction |
| cm | – | centimeter |
| eg | – | exempli gratia |
| etc | – | Et cetera |
| g | – | grams |
| ht | – | height |
| LCA | – | Lam Chilli Accessions |
| m | – | meters |
| ql | – | quintal |
| SI | – | Stability index |
| t | – | tonnes |
| *viz*. | – | videlicet |

# I INTRODUCTION

Chilli (*Capsicum annuum* L.) is one of the most valuable commercial spice crop of India and is grown for domestic as well as for export markets. It is grown for its green fruits as vegetable and red fruit as a spice. It belongs to the family Solanaceae having diploid chromosome number of 2n=24. It is believed to have originated from South and Central America. The genus *Capsicum* includes twenty-seven species of which five species namely *Capsicum annuum*, *C. frutescens, C. Chinense, C. baccatum* and *C. pubescens* are domesticated and twenty-two are undomesticated species (Bosland, 1993).

Chilli is an indispensable spice cum condiment used in every Indian cuisine due to its pungency, taste, spice, appealing colour and flavor. Itis cultivated either for pungent fruited genotypes called chilli(Synonyms: hot pepper, American pepper, chile, azi, cayenne, paprika *etc*.) or non-pungent fruited genotypes called sweet pepper (Synonyms: Capsicum, paprika, bell pepper, Shimla mirch).Chilli is used as green as well as dry in the form of powder and known for nutritional value, aroma, texture, flavor, color and also of pharmaceutical value. It is virtually an essential item in the kitchen, fruits are good source of folic acid and rich source of vitamin A, vitamin C, vitamin E. It contains small quantities of protein, fats, carbohydrates and minerals like phosphorus, iron and calcium (Bosland and Votava, 2000). Capsaicin has anti-cancerous properties and it is also used to make drugs for heart diseases, balm and cosmetics dry chillis are usually more pungent than the green peppers due to the presence of the chemical capsaicin which is a mixture of various amides denoted as capsaicinoids (Hoffman *et al.*1983) and the bright red colour is due to the pigment capsanthin. The chilli fruit is digestive stimulant, prevents heart diseases and therapeutic for rheumatic troubles.

India is the only country rich in several varieties with diverse quality factors. World‘s hottest chilli ―Naga Jolokia‖ is cultivated in hilly terrains of Assam in a small town Tezpur, India (Anon., 2013). Chilli is an essential ingredient of Indian curry. Curry is characterized by attractive colour and titillating pungency. Both are contributed by chilli. In curry, chilli is used as a powder, paste, broken split or whole form. There are Indian pickles, particularly with tender mango in which chilli powder is added lavishly to form a thick paste with biting sensation at the end of curing. The Paprika, Byadgi chilli and similar low pungent coloured varieties are widely used for colour extraction. This colour is highly popular among food and beverage processors for its use as a natural colourant.

Chilliis the second largest product after black pepper in the international spice trade. Chilli is grown in India, China, Ethiopia, Hungary, Indonasia, Japan, Mexico and other countries. India is the major producer accounting for 26% of the worldwide production followed by China (Singh, 2007). Chilli is grown extensively in almost all states of the country both under rainfed and irrigated conditions, covering an area of 0.83 million ha with annual production of 1.87 m tones (Anon., 2017).

Karnataka is the second largest chilli growing state with an area of 0.102 m ha and production of about 0.103 million tons (Anon., 2017).North Karnataka has highest area planted with chilli compared to south Karnataka. Important chilli growing districts in Karnataka are Dharwad, Bellary, Koppal, Haveri and Raichur.

However, India is the leading producer, the average yield of chilli is actually low (1.6 t $ha^{-1}$ dry chilli) as compared to developed countries like USA, China, Taiwan, South Korea etc. where the average yield ranges from 3-4 t $ha^{-1}$. Low productivity in chilli is primarily attributed to lack of high yielding, pest and disease resistant varieties or hybrids. Only about 2.60 percent chilli area is covered by hybrids in India, while in the countries like Korea and Taiwan more than 90 percent area is under hybrids.

Phenotypic expression of the genotype is variable when grown in diverse environments. It is observed that G × E interaction is widely present and adds considerably to the non-realization of expected gain from selection (Comstock and Moll, 1963). Stable genotypes are predominantly of great importance in chilli growing regions of Karnataka, where the crop is grown in diverse environmental conditions. It is difficult to anticipate a genotype to be stable in its performance from one environment to another, because of varied magnitude and distribution of rainfall.

The yield levels of the present-day recommended cultivars *viz.*, Chikkaballapur, Byadagi, G-4 and PusaJwala are not adequate and are also not stable performers. Identification of promising Lam genotypes with stable yields is essential to boost the average yield levels of red chilli. Stability parameters along with the knowledge of inter-relationship of plant characters with dry fruit yield plays significant role for improvement of yield for which direct selection is not much effective. To have phenotypically stable genotypes and increase the present level of yield per unit area is utmost importance because the environmental conditions vary from year to year.

Wide adaption to the particular environment and stable performance of recommended genotypes is one of the main objectives in any breeding programme. The effect of genotypes and environment on expression of phenotype may not be always independent. The phenotypic response to change in environment is not same for all the genotypes and the consequences of variation exhibited in phenotype depend upon the prevailing environment as (Srividhya and Ponnuswami, 2010). Very often plant breeders encounter situations where in the rankings of varieties change from environment to environment and from year to year. The interaction between genetic and non-genetic component is termed as “Genotype x Environment interaction.”

Because of genotype-environment interaction the genotypes performing well under particular environment may or may not perform well under other environments. A genotype with high G × E interaction will have low stability and *vice–versa*. Hence, when developing high yielding variety or hybrid care should be taken to select for yield and those stable performances, some genotypes give stable and high yield and for particular environment and they do not perform similar in other environmental conditions. It is desirable to isolate stable genotypes even if they give less yield than the high yielding genotypes that are unstable so as to increase the overall yield. Thus, there is a necessary to identify promising genotypes with wide adaptability for productivity traits.

However, a number of improved genotypes are cultivated by the farmers yet the information on the stability of different genotypes for yield and quality parameters is lacking for the different agro-climatic conditions of State Karnataka. Predominantly growing of low yielding open pollinated varieties under rain fed coupled with frequent-drought spells are the main causes for low productivity levels in Karnataka *i.e.* 1.35 t $ha^{-1}$ than the National average *i.e.* 1.6 t $ha^{-1}$ (Hand book of Horticulture, 2014). Considering better buffering capacity under adverse conditions, development and deployment of hybrid cultivars is essential. Chilli production and productivity could be augmented with the use of high yielding cultivars including hybrids that carry resistance to biotic and abiotic stresses.

Since most of the economic characters in chilli are quantitative in nature and susceptible to environmental variations. Thus, it becomes essential to assess the stability of desirable genotypes having high yield, good pungency level, flavor, bright red medium sized fruits with thin pericarp, multiple disease resistance, few seeds, high dry matter content and oleoresin percentage. Multi environmental trials of genotypes offers an opportunity to plant breeders to identify the adaptability of a genotype to a particular environment and correspondingly stability of the genotypes over different environments. Although a number of varieties have been suggested for cultivation, yet the information on stability is lacking across agro-climate conditions of this region. With this background, the present survey on stability studies in chilli were undertaken to evaluate and screen the potential genotypes capable of giving stable performance over varied environment on the basis of stability parameters with the following objectives:

1. To detect and quantify Genotype × Environment interaction.
2. To identify LCA genotypes suitable across different dates and locations of sowing.

# II REVIEW OF LITERATURE

Stability is the assessment of the adaptability of a genotype. To rise the present level of yield per unit area phenotypically stable genotypes are of greatest importance since the environmental conditions differ from year to year. Roy *et al.* (1998), Scooch *et al.* (1981) worked on stability in chilli. Stable performance of varieties under different environments with concerns to all economic characters like yield and quality has a major impact in any breeding programme. In order to develop stable genotypes; data on various stability aspects and their mode of transmission would be very essential. The success in choosing the best adapted types depends upon the recombinational variability. This variability differs from crop to crop depending on the mating scheme. In latest years, tools like stability analysis have turned out to be important technology in chilli breeding. The literature on these aspects in chilli is reviewed and given asunder the following head.

## 2.1 To detect and quantify genotype × environment interaction and identify LCA varieties suitable across different dates and locations of sowing.

Call (1980) in a study tested five parents and their $F_1$ for fruit number, marketable percentage, percentage dry weight, dry fruit yield, colour length and width. He observed that the effects of year × locality were significant. M75 was best parent and two of the M75 progenies were the best hybrids (M75 × 456 and M75 × M4) across locations.

Patil (1990) in a study including 8 parents and 28 $F_1$'sforadaptability across four environments were found significant G × E interaction for fruits plant$^{-1}$, plant height and fruit yield plant$^{-1}$, G × E (Linear) interaction when tested against pooled deviation, it revealed non-significant genetic differences among the varieties for their regression on environmental indices.

Stoffella *et al.* (1995) evaluated bell pepper (*Capsicum annuum* L.) cultivars for phenotypic stability of marketable fruit yield and fruit size. Observed super-sweet 860, whopper improved and ranger varieties were stable for mean marketable fruit weights and fruit size.

Sharma and Peshin (1995) evaluated the influence of planting dates at weekly interval from 22$^{nd}$ April to 27$^{th}$May on morphological characters related to seed production of capsicum and reported that the plant growth was best at the earliest transplanted crop (22$^{nd}$April).

Zewdie and Bosland (1996) studied highly significant genotype-environment interaction for fruit yield. The cultivars shown varied level of interaction effect and response relative to each other in various environments. Significant G × E interaction was also observed for fruit yield and plant height, showing the stability of parents and $F_1$ successively for three years.

Zewdiel and Poulos (2000) studied genotype, environment and genotype-by-environment interaction for capsaicinoids in chilli. Double haploid lines, an $F_1$ hybrid, and an open-pollinated cultivar estimated significant differences were observed among the genotypes and among genotype-by-environment interactions over the environments. Among the genotypes in an environment, the within-genotype variances were also significantly different. The double haploid line, HDA 207, had low within-genotype variance for individual and total capsaicinoids. While for HDA 270, the genotype-by-environment interaction was negligible for individual and total capsaicinoids, indicating stability across environments.

Lohithaswa *et al.* (2001) evaluated 55 chilli genotypes (10 parents and45 hybrid) for the effect of trace environments in Bengaluru region. Significant G × E interaction was observed for characters like earliness, fruit length, fruit diameter, average fruit weight and number of fruits plant$^{-1}$ has been revealed up on analysis of variance. The variance for the linear component of G × E interaction was non-significant for all these traits whereas the non-linear component of G × E interaction was significant for earliness, fruit length, fruit diameter, average fruit weight and number of fruits plant$^{-1}$.

Chowdhury *et al.* (2001) studied 13chilli genotypes *viz*., Gossaigaon, Bijni, Goalpara, Dhupdhara, Chamata, Rangia, Mangaldoy, Bijoynagar, Borpeta Road, Kharupetia, Laharghat, Dharapur and Baihata inassam condition to determine the G ×E interaction and stability parameters for fruit length, fruit circumference, plant height and number of primary branches plant$^{-1}$. The pooled analysis of variance showed significant differences among the genotypes for plant height and none of the genotypes showed average stability for all the growth characters under study.

Upadhay *et al.* (2001) evaluated 30 tomato genotypes in 4 environments, to identify the stability performance of tomato genotypes under varied environmental condition. Significant variance due to GE interaction was witnessed for all the traits except for number of marketable fruits per plant and fruit yield per plant.

Prasad *et al.* (2002) experimentally studied 45 inbred lines brinjal in three different environments for a period of three successive years *i.e*. 1993-94, 1994-95 and 1995-96 at Hessarghatta, Bangalore. They observed significant differences between all the genotypes tested for characters *viz.*, yieldplant$^{-1}$, yieldplot$^{-1}$, days to flowering, number of branches, plant spread, fruit weight, fruit length, fruit breadth, fruit firmness and plant height in all the three environments. The joint regression analysis of variance for different characters shown that the components genotype × environment interaction was highly significant for all the characters. The interpretation of stability analysis shown that the inbred line CH303 (xi=1.71kg, bi=1.60 and s2di=.01) revealed supremacy in yield and was stable for favourable environments followed by CH309, CH267 and CH250.

Dodiya and Joshi (2003) experimentally studied 86 genotypes of maize for genotype × environment interaction and stability parameters with respect to yield and maturity over three different environments. The results revealed significant G × E interaction for days to 50 percent tasseling and grain yield.

Reddy and Sadashiva (2003) evaluated chilli cultivars from Sri Lanka (MI-2 and KA-2). ArkaLohit served as the control. The cultivars differed significantly for green fruit yield per plot, fruit length, fruit width and days to first fruit harvest in different environments. G x E interaction was not significant for any of the characters studied. ArkaLohit showed superiority in yield (382.5 kg/plot), followed by MI-2 (343.8 kg/plot) and KA-2 (291.9 kg/plot) in 2000. Although MI-2 and KA-2 were determinate and highly suitable for fresh green fruit yield and KA-2 was highly suitable for favourable environments.

Wani *et al*. (2003) experimentally studied 30 hot pepper genotypes to identify stable performing and promising genotypes for both yield and quality characters. Significant G × E (Linear) component was found for fruit yield and capsaicin, with the linear component having a larger magnitude in most of the characters compared to corresponding non-linear component. The magnitude of linear components and the corresponding nonlinear components for fruit yield were 76.5 and 50.2 respectively. Genotypes SC106 and SC-114 besides having superior ascorbic acid content and yield potential, fruit colour and fruit pungency also exhibited stable across environments.

Nehru *et al.* (2003) in a study evaluated 16chilli genotypes for three years. Observed genetic advance and heritability values were high, while GCV values were moderate and stable over years for fruit yield. The analysis of variance 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.

Dhaduk *et al*. (2004) studied phenotypic stability analysis in nine varieties of tomato (*Lycopersicon esculentum* mill.) using randomized block design with three replications during *Rabi* season. The pooled analysis of variance indicated significant differences among the genotypes and G × E interactions for fruit yield, plant height, fruit girth and ten-fruit weight. Thus the results 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.

Arun and Singh (2004) evaluated seven parents and their 21 single crosses along with two standard checks for estimating the stability parameters by raising the crop at four different environments in maize. The stability analysis exhibited highly significant variation for genotypes, environments, G × E interactions and pooled deviation for most of the characters.

Mohanty and Prusti (2005) experimentally studied the genotypes BR Red, Sindhur, K 2, Utkal Rashmi, G 4, CO 2, X 235 and Pusa Jwala as a field experiment in Orissa, India, during the 1998 to 2000 *kharif* seasons and evaluated based on plant height, number of branches, fruits plant$^{-1}$, days to first harvest, fruit length and weight of ten green fruits. G 4 was found to be the earliest cultivar taking 103.1days to first harvest X 235 was recorded maximum number of fruits plant$^{-1}$ (243.5). The highest green fruit yield (146.4 qha$^{-1}$) was produced by X 235 followed by G 4 (135.1 qha$^{-1}$). The higher yield was the consequence of higher number of fruits plant$^{-1}$ and earliness. X 235 and G 4 were identified as best performing cultivars and recommended for commercial cultivation.

Jinsuk *et al*. (2005) peppers (*Capsicum spp*.) were grown for phytochemical analyses at three different locations including a greenhouse at college station and field plots at Uvalde and Weslaco, Texas. Immature fruit generally contained lower levels of lutein and xeaxanthin than mature and colored fruit. These differences were not always statistically significant. Greenhouse-grown peppers at College Station contained more carotenoids than the field-grown peppers in Uvalde and Weslaco, but there were no significant differences among locations for flavonoid concentrations.

Chaurasia *et al.* (2005) studied the stability analysis for growth and yield attributes in 15 brinjal genotypes for five years from 1993-94 to 1997-98. The study reported that Genotype × Environment (G x E) interactions were significant with respect to plant height, fruit length, weight diameter, size and number of fruit plant$^{-1}$indicating the importance of linear as well as own linear components. The overall performance of genotypes KS-331, KS-224 and H-7 were found promising with higher yield and also stable performance for other characters. However, the highest yield was recorded with KS-224 followed by KS-331 and H-7.

Suneetha *et al*. (2006) studied the stability of ten elite homozygous lines and 45hybrids derived from the 10 ×10 diallel lines in brinjal for fruit yield, quality and physiological characters under three different cropping systems. Based on the *per se* performance the stable brinjal hybrids PLR 1 x JBPR 1, Morvi 4-2 x JBPR 1 and Surati Ravaiya x JBPR 1 were found widely adaptable and suitable for wide cultivation during all theseasons studied. KS 224 x Bombay Gulabi, KS 224 × JBPR 1, AB 98-10 × JBPR 1, AB 98-13 **×** JBPR 1 and Morvi 4-2 × Surati Ravaiya were identified as most suitable for cultivation during rainy season. While hybrids, AB 98-10 ×Morvi 4-2 performed better under late summer cultivation.

Shobha *et al.* (2006) experimentally evaluated 60 $F_1$ hybrids and their 11 parents in randomized block design to study stability of hybrids over diverse environments for yield. Based on the stability analysis, the genotypes are clustered as group ‘A’ (Suitable for both normal and stressed environment), group ‘B’ (Suitable for normal environment only) and group ‘C’ (suitable for stress environment only).

Smitha and Basavaraja (2006) conducted study on 40 chilli genotypes for variability, heritability, genetic advance and correlation studies under rainfed condition. Analysis of variance showed significant differences among the genotypes with respect to both quantitative and qualitative characters. Whereas the yield varied from 2.77 $tha^{-1}$to 18.05 $tha^{-1}$ with a general mean of 8.44 $tha^{-1}$, among the 40 genotypes of chilli under study.

Prasanna *et al.* (2007) conducted an experiment to identify the 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 percent of flowering and 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.

Kikuchi *et al.* (2008) studied the stability of newly selected parthenocarpic eggplant lines at Kusawa, Japan for fruit set in different seasons with diverse in temperatures *i.e.* autumn-winter, early summer and winter farming in growth chambers under natural light and observed AE-P03 and AE-P01 to be the best lines under autumn-winter cultivation.

Tembhurne *et al*. (2008) in a study evaluated 11 elite advanced lines obtained from Chilli Research Station, Devihosur along with KDC 1, Byadgi Dabbi and Byadgi Kaddi as checks. Among the 11 advanced lines evaluated, the mean (2004 and 2005) dry chilli yield per hectare was highest in 9626-6-1(12.75 $qha^{-1}$) followed by HCS G1 (12.64 $q^{-1}$). During 2004, HCS G1 recorded significantly highest yield (18.52 $qha^{-1}$) due to fruit width (1.36 cm), highest number of fruits $plant^{-1}$ (144.2), and highest yield $plant^{-1}$ (100.2 g). The correlation studies indicated that the yield was positively related with most of the traits but its magnitude was high with number of fruits per $plant^{-1}$ (0.8026) and fruit diameter (0.64).

Mulema *et al.* (2008) studied the yield stability analysis for nine promising late blight resistant potato selections of which seven selections from population B, two from population A (qualitative resistance) and three control cultivars under three different cropping seasons with four environment conditions. The AMMI statistical model showed that, the genotypes 392618.3 (B5) and 392127.3 (B6) (high yield) and; 392618.3 (B1) and 391049.3 (B2) performed better in irrespective of the cropping and environmental conditions. However, the genotype selection 392127.256 (B7) recorded lowest yield and had negligible interactions with the environments. Across environments, the clones 381471.18 (A2), 387121.4 (A1) and cultivar Victoria had high average yield,but environmental effects results in below average yield.

Sandeep *et al.*(2008) studied 37 genotypes for their growth and yield potential to identify a superior variety for commercial cultivation under Ghataprabha Left Bank Command area conditions in North Karnataka. Maximum plant height was recorded in DCS-104 (75.48 cm), maximum plant diameter was recorded in DCA-127 (1.40 cm), maximum crown size was recorded in DCA-104 (59.14 cm). Genotype DCA-101 emerged as superior high yielding variety with dry chilli yield of 37.79 $qha^{-1}$ closely followed by DCA-104 (35.7 $qha^{-1}$) and highest ascorbic acid content (134.6 $mg100^{-1}$ g) was found in DCA-127.

Datta and Dey (2009) experimentally evaluated the stability of eight chilli genotypes for yield and yield parameters under open based agroforestry system. The genotype and environment interactions for fruit length, fruit diameter, plant height and yield were found to be significant and indicate the differential response of genotypes under different environments. The linear and nonlinear components of genotype - environments were recorded in genotype CA-5 for plant height, fruit length and yield hence suggested for cultivation under favourable (open) conditions due to its stability. Though, genotype Bhaghyalakshmi was stable in open and agroforestry condition and CA-12 was specifically adapted under agroforestry condition.

Venugopal and Madhavi Reddy (2010) studied the stability analysis for fruit yield and its attributing traits in 13 chilli varieties over three years (2004-06). Stability models(with R2 as 75.4 to97.5 %) 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 assessed least equivalence values as compared to others. However, KA-2 and PANT-5 were identified as lines suitable for favorable environment and LCA 206 was classified as above average varieties which will respond well to a poor environment.

Muhamad *et al*. (2011) observed stability of seven hybrid chilli pepper genotypes, the study used additive main effect multiplicative interaction (AMMI) methods and yield stability analysis. The design was randomized complete block design with three replications as blocks using the genotypes of IPB CH1, IPB CH5, IPB CH25, IPB CH2, IPB CH3, IPB CH28, IPB CH50 and these genotypes were planted at six different locations IPB CH25 and IPB CH28 being the most stable cultivars. Based on experimentation, the AMMI2 model was able to explain 85.51% of the interaction influenced variation.

Srividhya and Ponnuswami (2011) studied the genotype × environment interaction of five parents and four $F_1$ hybrids along with checks at four environments for paprika fruit yield with Additive Main Effects and Multiplicative Interaction (AMMI) model. The combined analysis of variance of AMMI showed that the environment, genotype and G × E interaction were highly significant, suggesting a broad range of genotypic diversity and environmental variation. Three parents *viz*., Bydagi – kaddi, Simla Paprika and KTPL – 18 were found to be stable across environments for number of fruits per plant. The parent Arka Abir was found to be stable yielder across environments. The hybrid Arka Abir × Bydagi – kaddi was identified as having general adaptability across environments.

Mehta *et al.* (2011) studied the phenotypic stability in brinjal for fruit yield and its components under three different environments. The results indicated that, genotypeIBWl-2007-1 was found to be most stable genotype under irrigated condition. The regression coefficient not deviated from unity and non-significant deviation from regression. Where as a local genotypes were suitable for fruit yield under low yielding environment.

Samnotra *et al*. (2011) reported on stability analysis of 25chilli genotypes for yield and its components at three environments, Karllah, Poonch and Chatha during *Kharif*. Higher genotype x environment interactions were recorded for days taken to first picking, number of fruits per plant, number of seeds per fruit and yieldplant$^{-1}$ and indicating the linear as well as non- linear components were important. The overall performance of genotypes over environments, were observed in hybrid CCH-3and found to be promising stable performance for yield and other characters.

Saravaiya *et al.* (2011) evaluated the various genotypes of chilli under south Gujarat conditions at Regional Horticultural Research Station of Navsari during *Rabi* season of 2009. A randomized block design was used with three replications, which comprised of 11 genotypes of chilli. Significant differences were observed among the genotypes for growth and yield parameters. The genotype GVC-111 was found significantly superior than all the genotypes under study, recorded the green fruit yield of 13.95 t ha$^{-1}$. The next best genotypes were Chivar-2, Chivar-8 and Chivar-3.

Tulsi Gurung *et al*. (2012) studied the stability analysis of yield and capsaicinoids content in six cultivars of chilli (*Capsicum spp*.) A large proportion (46.1 %) of variation on yield was attributed to environments, for total capsaicinoid contents, genotype effect accounted for 74.2 % of variation. Cultivar Dallaykhorsaney had high capsaicin, dihydrocapsaicin and total capsaicinoids but was very sensitive to environmental changes, andtherefore good for specific adaptation. Cultivar KKU-P-11003 with total capsaicinoid contents of 78,721 Scoville heat unit was stable for dry fruit yield, capsaicin, dihydrocapsaicin, and total capsaicinoids with regression coefficients b = 1.06, 1.06, 0.78, and0.96 respectively. Therefore, KKU-P-11003 was considered suitable for diverse environments.

Abu *et al.* (2013) assessed the correlation among quantitative characters and to determine stable pepper genotypes for fresh fruit yield in derived savanna ecology of Nigeria. Using a randomized complete block design of three replications ten genotypes of *C. annuum* were evaluated for three years under rainfed conditions. This study shows stability of these genotypes to variations in the random environment across years. Selecting stable genotypes and traits with high correlation between themselves and with fresh fruit yield would withstand high yield in *C. annuum* genotypes particularly as yield components are complementary in action.

Tembhurne and Rao (2013) proposed stability analysis in 20 cytoplasmic genetic male sterility (CGMS) based chilli $F_1$ hybrids under three different environments. Considering all the stability parameters, JCH-47, BCH-24 and BVC-37exhibited wider stability for dry fruit yield plant$^{-1}$, JCH-01 had stability for favourable environment and JCH-05, JCH-14, JCH-23, JCH-24, JCH-54 and RCH-23 showed below average stability. Path analysis indicated that the number of fruits plant$^{-1}$ and fresh fruit weight fruit-1 were the two factors that exerted the greatest influence both directly and indirectly upon the dry fruit yield. These two traits were the most important components that involved dry fruit yield plant$^{-1}$.

Sharma *et al.* (2014) studied 20chilligenotypes and evaluated for stability analysis for quality traits under four diverse environments with two different dates of planting and each date of planting had two doses of N-fertilizer during April, 2005. Wide genotypic variability among the genotypes was observed with significant mean squares for quality traits. The environmental component was non-significant for dry matter content and significant for colouring matter.

Amit *et al.* (2014) experimentally studied 23 genotypes of chilli and observed wide range of variation in mean of average yield per hectare. Green fruits yield per hectare was highest in the genotype 'CH-1' (25.00 $tha^{-1}$) followed by 'LCA-357' (24.00 $tha^{-1}$) and minimum yield was observed in the genotype 'AG-08' (7.66 $tha^{-1}$).Significant variations were observed for all the characters studied except for days to flowering and crop duration [mature (green) as well as dry (red)]. High Phenotypic Coefficient Variation (PCV) and Genotypic Coefficient Variation (GCV) were recorded for number of fruits $plant^{-1}$, fruit weight and dry (red) yield. Fruit yield (green and red) $plant^{-1}$ was positively and significantly correlated with number of fruits $plant^{-1}$ and fruit length. It revealed that the characters *viz.*, plant height, fruit length, number of fruits $plant^{-1}$, fruit weight and fruit yield (green & red) are the most important traits for genetic improvement of chilli.

Muhamad *et al*. (2014) studied 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, theresults could be classified into 2 groups, according to the agronomic and biological stabilities.

Vijaya *et al.* (2014) evaluated 24chilli genotypes for different growth and yield parameters. The genotype 'Chikballapur Local' was found to have maximum plant height (118.6 cm) and plant spread (0.481 m) while, genotype 'Sankeshwar' recorded higher number of primary branches $plant^{-1}$ (7.47) and maximum fruit length (14.61 cm). Genotype 'Byadgi Dabbi' registered maximum fruit diameter (1.60 cm), pericarp weight (0.80 g), stalk weight (0.14 g) and number of seeds $fruit^{-1}$ (98.42). The higher number of fruits $plant^{-1}$ (186.30) and dry fruit yield (97.33 g $plant^{-1}$) were recorded in the genotype 'Sankeshwar' followed by genotype LCA-206.

Stommel *et al*. (2015) studied the impact of production environments and stability of diverse genotypes across environments for brinjal fruit phenolic acid content. Ten *Solanum melongena* accessions containing of five $F_1$ hybrid cultivars, two land race accessions and three open pollinated cultivars, one accession each of *S. macrocarpon* and *S. aethiopicum,* were grown at two locations under greenhouse and open field environments. There existed significant differences between accessions for aggregate phenolic acid content. There were no significant differences noticed among the environments for any of the variables. Stability study demonstrated widespread variability for phenolic acid content across environments. Stability of the principal caffeoylquinic acid esters class positively influenced stability of total phenolic acid content for some but not all genotypes.

Datta and Jana (2015) were evaluated 15 chilli genotypes for studying their stability in the *rabi* (winter) season in two years under five fertility levels (0, 50, 100, 150) and 200 % of RDF 100:50:50 Kg NPK $ha^{-1}$). Pooled analysis of variance revealed highest fresh green fruit yield was also recorded in Ulka 686 (15.98 $tha^{-1}$) 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. 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.

Cabral *et al.* (2017) evaluated new pepper hybrids in two environments; Caceres, MT, and Campos dos Goytacazes, RJ, Brazil. Nine experimental hybrids of *C. baccatum* var. *pendulum* were tested and trials were performed in a randomized block design, with three replications and eight plants per plot. Seven of the eight traits have differed significantly due to environment variation. Furthermore, genotype and environment interaction was highly significant for number of fruit $plant^{-1}$, mean fruit mass $plant^{-1}$, fruit length, and fruit diameter.

# III MATERIAL AND METHODS

The material used and the techniques adopted for collection, analysis and interpretation of data are described in this chapter under the following headings.

## 3.1 To explore performance stability patterns of Lam chilli varieties released from Lam research station Guntur across three dates of sowing and three locations

### 3.1.1 Experimental material and methods

The material for the study consisted of 17 Lam chilli genotypes (Table 1) and four commercial checks *viz*., KBCH-1, Arka Haritha, Arka Meghana and US 341. These genotypes were evaluated during July, September and November 2017 for three dates of sowing at experimental plots of Department of Genetics and Plant Breeding (GPB), University of Agricultural Sciences (UAS), Gandhi Krishi Vignana Kendra (GKVK), Bengaluru. During November sowing the genotypes were taken up for sowing at three environments *viz.,* (i) Experimental plots of Department of Genetics and Plant Breeding (GPB), University of Agricultural Sciences (UAS), Gandhi Krishi Vignana Kendra (GKVK), Bengaluru, (ii) Farmers field at Srinivasapura, Kolar District and (iii) Farmers field at Siddalaghatta, Chikkaballapur District. The experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications. Each genotype was grown in a single row of five meter length consisting of 12 plants per row with a spacing of 0.40 m between plants within a row and 0.75 meter between rows. All the recommended package of practices was followed to raise a good crop (Plate 1 and 2).

### 3.1.2 Observations recorded for growth and fruit yield attributes

Five representative plants in each genotype were tagged at random from each replication for recording of observations on the following traits.

**3.1.2.1 Days to 50 per cent flowering:** The number of days taken for 50 *per cent* of the plants to flower from the day of sowing in each genotype and replication was recorded.

**Table 1. List of Lam chilli genotypes and checks used for experiment**

| Sl. No. | Genotype | Source |
|---|---|---|
| 1. | LCA 206 | Lam chilly research station, Guntur |
| 2. | LCA 235 | Lam chilly research station, Guntur |
| 3. | LCA 305 | Lam chilly research station, Guntur |
| 4. | LCA 333 | Lam chilly research station, Guntur |
| 5. | LCA 334 | Lam chilly research station, Guntur |
| 6. | LCA 336 | Lam chilly research station, Guntur |
| 7. | LCA 353 | Lam chilly research station, Guntur |
| 8. | LCA 424 | Lam chilly research station, Guntur |
| 9. | LCA 436 | Lam chilly research station, Guntur |
| 10. | LCA 620 | Lam chilly research station, Guntur |
| 11. | LCA 625 | Lam chilly research station, Guntur |
| 12. | LCA 639 | Lam chilly research station, Guntur |
| 13. | LCA 655 | Lam chilly research station, Guntur |
| 14. | LCA 960 | Lam chilly research station, Guntur |
| 15. | G3 | Lam chilly research station, Guntur |
| 16. | G4 | Lam chilly research station, Guntur |
| 17. | G5 | Lam chilly research station, Guntur |
| | **Checks** | |
| 18. | KBCH- 1 | UAS, GKVK, Bengaluru |
| 19. | Arka Haritha | IIHR, Bengaluru |
| 20. | Arka Meghana | IIHR, Bengaluru |
| 21. | US 341 | $F_1$ hybrid private |


**JULY**

**SEPTEMBER**

**NOVEMBER**

**Plate 1: General view of experimental crop during July, September and November sowing at K Block, GKVK during 2017-18**

**SIDDALAGHATTA**

**SRINIVASPURA**

**Plate 2: General view of experimental crop at Siddalghatta and Srinivasapura during 2017-18**

**3.1.2.1 Days to first fruit maturity**: The number of days taken from the date of sowing to formation of first red fruit in each genotype and replication was recorded.

**3.1.2.2 Plant height (cm):** The height was be measured from ground level to the tip of the plant at harvesting stage and expressed in centimeters.

**3.1.2.3 Fruit plant$^{-1}$:** Total number of green fruits over all pickings was counted and expressed on per plant basis.

**3.1.2.4 Fruit length (cm):** The length of ten fruits was measured from the tip to the base excluding the pedicel and expressed as mean of ten fruits in centimeters.

**3.1.2.5 Fruit width (cm):** Width of ten randomly chosen fruits from each Lam chilli variety was measured at their maximum width and expressed as mean centimeters per fruit.

**3.1.2.6 Average fruit weight (g):** Ten fruits chosen at random from each Lam chilli variety was weighed to the nearest decimal and expressed as mean weight in grams per fruit.

**3.1.2.7 Green fruit yield plant$^{-1}$:**Green fruits of all pickings from five randomly labelled plants was weighed and the mean was expressed in grams plant$^{-1}$.

**3.1.2.8 Red fruit yield plant$^{-1}$:** Weight of red fruits over all pickings from other five labelled plants wasbe recorded and the mean is expressed in grams plant$^{-1}$.

### 3.1.3 Analysis of Variance (ANOVA)

The mean data on selected productive traits over 3 environments was subjected to pooled analysis of variance. Total variation of varieties for selected productivity traits was partitioned into genotypes, environments and genotype × environment interaction (Table 2). Further the data was subjected to stability analysis as per the AMMI model.

### 3.1.4 Statistical analysis

**Detection of genotype × environment interaction (GEI)**

**Pooled and Additive Main Effect and Multiplicative Interaction (AMMI) ANOVA:**

The quantitative traits means of each genotype evaluated across three environment were subjected to pooled ANOVA to detect genotype and environment interaction. The structure of pooled ANOVA is described in (Table 2).

**Table 2: Structure of pooled ANOVA**

| Sources of variation | Degrees of freedom | MSS | Expected MSS |
|---|---|---|---|
| Replication (R) | R-1 | RMSS | - |
| Environment(E) | E-1 | EMSS | - |
| Genotypes (G) | G - 1 | GMSS | $\sigma^2_e + R\sigma^2_E + R\sigma^2_{GE} + R\sigma^2_G$ |
| G × E | (G – 1) (E– 1) | GEMSS | $\sigma^2_e + R\sigma^2_{GL}$ |
| Error (e) | (GE -1) | eMSS | $\sigma^2 e$ |

The quantitative traits means of each genotype were also subjected to ANOVA following additive main effects and multiplicative interaction (AMMI) model (Gauch and Zobel, 1988) to detect and characterize the patterns of genotype and environment interaction. The additive main effects of genotypes and environment were fitted by univariate ANOVA followed by fitting genotype and environment interaction by principal component (PC) analysis by the following AMMI II model (Table 3).

**Table 3: Structure of AMMI ANOVA**

| Source of variation | Degrees of Freedom | Mean sum of squares | 'F' Ratio | % Variation |
|---|---|---|---|---|
| Genotype (G) | G-1 | GMSS | GMSS/eMSS | (GSS/TSS)*100 |
| Environment (E) | E -1 | EMSS | EMSS/eMSS | (ESS/TSS)*100 |
| G × E | (G-1)(E -1) | GEMSS | GEMSS/eMSS | (GESS/TSS)*100 |
| IPC 1 | G + E – 1-2n | IPCA1MSS | IPCA1MSS/eMSS | (IPCA1SS/GESS)*100 |
| IPC 2 | G+ E – 1-2n | IPCA2MSS | IPCA2MSS/eMSS | (IPCA2SS/GESS)*100 |
| Residual | (G-1)(E-1)-{df PCA1 + df PCA2 + …… + PCAn} | RMSS | RMSS/eMSS | RSS |
| Error | - | eMSS | eMSS | eSS |

$$Y_{ij} = \mu + g_i + e_j + \sum_{k=1}^{n} \lambda_k \alpha_{ik} \gamma_{jk} + \varepsilon_{ij}$$

Where,

$Y_{ij}$ is the quantitative trait value of $i^{th}$ genotype in the $j^{th}$ Environment, μ is the experimental quantitative trait mean value, $g_i$ and ej are the $i^{th}$ genotype and $j^{th}$ environment mean deviation from experimental quantitative trait mean values respectively. $\lambda_k$ is the square root of eigen value of the $k^{th}$ IPC axis, $\alpha_{ik}$ and $\gamma_{jk}$ are the interaction IPC scores for $k^{th}$ IPC of the $i^{th}$ genotype and $j^{th}$ Environment, respectively and $\varepsilon_{ij}$ is the residual. The parameters of AMMI II model were estimated using least square principle implemented by GENSAT software, version 12.

Visual and objective criteria were used to interpret GEI patterns of a genotype and their specific wide adaptation. The visual criterion was based on Genotype + Genotype × Environment (GGE) bi-plot (Yan *et al.,* 2000). Objective criterion was based on the estimates of AMMI stability value (ASV) (Purchase *et al*., 2000) and Stability Index (SI) (Farshadfar, 2011). These two criteria are described in the following sections

### 3.1.5 GGE bi-plot analysis

GGE bi-plot methodology, which is a combination of AMMI bi-plot and GGE concepts (Yan *et al.,* 2000) was used for visual interpretation of patterns of GI. The GGE bi-plot is based on the following model.

$$\overline{Y_{ij}} - \overline{Y_j} = \lambda_1 \alpha_{i1} \gamma_{j2} + \lambda_2 \alpha_{i2} \gamma_{j2} + \varepsilon_{ij}$$

Where,

$Y_{ij}$= quantitative trait means of $i^{th}$ genotype in the $j^{th}$ environment;$\overline{Yj}$=quantitative traits means of all the genotypes in the $j^{th}$ environment; $\lambda_1$ and $\lambda_2$ are the square root of eigen values of first and second genotype-by-environment interaction principal components (IPC) axes, respectively; $\alpha_{i1}$ and $\alpha_{i2}$ are the scores of the first and second IPC, respectively for the $i^{th}$ genotype, $\gamma_{i1}$ and $\gamma_{i2}$ are the first and second IPCs respectively for $i^{th}$ environment.

### 3.1.6 Structure of AMMI ANOVA

There are numerous ways to use a GGE bi-plot. However, four views of the GGE bi-plot are most relevant (Segherloo *et al*., 2010). These are (1) Polygon view of GGE bi-plot based on symmetrical scaling for determining 'which-won-where' pattern of genotypes with test environments, (2) Discriminating and representativeness of test environments view of GGE bi-plot, (3) Average-environment coordination (AEC) view of GGE bi-plot based on genotype-focused scaling for raking of the test genotypes relative to ideal genotype; the ideal genotype is the one whose point is located in the center of concentric circles in the GGE bi-plot and (4) AEC view of bi-plot based on environment-focused scaling for interpreting mean performance of the genotypes *vs.* their adaptability patterns.

**3.1.7 Polygon view:** IPC1 scores were plotted against their IPC 2 scores to visually identify accessions with specific/wide adaptation and similarity between accessions and environments. The genotypes/accessions that are more similar to each other in terms of their trait expression are more close to each other in the GGE bi-plot than those that are less similar. The genotypes located near the origin of IPC1 *vs* IPC 2 bi-plot are those with wide adaptation across environments than those located far from the origin (Crossa*etal.*,1990). The genotypes that are farther from bi-plot origin are connected with straight lines so that a polygon is formed with all other genotypes contained within the polygon. A set of straight lines were drawn from the bi-plot origin perpendicular to each side of the polygon. The perpendicular lines to the polygon sides divide the polygon into sectors, each having its own winning genotype which is the vertex genotype for that sector (Yan *et al*. 2000). The areas between the two perpendicular axes cutting the polygon side are considered as mega environments. These mega environments in the present study are regarded as mega Environments. The vertex genotype for each sector is the one which is the best performer in the Environments falling within that sector and mega environment.

### 3.1.8 AMMI stability value (ASV) and Stability Index (SI) estimation

To facilitate an objective method of identifying genotypes with specific/wide adaptation across environments, the AMMI stability value (ASV) was estimated (Purchase *etal*., 2000).

$$ASV = \sqrt{\left[\frac{SSIPC1}{SSIPC2}\right](IPC1\ score)^2 + (IPC2\ score)^2}$$

Where,

SSIPC 1 and SSIPC 2 are sum of squares attributable to first two IPC's. Conceptually, ASV is the distance from zero in a two dimensional scatter diagram of IPCA 1 *vs* IPCA 2 scores (Purchase *et al*., 2000). Since the IPCA 1 score generally contributes proportionately more to GEI, it is weighted by the proportional difference between IPCA 1 and IPCA 2 scores in order to compensate for the relative contribution of IPCA 1 and IPCA 2 scores to total GEI sum of squares. Higher magnitude of estimates of ASV indicates specific adaptation, while lower magnitude of ASV indicates wide adaptation (Purchase *et al*., 2000). To facilitate simultaneous selection of genotypes for different quantitative traits and adaptability, stability (adaptability in the present study) index (SI) which incorporates both quantitative traits mean and stability in a single criterion (Farshadfar, 2011) was estimated as SI= RASV+ RY where, RASV is rank of the genotypes based on ASV and RY is the rank of genotype based on quantitative trait mean over three environments. The genotypes with low SI were regarded as those with high trait expression and wide adaptation.

# IV RESULTS AND DICSUSSION

The results of the present investigation are presented under the following heads.

## 4.1 Exploring performance adaptability patterns of chilli varieties released by Lam research station Guntur across environments for three dates and three locations

### 4.1.1 Detection of GEI

#### 4.1.1.1 Pooled ANOVA

The total variation was partitioned into sources attributable to genotypes, location, genotype × location interaction (GLI) and pooled error. Mean squares attributable to genotypes, location and GLI were significant for all the productivity traits (Table 4a and 4b) (Noman *et al.*, 2015).

#### 4.1.1.2 AMMI ANOVA

The per cent variance attributable to GEI towards total variability of the genotypes was higher than that attributable to main effects of genotypes and dates of sowing, genotypes and locations for days to fifty percent flowering. The main effects of genotypes contributed more towards total variability of the genotypes than those of dates of sowing, locations and GEI for first fruit maturity ,plant height (cm), number of fruits plant$^{-1}$,average fruit length (cm), average fruit width (cm), average fruit weight (g), green fruit yield plant$^{-1}$(g) and red fruit yield plant$^{-1}$(g), contribution of locations main effects towards total variability of the genotypes was not noticed for any of the trait (Table 5a and 5b).

### 4.1.2 GGE bi-plot analysis of GEI patterns

#### 4.1.2.1 Discriminating ability and representativeness of environments

Assessment of discriminating and representativeness of test environments is based on the length of environment (here after referred to as both dates of sowing and locations) vectors, and the angle between the test environment vectors and average environment coordination (AEC) in the GGE bi-plot. The lines that connect the test environment

**Table 4a: Pooled ANOVA of Lam chilli genotypes evaluated over three dates of sowing for yield and its component traits**

| Sources of variation | Degrees of freedom | Mean Sum of Squares | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to first fruit maturity | Plant height (cm) | No. of fruits plant$^{-1}$ | Average Fruit length (cm) | Average Fruit width (cm) | Average Fruit weight (g) | Green fruit yield plant$^{-1}$ (g) | Red fruit yield plant$^{-1}$ (g) |
| Genotypes (G) | 20 | 341.0$^{**}$ | 296.46$^{**}$ | 456.1$^{**}$ | 1625$^{**}$ | 13.664$^{**}$ | 0.21016$^{**}$ | 7.693$^{**}$ | 53441$^{**}$ | 5876$^{**}$ |
| Season (S) | 2 | 165.0$^{**}$ | 4.58 | 4462.2$^{**}$ | 11608$^{**}$ | 7.634$^{**}$ | 0.00937 | 7.025$^{**}$ | 82913$^{**}$ | 10659$^{**}$ |
| G X S | 40 | 304.6$^{**}$ | 12.20 | 119.6$^{**}$ | 530$^{**}$ | 0.952$^{**}$ | 0.02881$^{**}$ | 1.228$^{**}$ | 4312 | 544$^{*}$ |
| Block | 3 | 6.5 | 8.46 | 5.4 | 290 | 0.823 | 0.00728 | 0.014 | 4677 | 535 |
| IPCA 1 | 21 | 578.6 | 14.84 | 218.9 | 654 | 1.216 | 0.03311 | 1.505 | 5124 | 605 |
| IPCA 2 | 19 | 1.9 | 9.28 | 10.0 | 393 | 0.659 | 0.02405 | 0.922 | 3415 | 477 |
| Pooled error (e) | 60 | 3.0 | 11.19 | 16.5 | 141 | 0.121 | 0.00267 | 0.048 | 2867 | 293 |

$^{*, **}$ Significance at 5% and 1% probability levels, respectively.

**Table 4b: Pooled ANOVA of Lam chilli genotypes evaluated over three locations for yield and its component traits**

| Sources of variation | Degrees of freedom | Mean Sum of Squares | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to first fruit maturity | Plant height (cm) | No. of fruits plant$^{-1}$ | Average Fruit length (cm) | Average Fruit width (cm) | Average Fruit weight (g) | Green fruit yield plant$^{-1}$ (g) | Red fruit yield plant$^{-1}$ (g) |
| Genotypes (G) | 20 | 99.92 | 288.52$^{**}$ | 286.3$^{**}$ | 1957$^{**}$ | 16.994$^{**}$ | 0.17830$^{**}$ | 5.533$^{**}$ | 76383$^{**}$ | 10037$^{**}$ |
| Locations (L) | 2 | 95.41 | 20.74 | 506.9$^{**}$ | 11454$^{**}$ | 6.158$^{**}$ | 0.03935$^{**}$ | 6.535$^{**}$ | 372464$^{**}$ | 55686$^{**}$ |
| G X L | 40 | 86.72 | 16.57 | 85.1$^{**}$ | 667$^{**}$ | 0.909$^{**}$ | 0.01972$^{**}$ | 0.965$^{**}$ | 7028$^{**}$ | 966$^{**}$ |
| Block | 3 | 94.55 | 10.43 | 60.2 | 1008 | 0.151 | 0.00304 | 0.018 | 14955 | 1971 |
| IPCA 1 | 21 | 164.14 | 21.16 | 144.1 | 973 | 1.374 | 0.02666 | 1.252 | 12222 | 1701 |
| IPCA 2 | 19 | 1.16 | 11.50 | 20.0 | 329 | 0.394 | 0.01204 | 0.647 | 1289 | 153 |
| Pooled error (e) | 60 | 94.87 | 11.20 | 11.6 | 189 | 0.071 | 0.00174 | 0.046 | 3168 | 407 |

$^{**}$ Significance at 1% probability levels.

**Table 5a: AMMI ANOVA of Lam chilli varieties released from Lam research station Guntur for yield and its component traits for three dates of sowing**

| Source of variation | Degrees of freedom | Days to 50% flowering | | | First fruit maturity | | | Plant height (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MSS | F cal | % Variation | MSS | F cal | % Variation | MSS | F cal | % Variation |
| Genotypes (G) | 20 | 341 | 112.09 | 0.35 | 296.46 | 26.48 | 0.83 | 456.1 | 27.69 | 0.38 |
| Season (S) | 2 | 165 | 25.36 | 0.02 | 4.58 | 0.54 | 0.00 | 4462.2 | 825.8 | 0.37 |
| G × S | 40 | 304.6 | 100.14 | 0.62 | 12.2 | 1.09 | 0.07 | 119.6 | 7.26 | 0.20 |
| IPCA 1 | 21 | 578.6 | 190.18 | 0.62 | 14.84 | 1.33 | 0.04 | 218.9 | 13.29 | 0.19 |
| IPCA 2 | 19 | 1.9 | 0.62 | 0.00 | 9.28 | 0.83 | 0.02 | 10 | 0.61 | 0.01 |
| Error | 60 | 3 | | 0.01 | 11.19 | | 0.09 | **MSS** | **F cal** | **% Variation** |

| Source of variation | Degrees of freedom | Number of fruits plant$^{-1}$ | | | Average fruit length (cm) | | | Average fruit width (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MSS | F cal | % Variation | MSS | F cal | % Variation | MSS | F cal | % Variation |
| Genotypes (G) | 20 | 1625 | 11.54 | 0.38 | 13.66 | 112.74 | 0.81 | 0.21 | 78.63 | 0.76 |
| Season (S) | 2 | 11608 | 39.98 | 0.27 | 7.63 | 9.28 | 0.05 | 0.01 | 1.29 | 0.00 |
| G × S | 40 | 530 | 3.77 | 0.25 | 0.95 | 7.85 | 0.11 | 0.03 | 10.78 | 0.21 |
| IPCA 1 | 21 | 654 | 4.65 | 0.16 | 1.21 | 10.03 | 0.08 | 0.03 | 12.39 | 0.13 |
| IPCA 2 | 19 | 393 | 2.79 | 0.09 | 0.66 | 5.44 | 0.04 | 0.02 | 9 | 0.08 |
| Error | 60 | 16.5 | | 0.04 | 0.12 | | 0.02 | 0.00 | | 0.03 |

| Source of variation | Degrees of freedom | Average Fruit weight (g) | | | Green fruit yield plant$^{-1}$ (g) | | | Red fruit yield plant$^{-1}$ (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MSS | F cal | % Variation | MSS | F cal | % Variation | MSS | F cal | % Variation |
| Genotypes (G) | 20 | 7.69 | 160.71 | 0.70 | 53441 | 18.64 | 0.67 | 5876 | 20.04 | 0.65 |
| Season (S) | 2 | 7.02 | 489.02 | 0.06 | 82913 | 17.73 | 0.10 | 10659 | 19.93 | 0.12 |
| G × S | 40 | 1.23 | 25.65 | 0.22 | 4312 | 1.5 | 0.11 | 544 | 1.86 | 0.12 |
| IPCA 1 | 21 | 1.51 | 31.44 | 0.14 | 5124 | 1.79 | 0.07 | 605 | 2.06 | 0.07 |
| IPCA 2 | 19 | 0.92 | 19.26 | 0.08 | 3415 | 1.19 | 0.04 | 477 | 1.63 | 0.05 |
| Error | 60 | 0.05 | | 0.01 | 2867 | | 0.11 | 293 | | 0.10 |

**Table 5b: AMMI ANOVA of Lam chilli varieties released from Lam research station Guntur for yield and its component traits for three locations of sowing**

| Source of variation | Degrees of freedom | Days to 50 per cent flowering | | | Days to first fruit maturity | | | Plant height (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MSS | F cal | % Variation | MSS | F cal | % Variation | MSS | F cal | % Variation |
| Genotypes(G) | 20 | 99.92 | 1.05 | 0.17 | 288.52 | 25.77 | 0.80 | 286.3 | 24.72 | 0.52 |
| Location (L) | 2 | 95.41 | 1.01 | 0.02 | 20.74 | 1.99 | 0.01 | 506.9 | 8.42 | 0.09 |
| G × L | 40 | 86.72 | 0.91 | 0.30 | 16.57 | 1.48 | 0.09 | 85.1 | 7.35 | 0.31 |
| IPCA 1 | 21 | 164.14 | 1.73 | 0.30 | 21.16 | 1.89 | 0.06 | 144.1 | 12.44 | 0.27 |
| IPCA 2 | 19 | 1.16 | 0.01 | 0.00 | 11.5 | 1.03 | 0.03 | 20 | 1.72 | 0.03 |
| Error | 60 | 94.87 | | 0.49 | 11.2 | | 0.09 | 11.6 | | 0.06 |

| Source of variation | Degrees of freedom | Fruits plant$^{-1}$ | | | Fruit length (cm) | | | Fruit width (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MSS | F cal | % Variation | MSS | F cal | % Variation | MSS | F cal | % Variation |
| Genotypes (G) | 20 | 1957 | 10.34 | 0.38 | 16.99 | 238.61 | 0.86 | 0.17 | 102.24 | 0.78 |
| Location (L) | 2 | 11454 | 11.37 | 0.22 | 6.16 | 40.9 | 0.03 | 0.04 | 12.96 | 0.02 |
| G × L | 40 | 667 | 3.52 | 0.26 | 0.91 | 12.76 | 0.09 | 0.02 | 11.31 | 0.17 |
| IPCA 1 | 21 | 973 | 5.14 | 0.20 | 1.37 | 19.29 | 0.07 | 0.03 | 15.29 | 0.12 |
| IPCA 2 | 19 | 329 | 1.74 | 0.06 | 0.39 | 5.53 | 0.02 | 0.01 | 6.91 | 0.05 |
| Error | 60 | 189 | | 0.11 | 0.07 | | 0.01 | 0.00 | | 0.02 |

| Source of variation | Degrees of freedom | Average fruit weight (g) | | | Green fruit yield plant$^{-1}$(g) | | | Red fruit yield plant$^{-1}$ (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MSS | F cal | % Variation | MSS | F cal | % Variation | MSS | F cal | % Variation |
| Genotypes (G) | 20 | 5.533 | 119.4 | 0.67 | 76383 | 24.11 | 0.54 | 10037 | 24.66 | 0.53 |
| Location (L) | 2 | 6.535 | 359.56 | 0.07 | 372464 | 24.91 | 0.27 | 55686 | 28.25 | 0.29 |
| G × L | 40 | 0.965 | 20.81 | 0.23 | 7028 | 2.22 | 0.10 | 966 | 2.37 | 0.10 |
| IPCA 1 | 21 | 1.252 | 27.01 | 0.16 | 12222 | 3.86 | 0.09 | 1701 | 4.18 | 0.09 |
| IPCA 2 | 19 | 0.647 | 13.97 | 0.07 | 1289 | 0.41 | 0.01 | 153 | 0.38 | 0.01 |
| Error | 60 | 0.046 | | 0.017 | 3168 | | 0.07 | 407 | | 0.06 |

points to the origin of GGE bi-plot is referred to as environment vectors. A single-arrowed line (ray) passing through the origin of the bi-plot and the average of the environments (in the present study, it is the average of three dates of sowing and locations) is referred as AEC. The average environment is represented by the small circle at the end of the arrow of AEC (Yan and Tinker, 2006). Shorter the environment vectors, lower is the discriminating ability of the location; longer the vector, higher is the discriminating ability of the location.

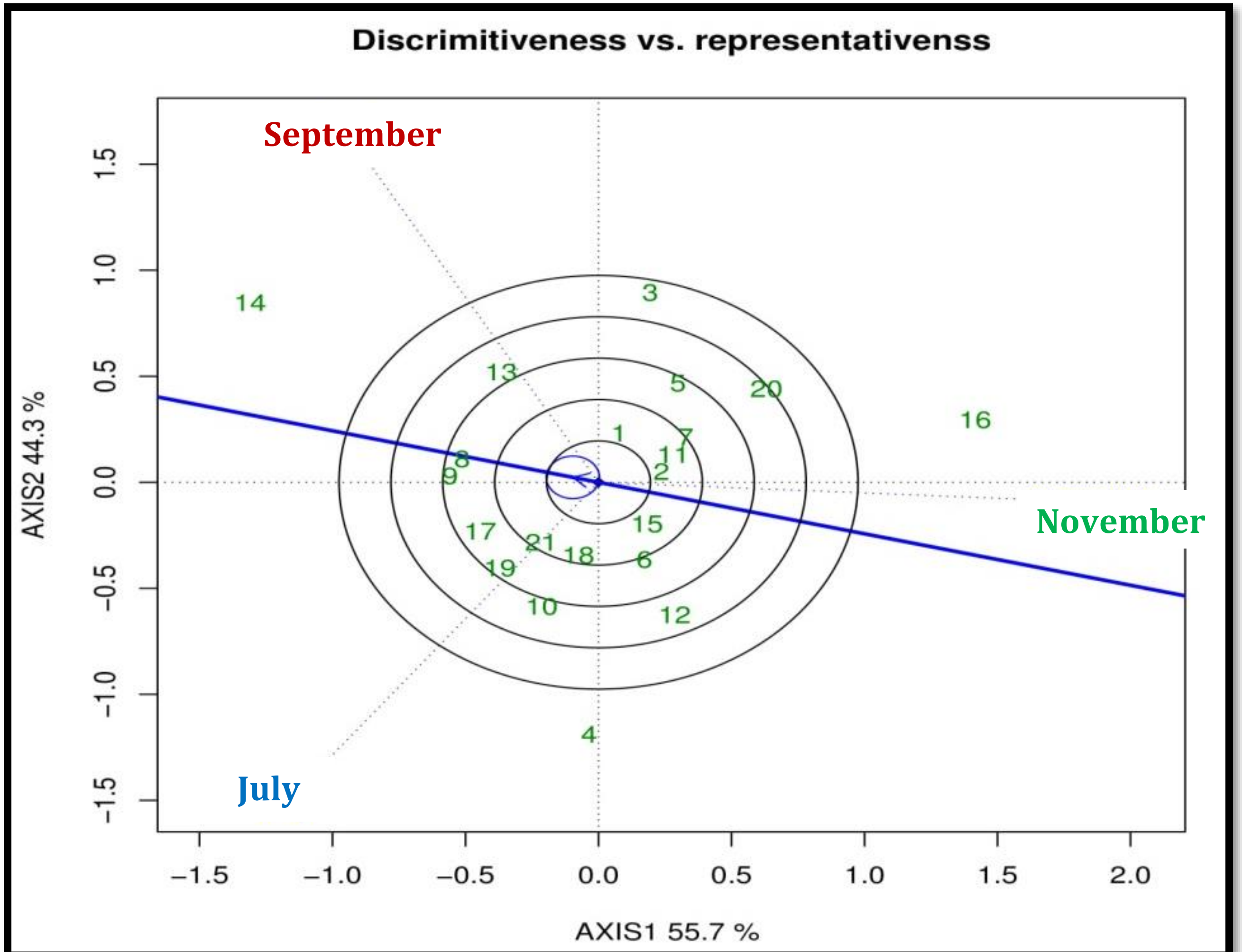
A test vector location that has a smaller angle with AEC is more representative of test environment. A test environment vector that has a wider angle with AEC is least representative of test environment. The cosine of the angle between the vectors of two environments approximates the correlation between them. While acute angle between the vectors of test locations indicate positive correlation or similarity between them, obtuse and right angles indicate negative correlation/dissimilarity, and no relationship, respectively between the test locations.

**Discriminating ability and representativeness for dates of sowing**

In the present study, the vectors of all the three dates of sowing were almost of equal length with respect to average fruit width (Fig. 1a), green fruit yield plant$^{-1}$ (Fig. 1b) and red fruit yield plant$^{-1}$ (Fig. 1c). The angle between all the vectors of July sowing, September sowing and November sowing were obtuse. The angles of vectors of July sowing and September sowing were closer to AEC than that of November sowing for average fruit width, the angles of vectors of November sowing was closer to AEC than that of July sowing and September sowing for green fruit yield plant$^{-1}$ (Fig. 1b) and for red fruit yield plant$^{-1}$ (Fig. 1c).

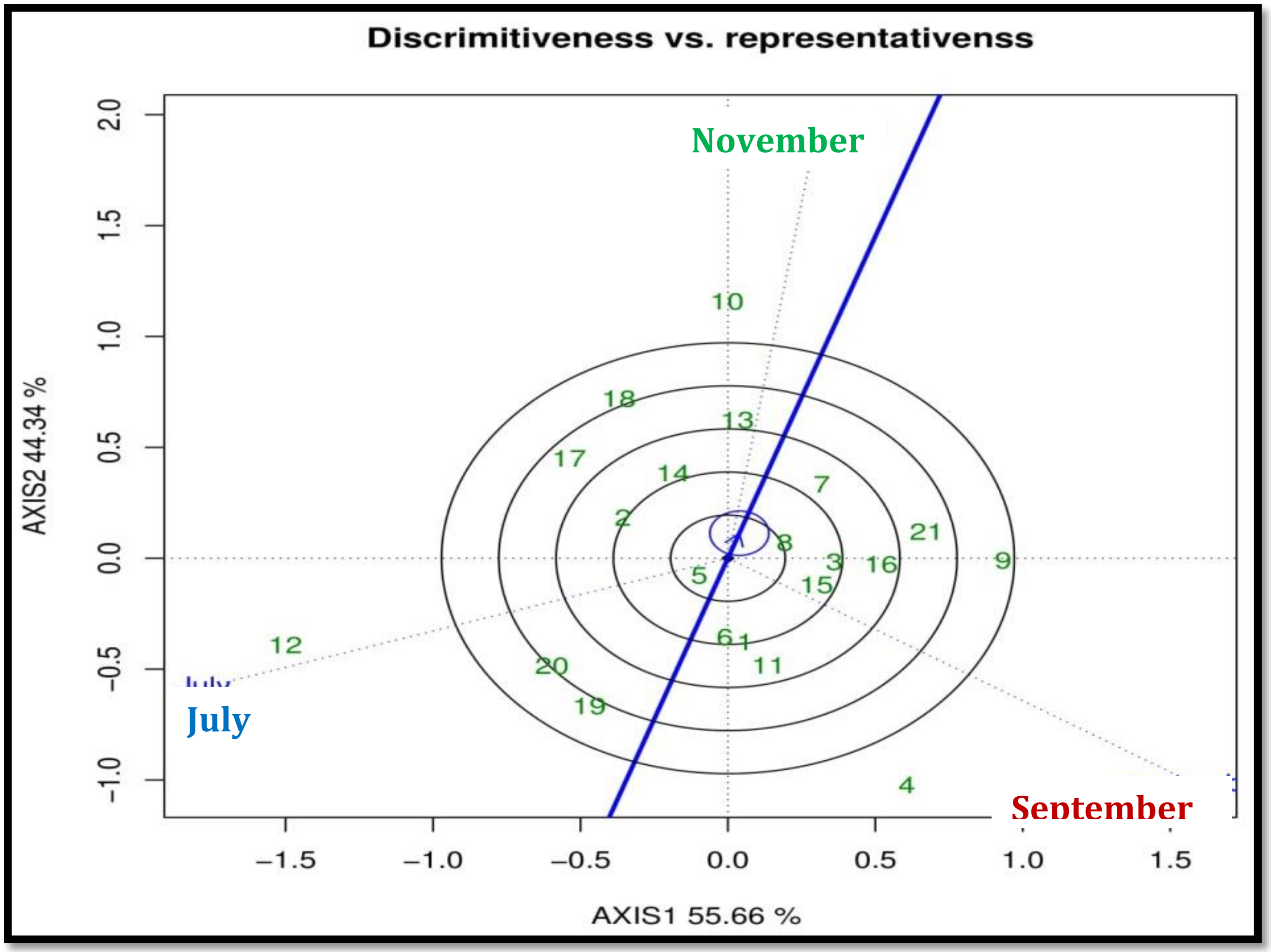
**Discriminating ability and representativeness for locations of sowing**

In the present study, along with three dates of sowing Lam chilli varieties released from Lam research station, Guntur are evaluated for three locations and the vectors of all the three locations of sowing were almost of equal length with respect to average fruit width (Fig. 1d). The angle between the vectors of GKVK, Siddalaghatta and Srinivaspura



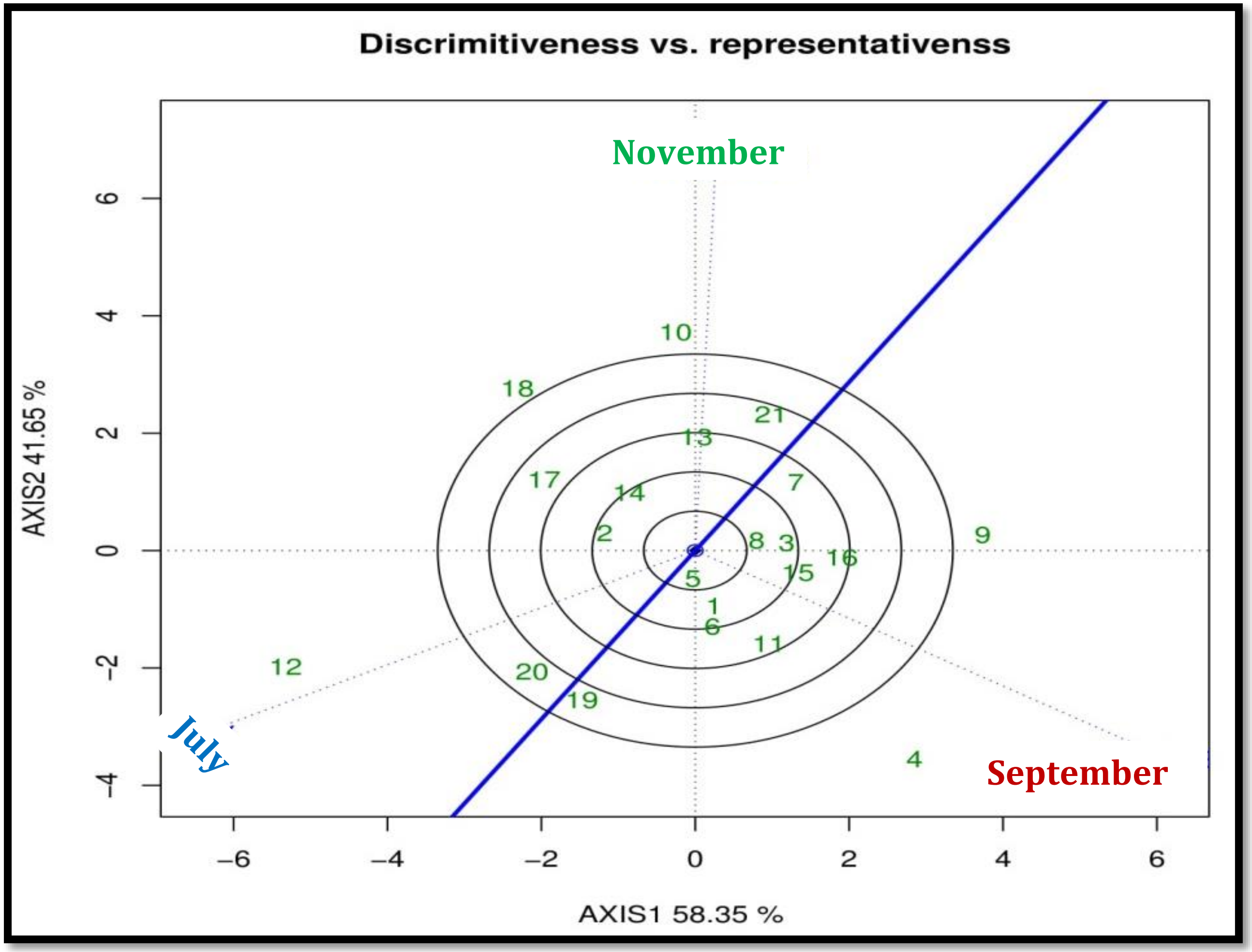

| | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 1a: Discriminative *vs.* representativeness view of GGE bi-plot for fruit width across dates of sowing**



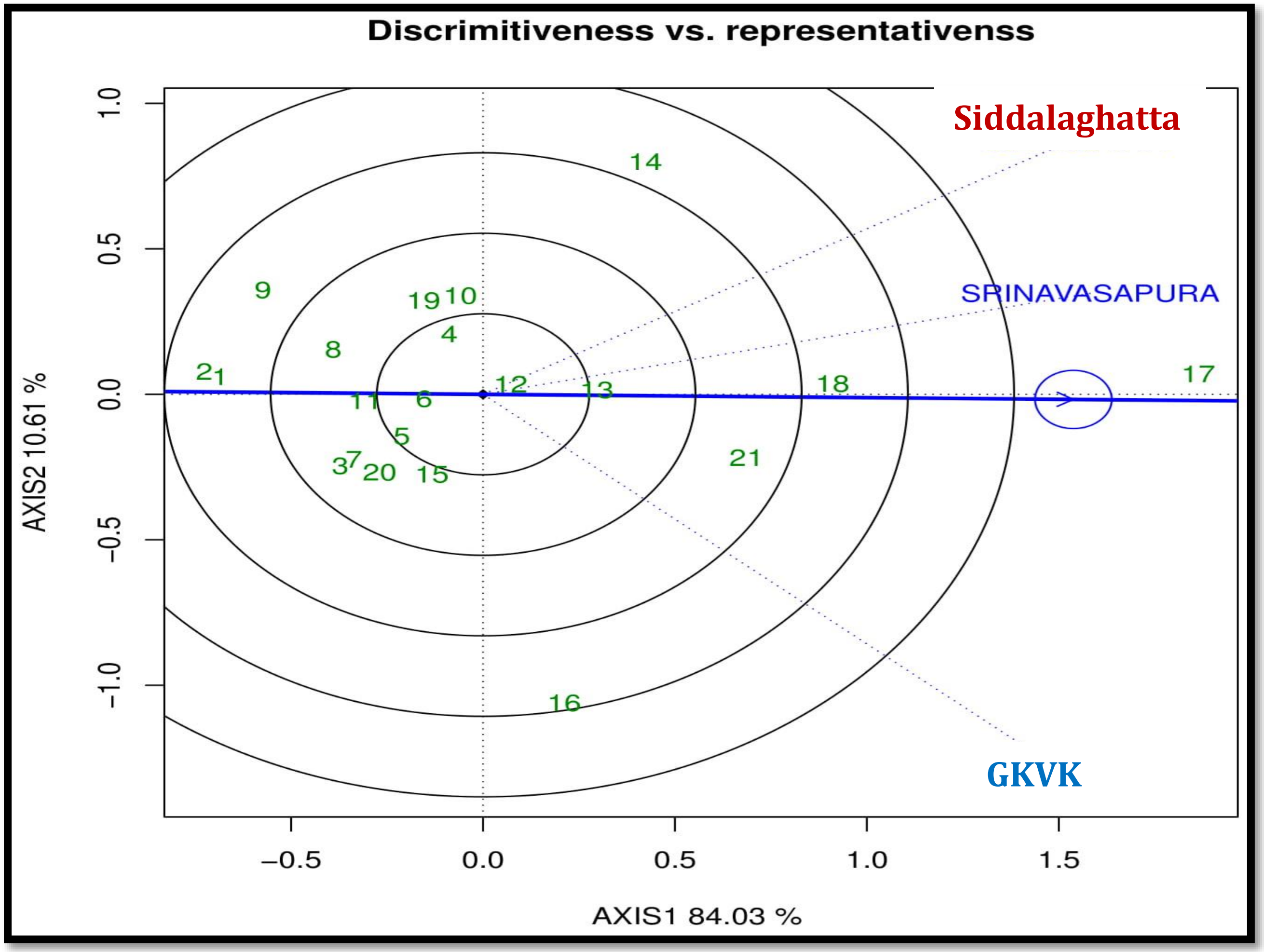

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 1b: Discriminative *vs.* representativeness view of GGE bi-plot for green fruit yield plant$^{-1}$ across dates of sowing**



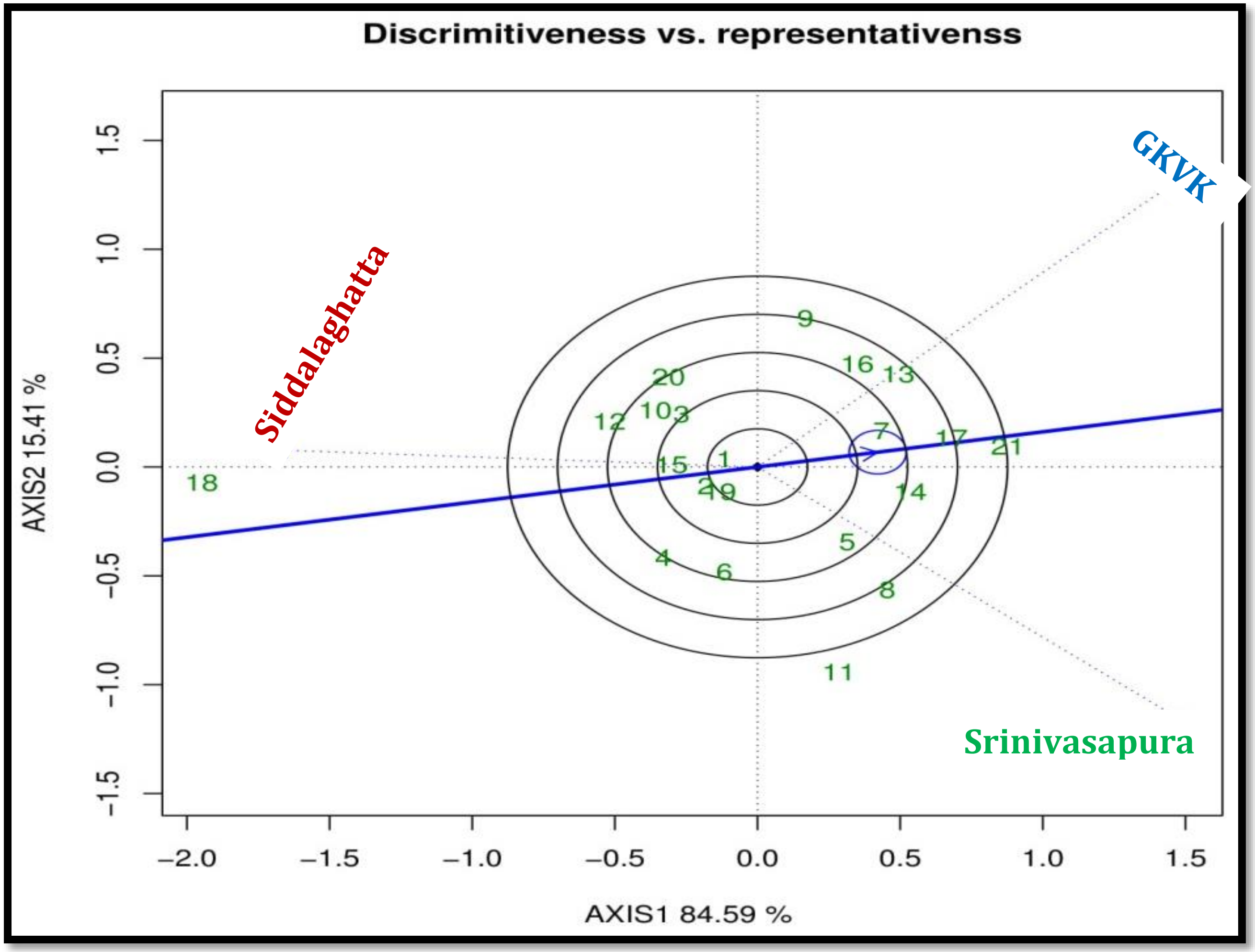

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 1c: Discriminative *vs.* representativeness view of GGE bi-plot for red fruit yield plant$^{-1}$ across dates of sowing**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 1d: Discriminative *vs.* representativeness view of GGE bi-plot for average fruit width across locations**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 1e: Discriminative *vs.* representativeness view of GGE bi-plot for green fruit yield plant$^{-1}$ across locations**

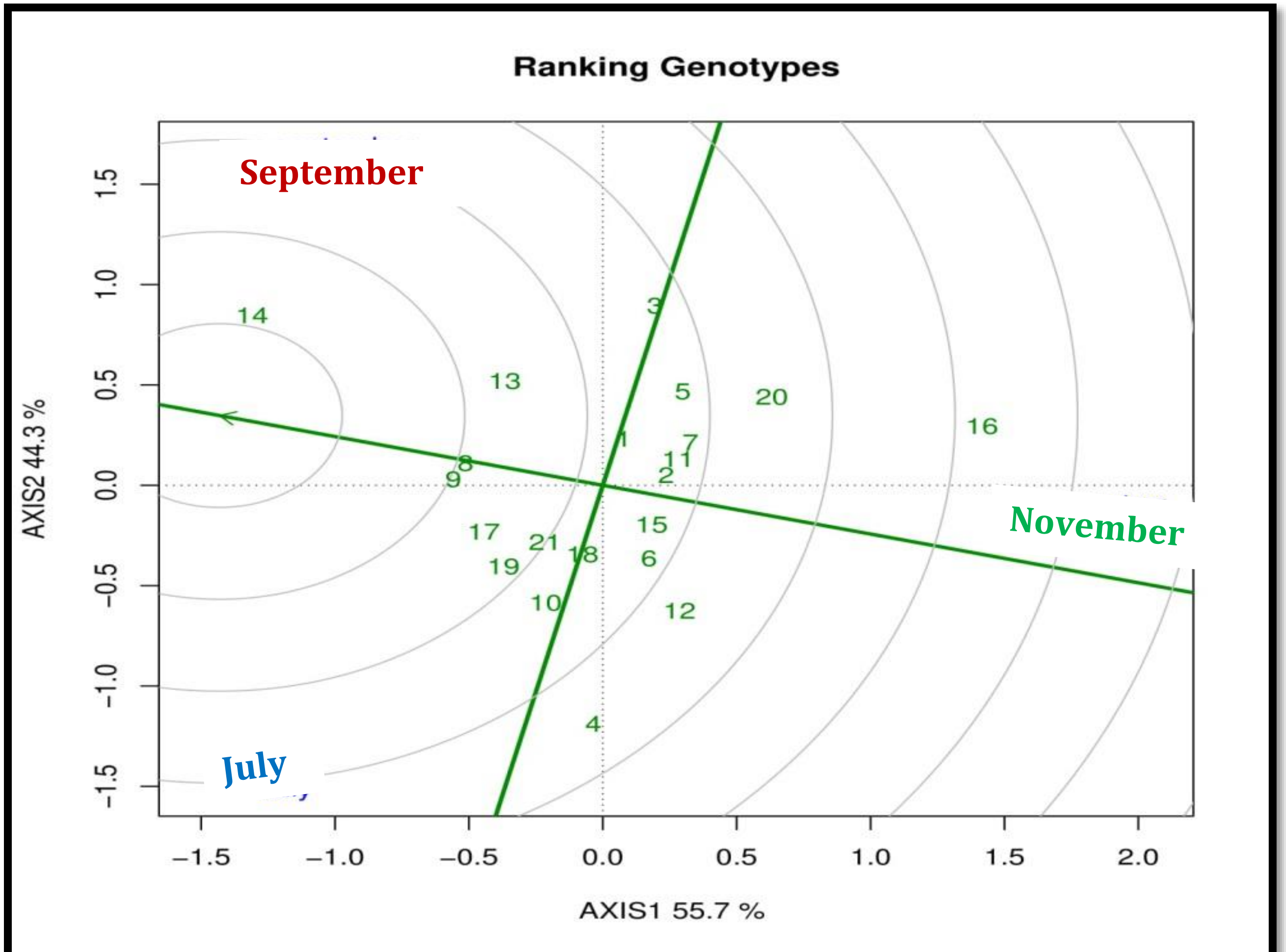
were acute angle. The angles of vectors of Srinivaspura was closer to AEC than that of Sidlagatta and GKVK for average fruit width. The vector of Sidlaghatta has shorter vector length compared to the vectors of GKVK and Srinivaspur, where both of them has almost of equal vector length respect to green fruit yield plant$^{-1}$ (Fig. 1e). The angle between the vectors of GKVK and Srinivaspur were acute angle than compared to GKVK and Sidlaghatta; and Sidlaghatta and Srinivaspur which were obtuse. GKVK was closer to AEC than that of Srinivaspurand Siddalaghatta, Srinivaspur is closer to AEC than that of Sidlaghatta for green fruit yield plant$^{-1}$ (Fig. 1e).

Discriminating ability and representativeness of dates of sowing for evaluating the genotypes varied with the trait. All the three test dates of sowing adequately discriminated the genotypes and represented the average of environments of the dates of sowing for the expression of average fruit width (Fig. 1a) and green fruit yield plant$^{-1}$ (Fig. 1b) of the test genotypes. On the other hand July sowing for red fruit yield plant$^{-1}$(Fig. 1c) effectively discriminated the genotypes and represented the average of the environments that prevailed at the three dates of sowing. Thus, dates of sowing provide effective test environments for selecting genotypes for wide adaptation for the respective traits. However, although November sowing for average fruit width (Fig. 1a), July sowing for green fruit yield plant$^{-1}$ (Fig. 1b) and red fruit yield plant$^{-1}$ (Fig. 1c) effectively discriminated the genotypes, they were non-representative of the average of the three environments. Hence test dates of sowing are useful for selecting the genotypes for dates-specific adaptation for the respective traits. The obtuse angle indicates strong negative correlation between the vectors of July, September and November sowing suggested dissimilarity of environment at these three dates of sowing for discriminating the genotypes for the traits under consideration. The presence of negative association between dates of sowing suggests that dissimilar information on the performance of genotypes could not be elicited from any of the dates of sowing.

Discriminating ability and representativeness of locations for evaluating the genotypes varied with the trait. All the three test dates of sowing adequately discriminated the genotypes and represented the average of environments of the locations for the expression of average fruit width. The test location Srinivaspura effectively represented the average of environments of the location for the expression of average fruit width (Fig. 1d) of the test genotypes compared to Siddalaghatta and GKVK which equally represented. On the other hand, GKVK and Srinivaspur effectively discriminated the genotypes and represented the average of environments of the location for the expression of green fruit yield plant$^{-1}$ (Fig. 1e) of the test genotypes compared to Siddalaghatta. Thus, test locations provide effective test environments for selecting genotypes for wide adaptation for the respective traits. The acute angle and hence strong positive correlation between the vectors of GKVK, Siddalghatta and Srinivaspur suggested similarity of environment at these three locations for discriminating the genotypes for average fruit width (Fig. 1d). The presence of close association between locations suggests that similar information on the performance of genotypes could be elicited from either GKVK, Siddalaghatta or Srinivaspur locations. The acute angle and hence strong positive correlation between the vectors of GKVK and Srinivaspura suggested similarity of environment at these two locations for discriminating the genotypes for green fruit yield plant$^{-1}$ (Fig. 1e). The presence of close association between locations suggests that similar information on the performance of genotypes could be elicited from either GKVK or Srinivaspura locations. Evaluating the genotypes in any of these locations would substantially reduce the testing cost without compromise in the performance of genotypes. On the contrary, obtuse angle and hence strong negative correlation between the vectors of Siddalaghatta and GKVK, and Siddalaghatta and Srinivaspur suggest dissimilarity of these environments that prevailed at pairs of locations for discriminating the genotypes for green fruit yield plant$^{-1}$ (Fig. 1e).

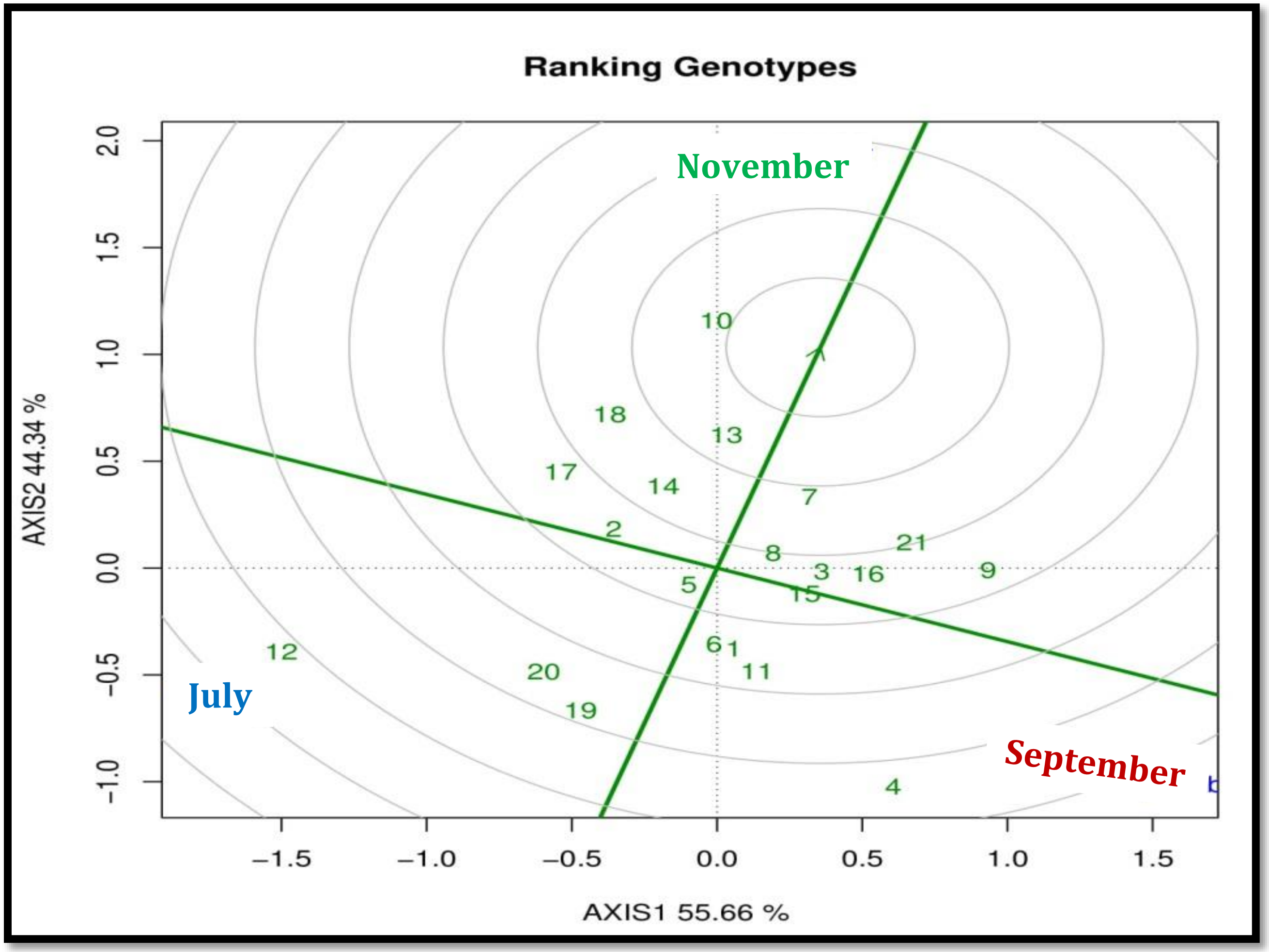
### 4.1.3 Ranking genotypes relative to ideal genotype

An ideal genotype should have both high mean performance and high stability (wide adaptation in the present study) across environments (across dates of sowing and locations in the present study). An ideal genotype (center of concentric circles) is the point on AEC (wide adaptation) in the GGE bi-plot in the positive direction and has a vector length equal to the longest vector of the genotypes on the positive side of AEC. Using the ideal genotype as the center, concentric circles are drawn to help visualize the distance between each genotype and ideal genotype. The genotypes located closer to the



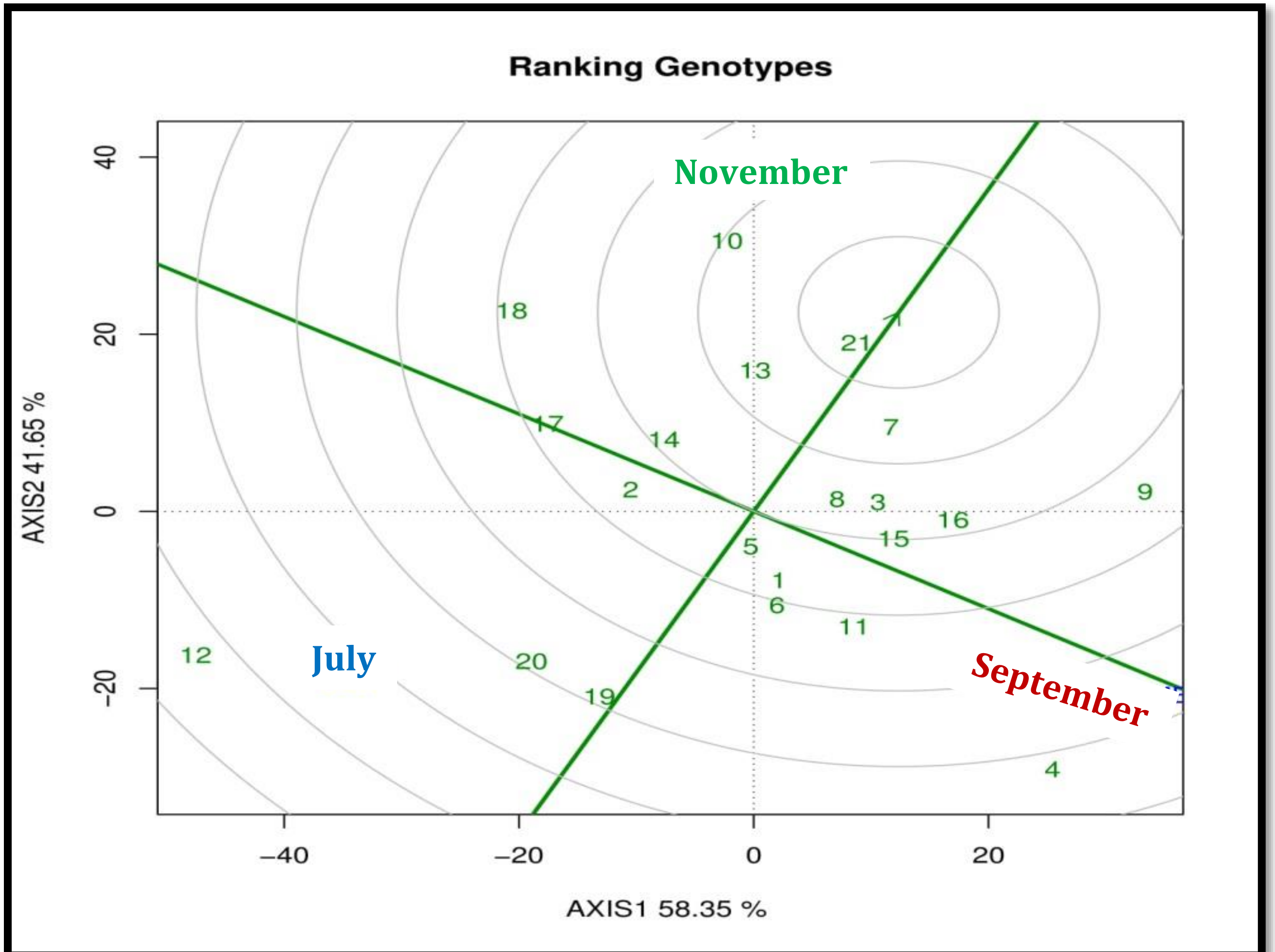

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 2a: Average environment coordination (AEC) view of GGE bi-plot based on genotype-focused scaling for comparison of genotypes with the ideal genotype for fruit width across dates of sowing**



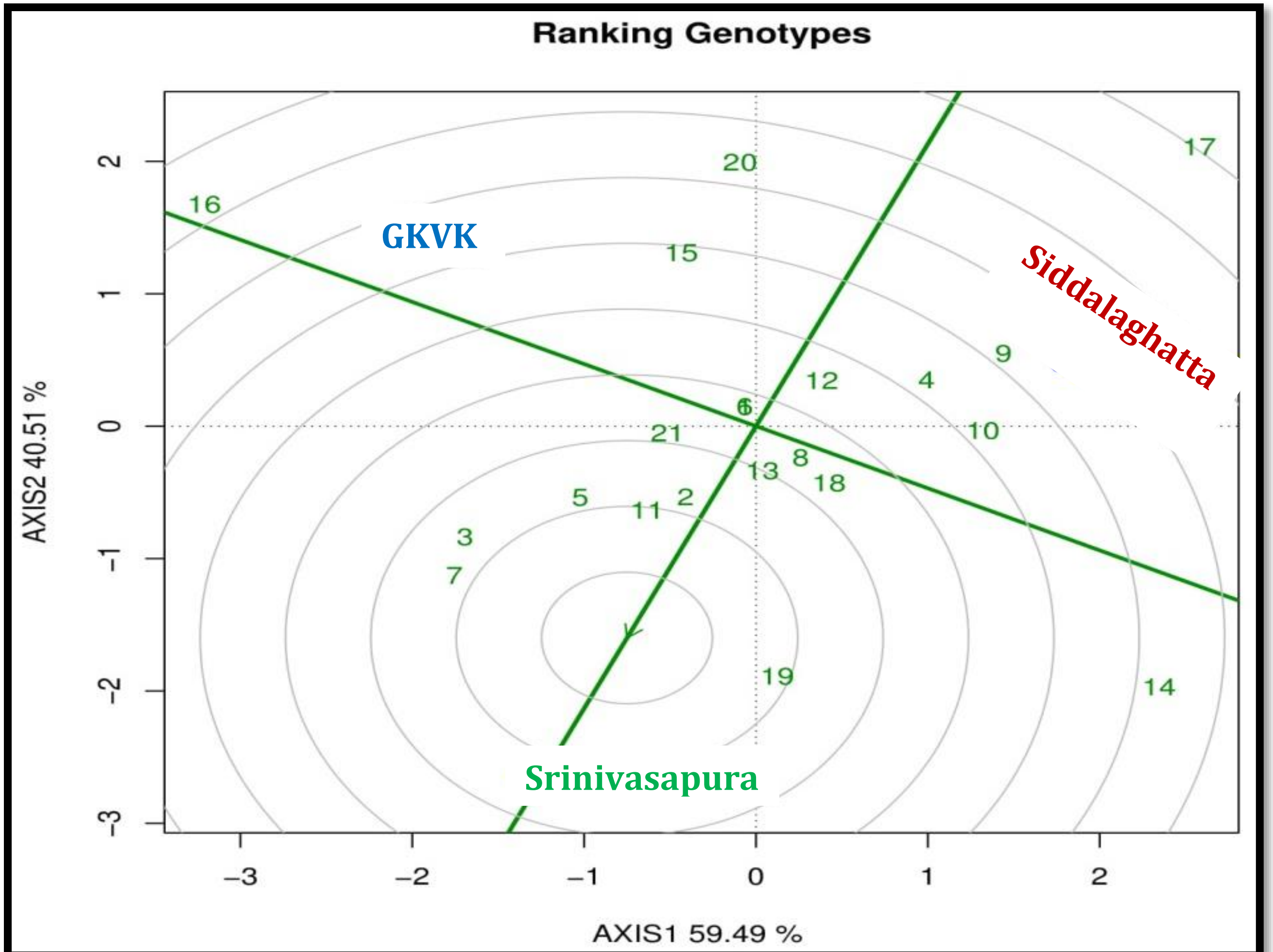

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 2b: Average environment coordination (AEC) view of GGE bi-plot based on genotype-focused scaling for comparison of genotypes with the ideal genotype for green fruit yield across dates of sowing**



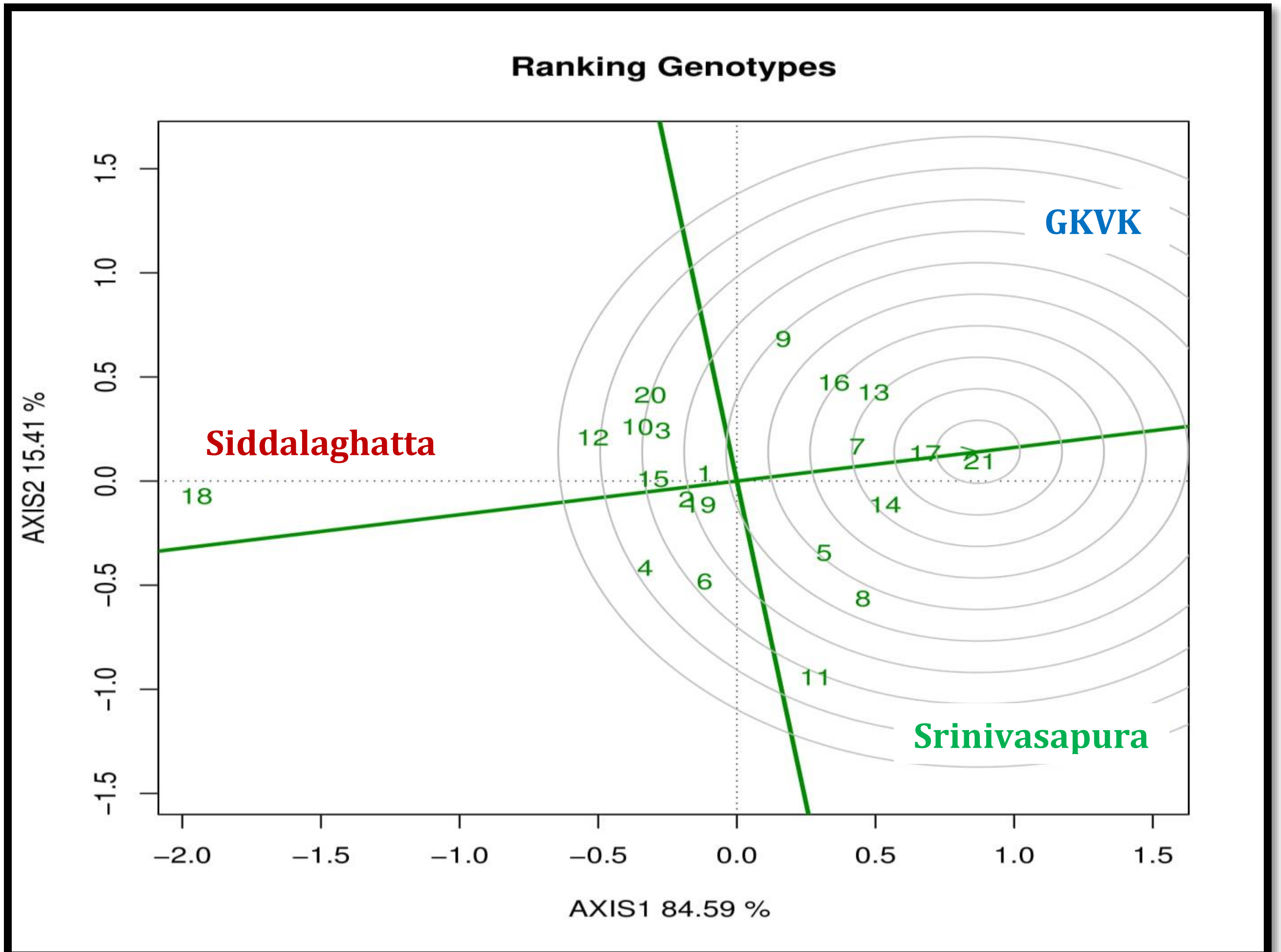

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 2c: Average environment coordination (AEC) view of GGE bi-plot based on genotype-focused scaling for comparison of genotypes with the ideal genotype for red fruit yield plant$^{-1}$ across dates of sowing**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 2d: Average environment coordination (AEC) view of GGE bi-plot based on environment-focused scaling for the mean performance *vs.* adaptability for average fruit width across locations**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 2e: Average environment coordination (AEC) view of GGE bi-plot based on genotype-focused scaling for comparison of genotypes with the ideal genotype for green fruit yield plant$^{-1}$ across locations**

"ideal genotype" are more desirable than others; obviously those that are away from ideal genotype are more undesirable.

**Ranking genotypes relative to ideal genotype under different dates of sowing**

In the present study in evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing, LCA 960 was found located very near to center of concentric circles for average fruit width (Fig. 2a). The LCA varieties and checks, LCA 436, LCA 424, LCA 655, G5, Arka Meghana, US 341, LCA 620 and LCA 305 were located little away from the center of concentric circles in GGE bi-plot for average fruit width. On the contrary, KBCH-1, LCA 206, LCA 333, LCA 235, G3, LCA 336, LCA 334, LCA 625, LCA 353, Arka Haritha, LCA 639 and G4 were located far away from the center of concentric circles for average fruit width. LCA 620 was found located very near to center of concentric circles for green fruit yield plant$^{-1}$ (Fig. 2b). The LCA varieties and checks, LCA 655, LCA 353, KBCH-1, LCA 960, LCA 424, US 341, G5, LCA 235, LCA 305, G4, LCA 436 and G3 were located little away from the center of concentric circles in GGE bi-plot for green fruit yield plant$^{-1}$. On the contrary, LCA 334, LCA 336, LCA 206, LCA 625, Arka Haritha, Arka Meghana LCA 333 and LCA 639 were located far away from the center of concentric circles for green fruit yield plant$^{-1}$. US 341 was found located in the center of concentric circles for red fruit yield plant$^{-1}$ (Fig. 2c). The LCA varieties and checks, LCA 655, LCA 353, LCA 620, LCA 305, LCA 424, G4, LCA 960, G3, LCA 436, KBCH-1 and G5 were located little away from the center of concentric circles in GGE bi-plot for red fruit yield plant$^{-1}$. On the contrary, LCA 235, LCA 334, LCA 206, LCA 336, LCA 625, Arka Haritha, Arka Meghana, LCA 333 and LCA 639 were located far away from the center of concentric circles for red fruit yield plant$^{-1}$.

**Ranking genotypes relative to ideal genotype under different locations of sowing**

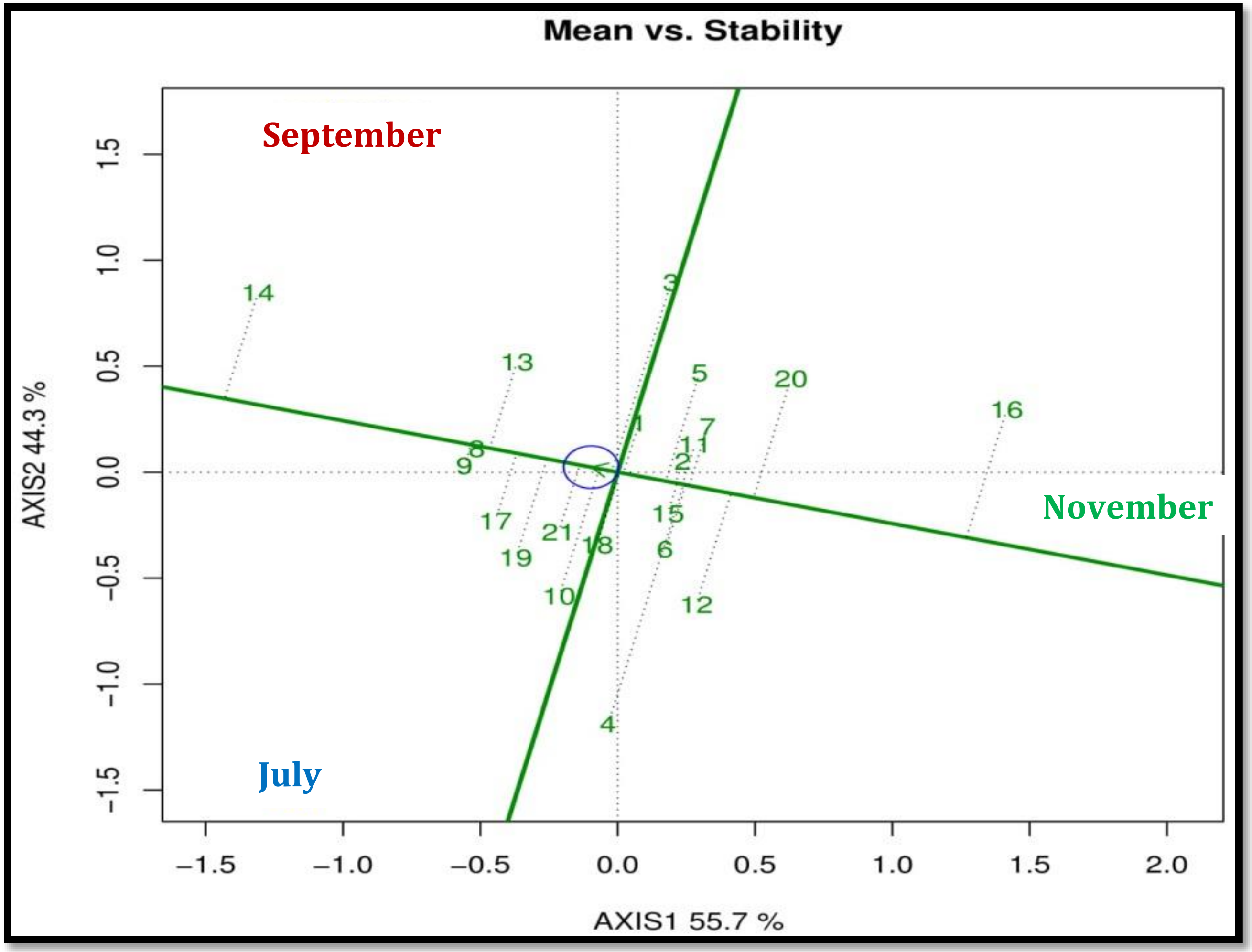
In the present study apart from evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing also evaluated for across location, the LCA varieties and checks, ArkaMeghana, LCA 625, LCA 235, LCA 334, LCA 305, LCA 353, LCA 655 and US 341 were located little away from the center of concentric circles in GGE bi-plot for average fruit width (Fig. 2d). On the contrary, remaining all genotypes were located far away from the center of concentric circles for average fruit width. The check US 341 was found located in the centre of the concentric circles for green fruit yield plant$^{-1}$(Fig. 2e). TheLCA varieties, G5, LCA 960, LCA 353, LCA 655, and G4 were located little away from the center of concentric circles in GGE bi-plot for green fruit yield plant$^{-1}$. On the contrary, remaining Lam chilli varieties and checks were located far away from the center of concentric circles for green fruit yield plant$^{-1}$.

The ideal genotype is the one which is widely adapted with high performance in the desired direction. In the present study with respect to dates of sowing, as far as average fruit width trait was concerned LCA 960, LCA 436 and LCA 424 were identified as ideal genotypes which are almost closer to the circle of average environment. The genotypes, LCA 620, LCA 305 and LCA 353 were identified as ideal genotypes which are almost closer to the circle of average environment. The genotype US 341 is the most ideal genotype since it falls inside the circle of average environment, the genotypes LCA 353, LCA 655 and LCA 620 were identified as ideal genotypes which are almost closer to the circle of average environment. Hence these genotypes could be used in breeding widely adapted varieties or parents in hybridization.

In the present study with respect to locations of sowing, as far as average fruit width was concerned Arka Meghana, LCA 625 and LCA 235 were identified as ideal genotypes which are almost closer to the circle of average environment. The genotype US 341 is the most ideal genotype as it falls inside the circle of average environment, the genotypes G5, LCA 655 and LCA 353 were identified as ideal genotypes which are almost closer to the circle of average environment for green fruit yield plant$^{-1}$. Hence these genotypes could be used in breeding widely adapted varieties or parents in hybridization.

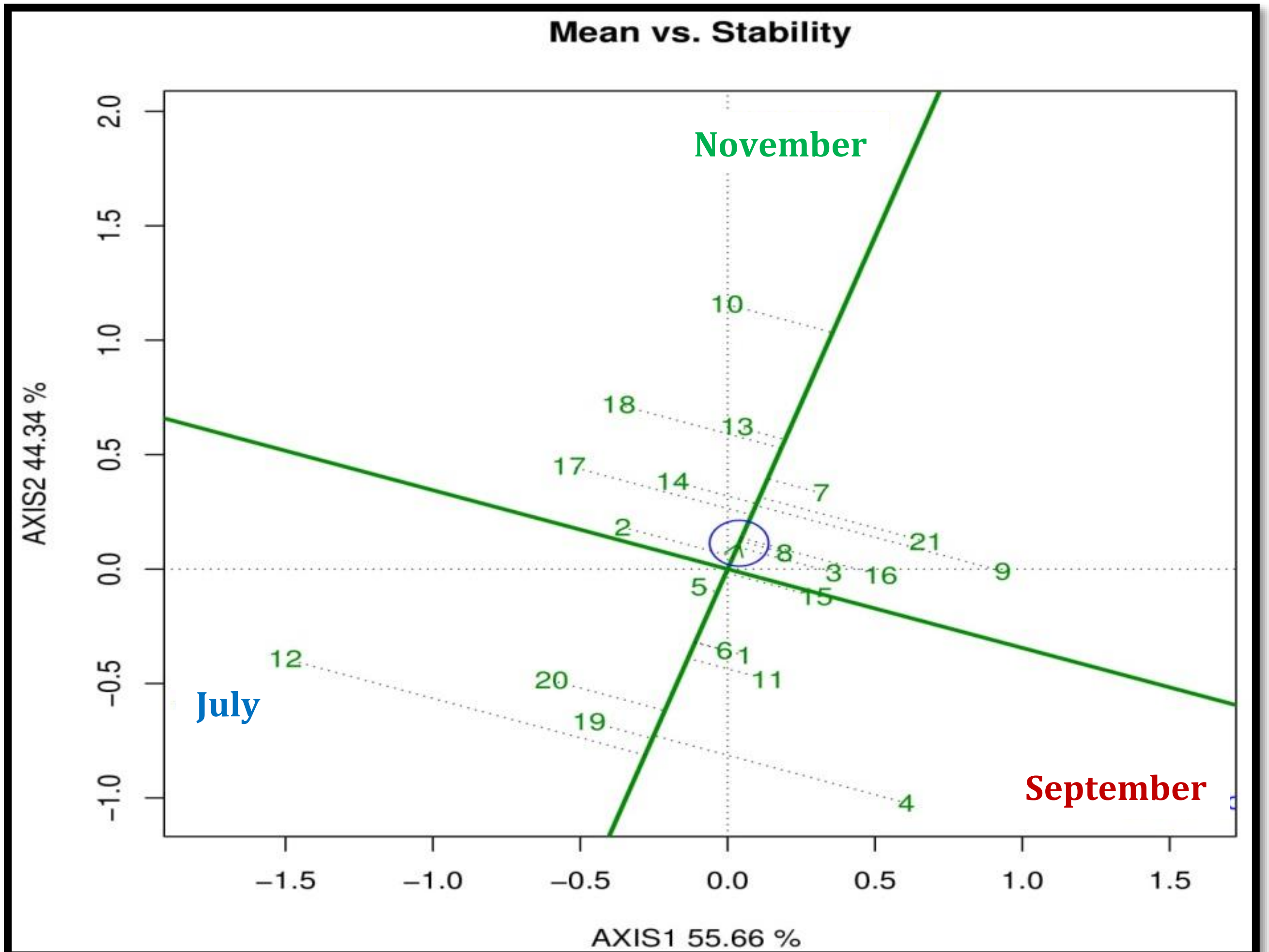
#### 4.1.4 Mean performance *vs*. adaptability patterns

The mean performance and adaptability could be visualized based on the environment of genotypes in relation to AEC using AEC view of GGE bi-plot. The single arrowed AEC points to higher mean performance of the genotypes across locations (Yan



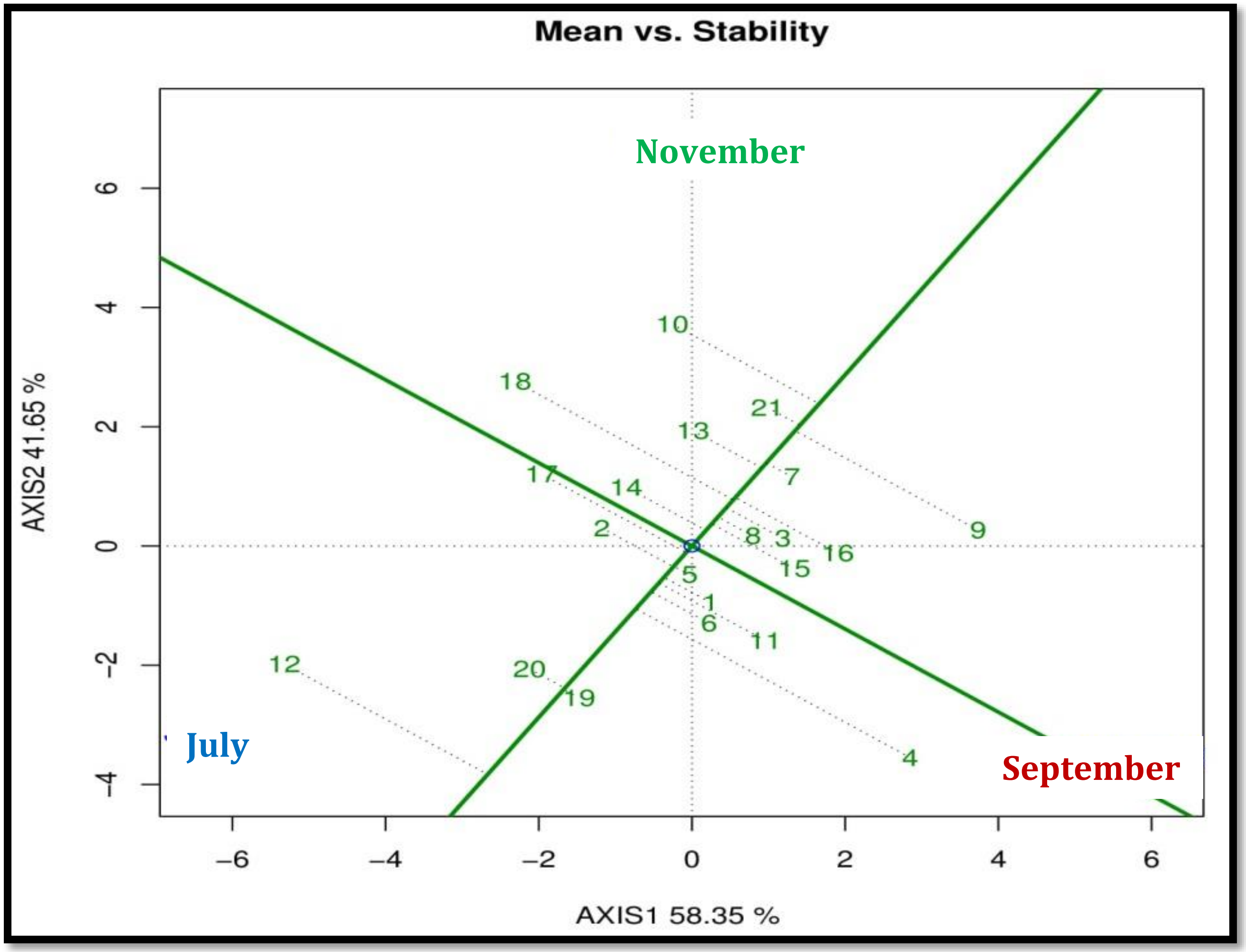

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 3a: Average environment coordination (AEC) view of GGE bi-plot based on environment-focused scaling for the mean performance *vs.* adaptability for fruit width across dates of sowing**



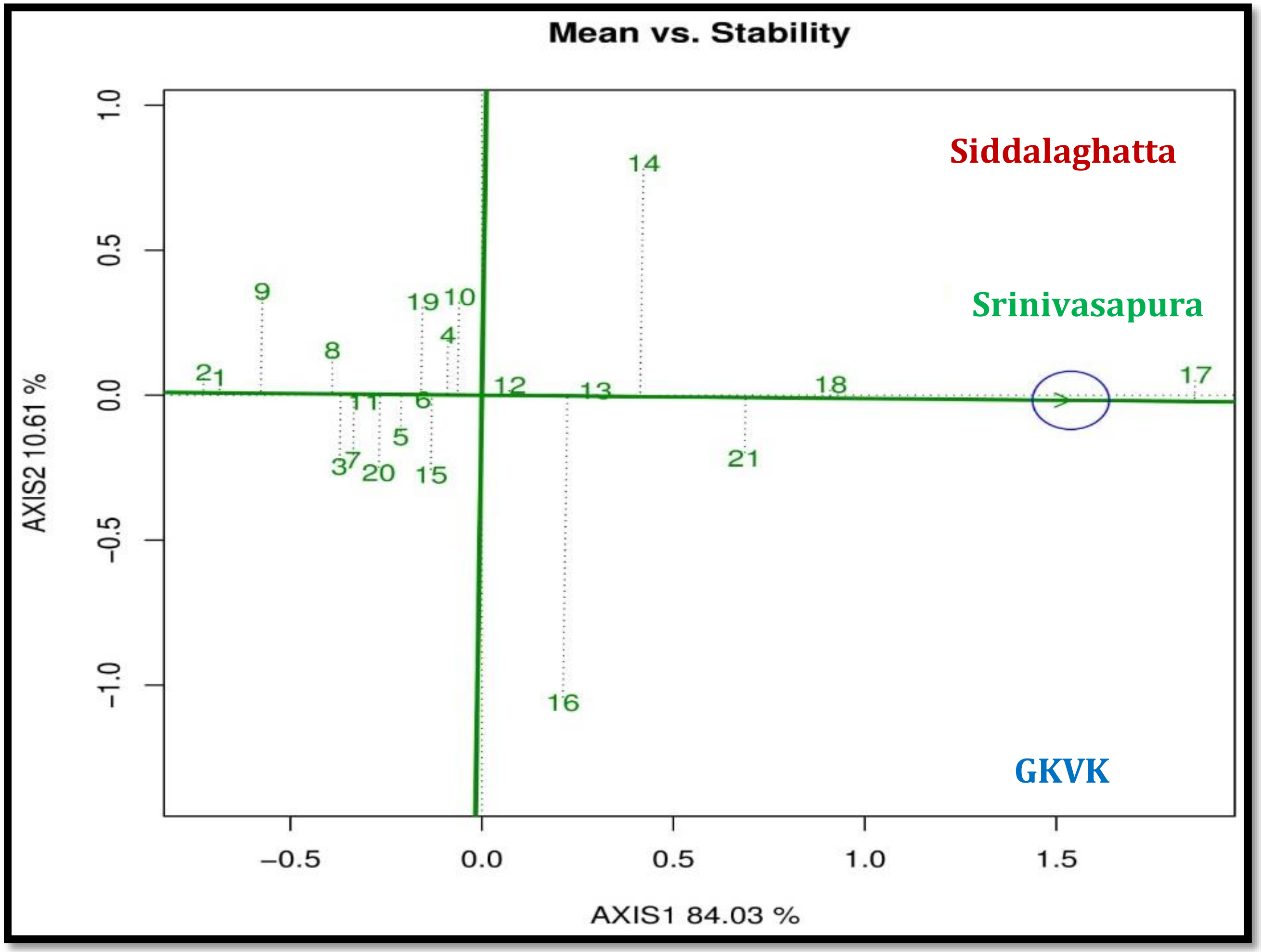

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 3b: Average environment coordination (AEC) view of GGE bi-plot based on environment-focused scaling for the mean performance *vs.* adaptability for green fruit yield plant$^{-1}$ across dates of sowing**



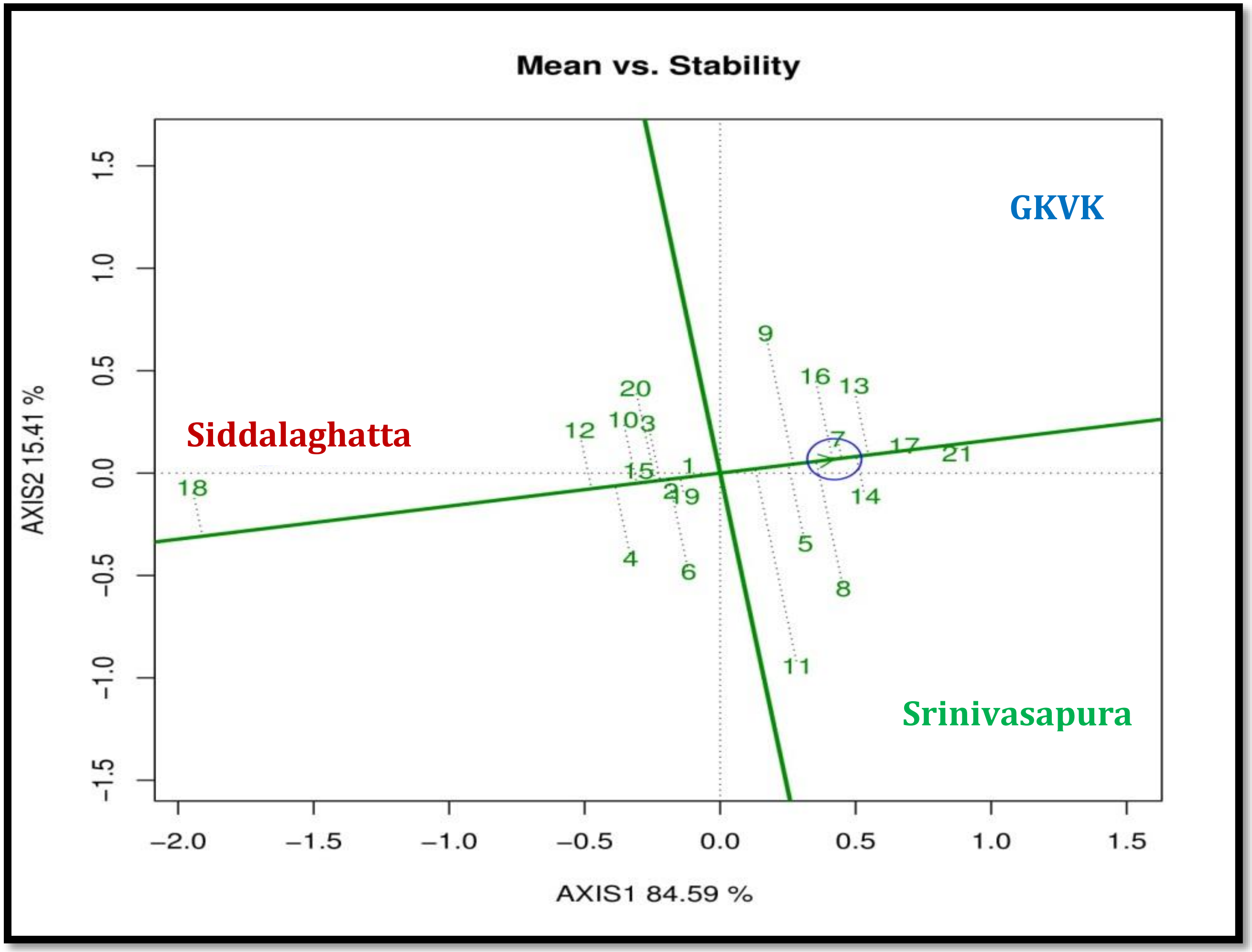

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 3c: Average environment coordination (AEC) view of GGE bi-plot based on environment-focused scaling for the mean performance *vs.* adaptability for red fruit yield plant$^{-1}$ across dates of sowing**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 3d: Average environment coordination (AEC) view of GGE bi-plot based on environment-focused scaling for the mean performance *vs.* adaptability for average fruit width across locations**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 3e: Average environment coordination (AEC) view of GGE bi-plot based on environment-focused scaling for the mean performance *vs.* adaptability for green fruit yield plant$^{-1}$ across locations**

*et al.*, 2001). The genotypes with their points located towards arrow of AEC are considered to exhibit high mean performance. On the contrary, the genotypes with their points located opposite to AEC arrow are considered to exhibit lower performance. Further, the relative lengths of projections of the genotypes from AEC are indicative of their relative adaptability shorter the length of the projections of genotypes from AEC, greater (wide) is the adaptability of the genotypes. The greater the absolute length of the projections of genotypes, greater would be their poor adaptability.

**Mean performance *vs*. adaptability patterns for dates of sowing**

In the present study in evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing, the points of LCA 960, LCA 424, LCA 436, LCA 655, G5, Arka Meghana, US 341 and LCA 620 were found located more towards AEC arrow than those of LCA 305 and KBCH-1 were relatively closer to the arrow of AEC (Fig. 3a). On the contrary, the points of G4, Arka Haritha, LCA 639, LCA 353, LCA 625, LCA 235, G3, LCA 336 and LCA 206 were located opposite to AEC arrow for average fruit width. The length of the projections of LCA 424, LCA436, LCA235 and G3 from AEC was least compared to all other projections. The points of LCA 620, LCA 655, KBCH-1, LCA 353, US 341, LCA 960, LCA 436, G5, G4, LCA 424 and LCA 305 were found located more towards AEC arrow than those of LCA 235 and G3 were relatively closer to the arrow of AEC (Fig. 3b). On the contrary, the points of LCA 334, LCA 336, LCA 206, LCA 625, Arka Haritha, Arka Meghana, LCA 333 and LCA 639 were located opposite to AEC arrow for green fruit yield plant$^{-1}$. The length of the projections of LCA 334, LCA336, LCA206 and LCA 424 from AEC was least compared to all other projections. The points of LCA 620, LCA 655, US 341, LCA 436, LCA 353, LCA 655, G4, KBCH-1, LCA 305, LCA424, G3 and LCA 960 were found located more towards AEC arrow than those of G5, LCA235, LCA 334, LCA 206, LCA 625 and LCA 336 were relatively closer to the arrow of AEC (Fig. 3c). On the contrary, the points of LCA 333, Arka Haritha, Arka Meghana and LCA 639 were located opposite to AEC arrow for red fruit yield plant$^{-1}$. The length of the projections of Arka Meghana, LCA 334, LCA 424, LCA 353, US 341 and Arka Haritha from AEC was least compared to all other projections.

**Mean performance *vs*. adaptability patterns for different locations**

In the present study apart from evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing also evaluated for across location, the points of G5, KBCH-1, LCA 655, LCA 960 and US 341 were found located more towards AEC arrow than all other points. The length of the projections of G5, KBCH-1, LCA 655, and US 341 from were least compared to all other projections (Fig. 3d). The points of G4, LCA 353, LCA 960, LCA 655 and US 341 were found located more towards AEC arrow. On the contrary, the points of LCA 424, LAC 334, LAC 436, LCA 625, LCA 206, Arka Meghana, LCA 235, LCA 336, LCA 305, Arka Haritha, LCA 620, G3, LCA 333, LCA 639 and KBCH-1 were located opposite to AEC arrow for green fruit yield plant$^{-1}$. The length of the projections of LCA 353, G5 and US 341 from AEC was least compared to all other projections (Fig. 3e).

The mean performance of the genotypes and their adaptability patterns were inferred based on the dates of sowing of genotypes in relation to AEC in the AEC view of GGE bi-plot. The genotypes, LCA 424, LCA436, LCA235 and G3 were found widely adapted across the dates of sowing for average fruit width. The genotypes, LCA 334, LCA336, LCA206 and LCA 424 were found widely adapted across the dates of sowing for green fruit yield plant$^{-1}$. The genotypes, LCA 334, LCA 424, LCA 353, US 341 and Arka Haritha were found widely adapted across the dates of sowing for red fruit yield plant$^{-1}$. Hence, LCA 424 should be first-look genotype by the breeders for its use in breeding widely adapted high yielding chilli varieties or one of the parent in hybridization.

The mean performance of the genotypes and their adaptability patterns were also inferred based on the location of genotypes in relation to AEC in the AEC view of GGE bi-plot. The genotypes, except G5, KBCH-1, LCA 655, and US 341 f were found widely adapted across the locations of sowing for average fruit width. The genotypes, LCA 353, G5 and US 341 were found widely adapted across the locations of sowing for green fruit yield plant$^{-1}$.

#### 4.1.5 'Which–won–where' patterns

One of the features of GGE bi-plot is its ability to display 'which–won–where' pattern of genotypes. This feature is shown by polygon view of the GGE bi-plot. A polygon is drawn on the genotypes that are farthest from the bi-plot origin so that all other genotypes fall within the polygon. The perpendicular lines starting from GGE bi-plot origin are drawn to each side of the polygon. The perpendicular lines are equality lines between adjacent genotypes on the polygon. The genotypes located on the vertices of the polygon perform either the best or poorest in one or more environment (Yan *et al*. 2000). The equality lines divide the bi-plot into sectors. The vertex genotype in each sector is the winning genotype at environment whose markers (points) fall into the respective sector (Yan *et al*. 2000). Locations within the same sector share the same winning genotype and environments in different sectors have different winning genotypes. Thus polygon view of a GGE bi-plot indicates presence or absence of cross-over GEI (Yan and Rajcan, 2002).

**'Which–won–where' patterns for dates of sowing**

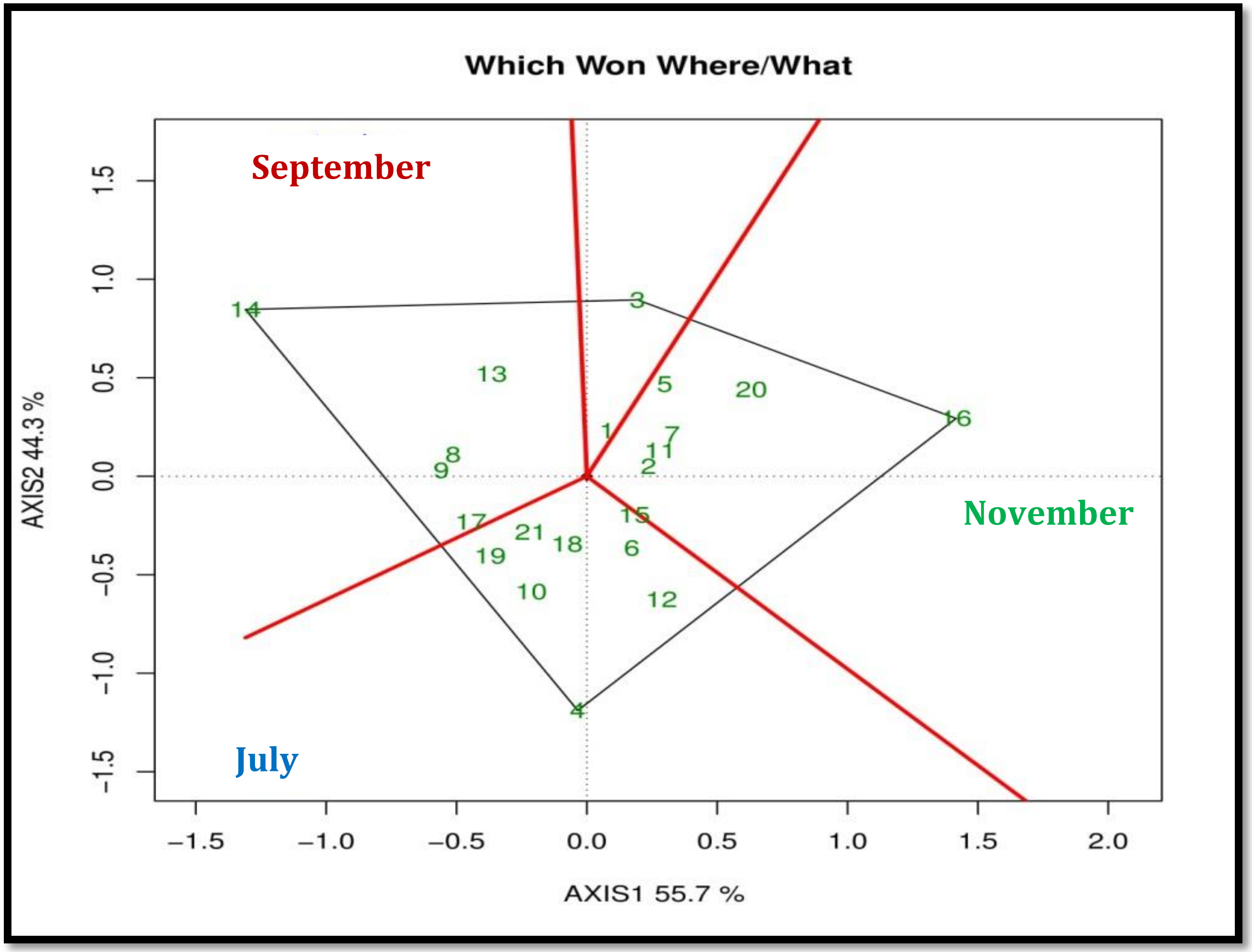
In the present study in evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing, the genotypes, Arka Meghana, KBCH-1, LCA 620, G5 and LCA 639 occupied vertices of the polygon for average fruit width in GGE bi-plot. The genotypes, Arka Meghana was winner during July sowing; KBCH-1 and LCA 620 were the winners during September sowing andG5 was winners during November sowing for fruit width (Fig. 4a) (Table 6a). The genotypes, LCA 620, LCA 436, LCA 333 and LCA 639 occupied vertices of the polygon for green fruit yield plant$^{-1}$in GGE bi-plot. The genotypes, LCA 639 was winner during July sowing; LCA 333 was the winners during September sowing and LCA 620 was winners during November sowing forgreen fruit yield plant$^{-1}$ (Fig. 4b) (Table 6a). The genotypes, LCA 620, LCA 436, LCA 333, LCA 639 and G4 occupied vertices of the polygon for red fruit yield plant$^{-1}$in GGE bi-plot. The genotypes, LCA 639 was winner during July sowing; LCA 333 was the winners during September sowing and LCA 620 was winners during November sowing for red fruit yield plant$^{-1}$ (Fig. 4c) (Table 6a).

**‘Which–won–where’ patterns for locations of sowing**

In the present study apart from evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing also evaluated for across location, the genotypes; G5, G4, US 341, LCA 436 and LCA 960 occupied vertices of the polygon for average fruit width in GGE bi-plot. The genotypes, G5 was winner at all the location for average fruit width (Fig. 4d) (Table 6b). The genotypes, US 341,KBCH-1, LCA 625 and LCA 436 occupied vertices of the polygon for green fruit yield plant$^{-1}$in GGE bi-plot. The genotypes, US 341 was winner at GKVK; KBCH-1 was the winners at Siddlaghatta and LCA 625 was winners at Srinivaspura for green fruit yield plant$^{-1}$ (Fig. 4e) (Table 6b).

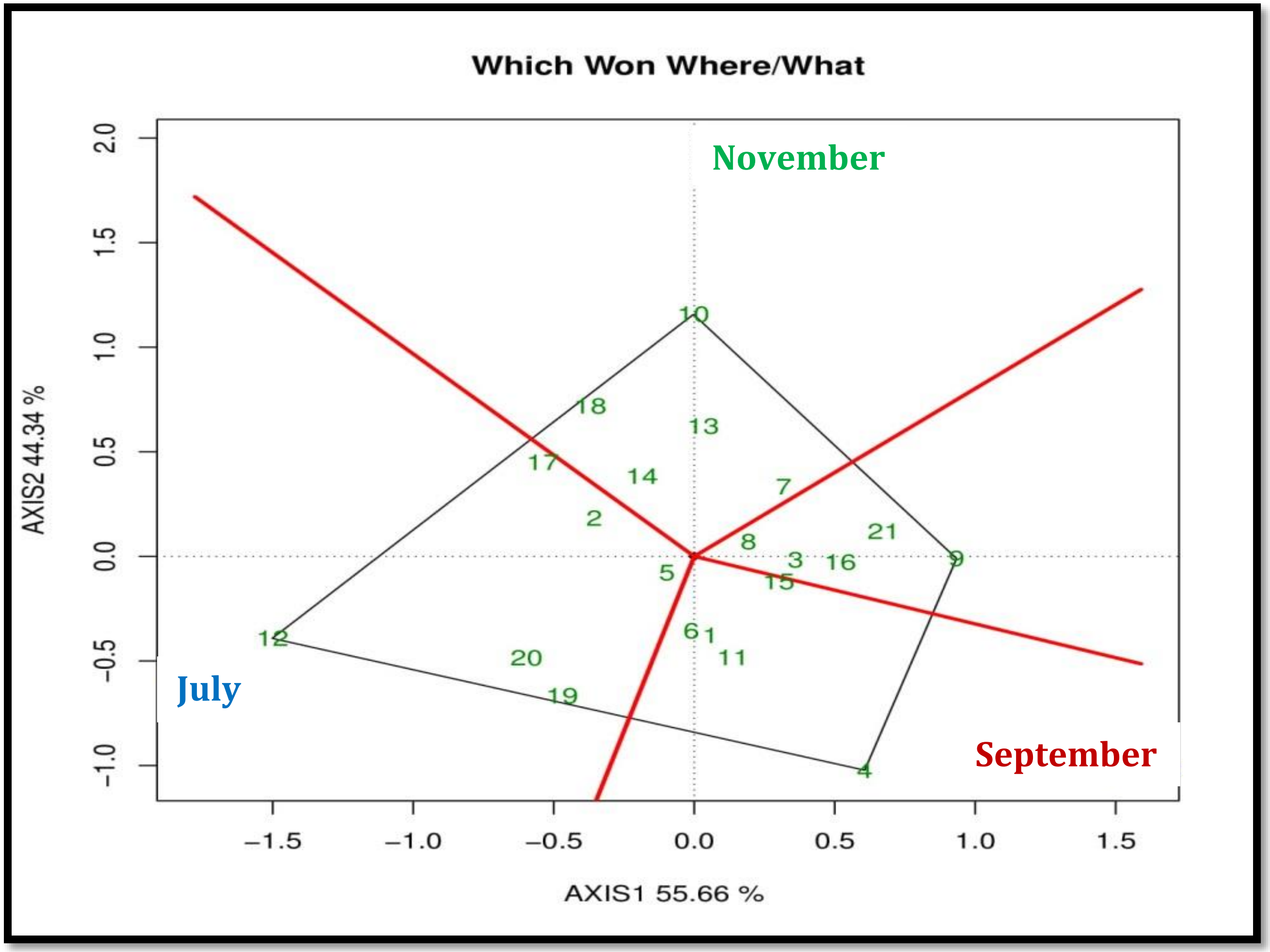
One of the most attractive feature of GGE bi-plot is its ability to exhibit ‘which-won-where’ pattern of genotypes in relation to test environments. In general, different genotypes won in different environments for different traits. In the present study in evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing, the genotypes, Arka Meghana was winner during July sowing; KBCH-1 and LCA 620 were the winners during September sowing and G5 was winners during November sowing for average fruit width (Fig. 4a). The genotypes, LCA 639 was winner during July sowing; LCA 333 was the winners during September sowing and LCA 620 was winners during November sowing for green fruit yield plant$^{-1}$ (Fig. 4b). The genotypes, LCA 639 was winner during July sowing; LCA 333 was the winners during September sowing and LCA 620 was winners during November sowing for red fruit yield plant$^{-1}$ (Fig. 4c).

In the present study apart from evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing also evaluated for across location, the genotypes; G5 was winner at all the location for average fruit width (Fig. 4d) (Table 6b). The genotypes, US 341 was winner at GKVK; KBCH-1 was the winners at Siddlaghatta and LCA 625 was winners at Srinivaspura for green fruit yield plant$^{-1}$ (Fig. 4e) (Table 6b).



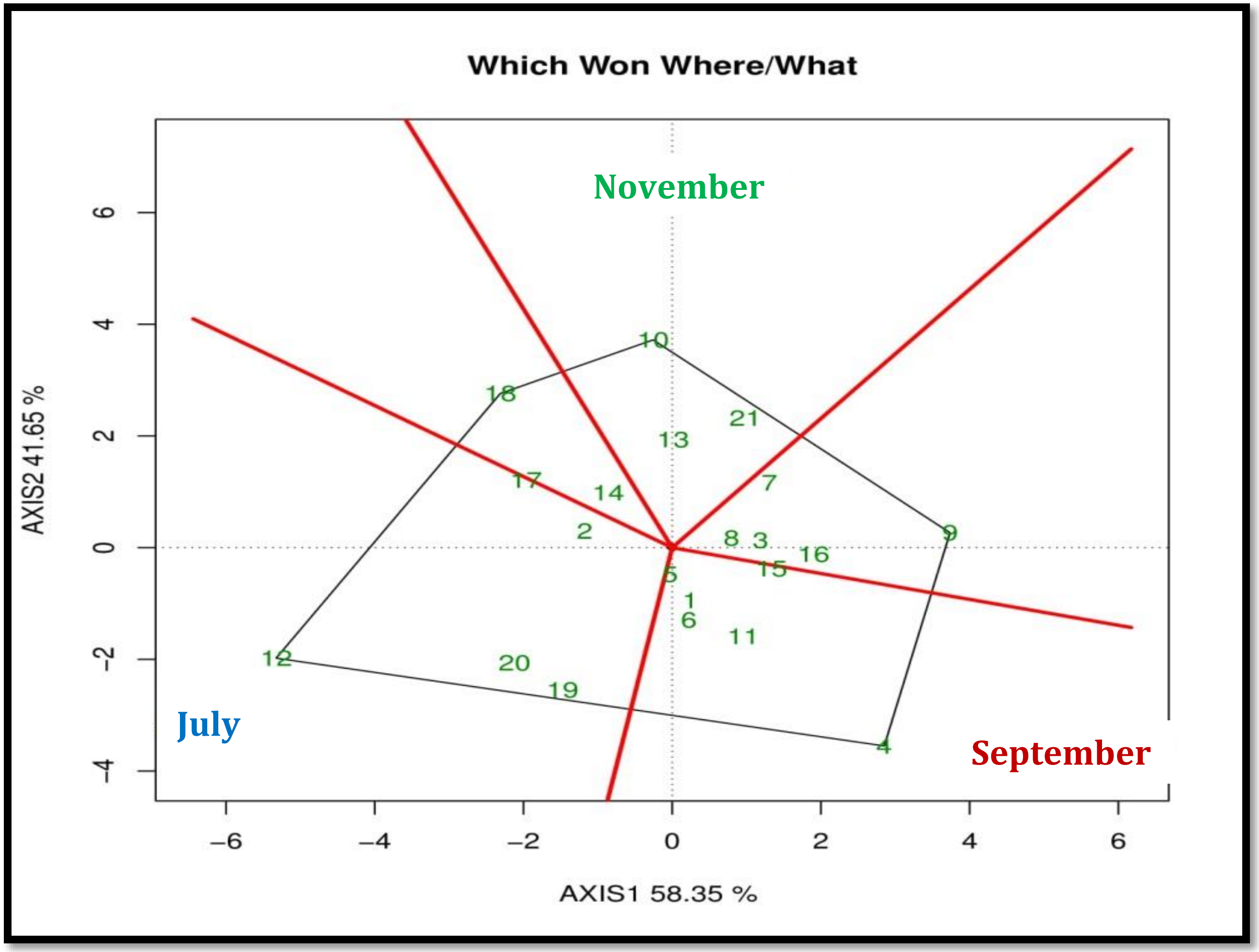

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 4a: Polygon view of GGE bi-plot based on the symmetrical scaling for 'which-won-where' pattern of genotypes and environment for fruit width across dates of sowing**



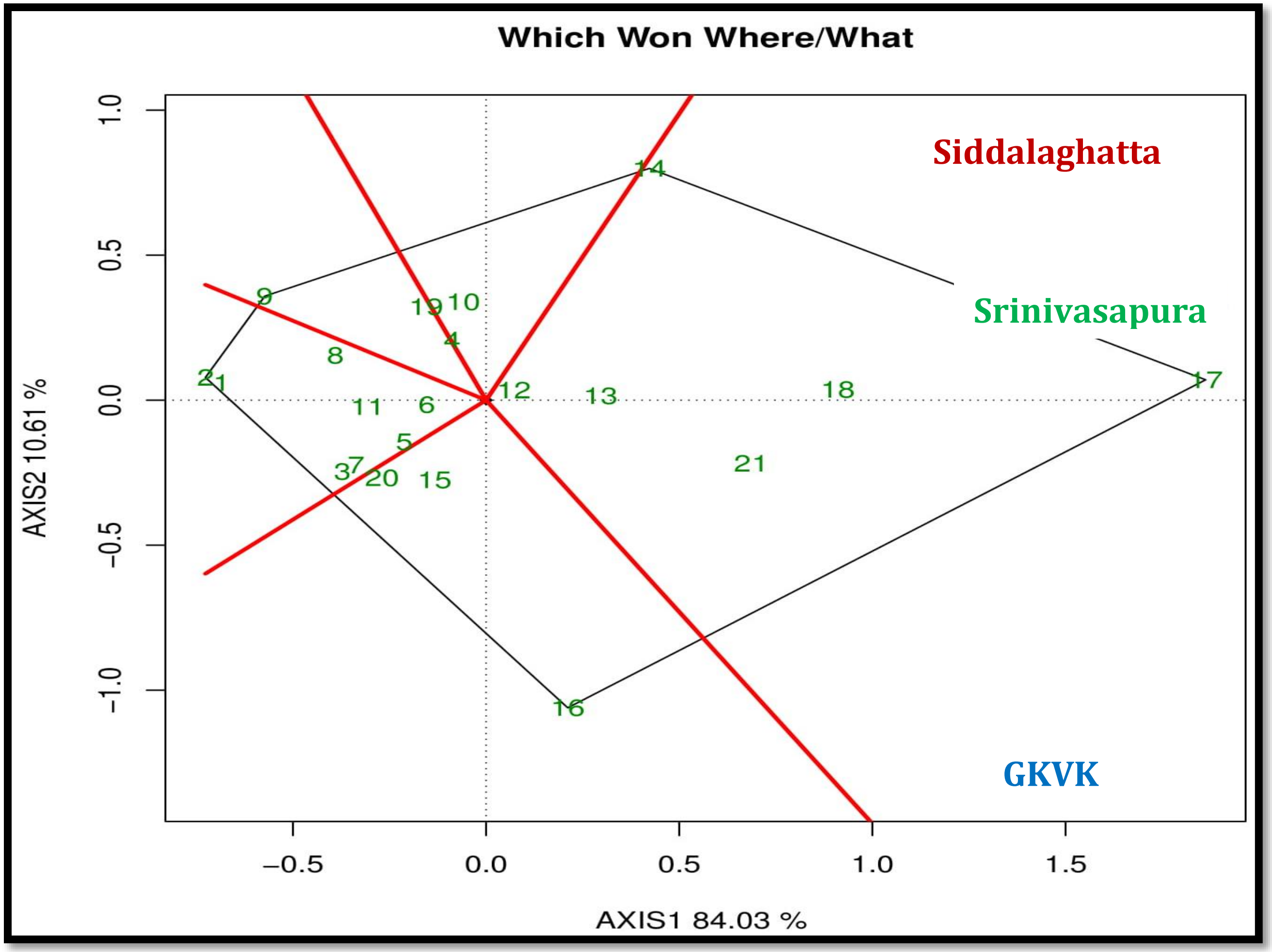

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 4b: Polygon view of GGE bi-plot based on the symmetrical scaling for 'which-won-where' pattern of genotypes and environment for green fruit yield plant$^{-1}$ across dates of sowing**



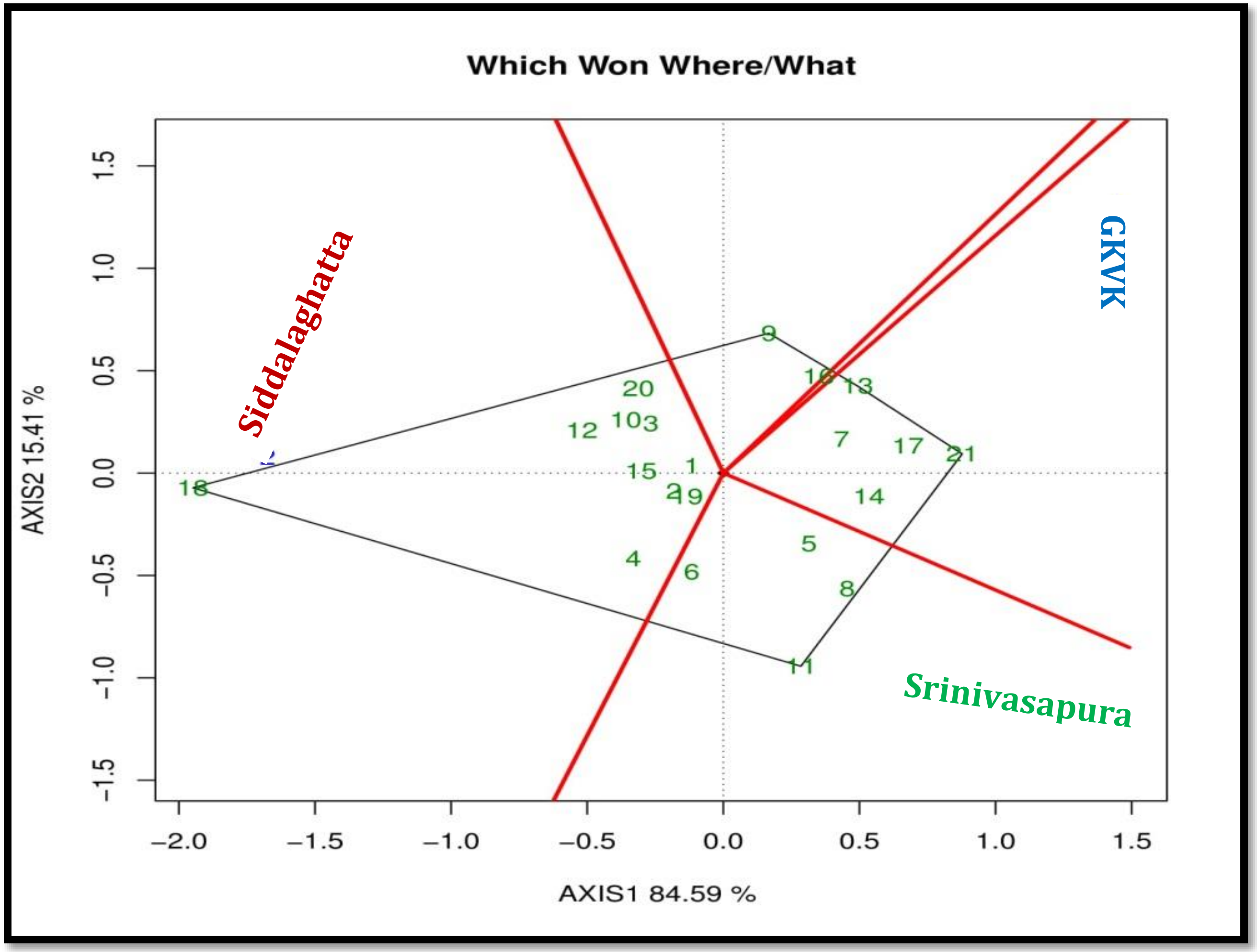

| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 4c: Polygon view of GGE bi-plot based on the symmetrical scaling for 'which-won-where' pattern of genotypes and environment for red fruit yield plant$^{-1}$ across dates of sowing**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 4d: Polygon view of GGE bi-plot based on the symmetrical scaling for 'which-won-where' pattern of genotypes and environment for average fruit width across locations**




| Sl. No. | Genotype |
|---|---|
| 01. | LCA 206 |
| 02 | LCA 235 |
| 03. | LCA 305 |
| 04. | LCA 333 |
| 05. | LCA 334 |
| 06. | LCA 336 |
| 07. | LCA 353 |
| 08. | LCA 424 |
| 09. | LCA 436 |
| 10. | LCA 620 |
| 11. | LCA 625 |
| 12. | LCA 639 |
| 13. | LCA 655 |
| 14. | LCA 960 |
| 15. | G3 |
| 16. | G4 |
| 17. | G5 |
| **Checks** | |
| 18. | KBCH-1 |
| 19. | Arka.Meghana |
| 20. | Arka Haritha |
| 21. | US 341 |

**Fig. 4e: Polygon view of GGE bi-plot based on the symmetrical scaling for 'which-won-where' pattern of genotypes and environment for green fruit yield plant$^{-1}$ across locations**

**Table 6a: Specifically suitable Lam chilli varieties for different dates of sowing**

| Sl. No. | Trait | July | September | November |
|---|---|---|---|---|
| 01. | Plant height (cm) | LCA 334 | KBCH-1 | Arka Meghana |
| 02. | Fruits plant$^{-1}$ | LCA 639 | LCA 333 | LCA 655 |
| 03. | Average Fruit length (cm) | LCA 333 | LCA 655, LCA 206 | LCA 960, US 341 |
| 04. | Average Fruit width (cm) | LCA 333 | LCA 960 | G4 |
| 05. | Green fruit yield plant$^{-1}$(g) | LCA 639 | LCA 333 | LCA 620 |
| 06. | Red fruit yield plant$^{-1}$ (g) | LCA 639 | LCA 333 | LCA 620 |

**Table 6b: Specifically suitable Lam chilli varieties and checks for different locations of sowing**

| Sl. No. | Trait | GKVK | Siddlaghatta | Srinivasapur |
|---|---|---|---|---|
| 01. | Days to 50 per cent flowering | LCA 235 | LCA 620 | G5 |
| 02. | Days to first fruit maturity | US 341 | G3 | LCA 424 |
| 03. | Plant height (cm) | LCA 333, LCA 336 | KBCH-1 | LCA 655 |
| 04. | Fruits plant$^{-1}$ | LCA 655 | KBCH-1 | G5 |
| 05. | Average Fruit length (cm) | LCA 960 | LCA 655 | LCA 206, G4 |
| 06. | Average Fruit width (cm) | G5 | G5 | G5 |
| 07. | Average fruit weight (g) | G5 | LCA 206, LCA 235 | G4 |
| 08. | Green fruit yield plant$^{-1}$(g) | US 341 | KBCH-1 | LCA 625 |
| 09. | Red fruit yield plant$^{-1}$ (g) | LCA 436 | KBCH-1 | LCA 625 |

### 4.1.6 AMMI Stability Value (ASV)

The estimate of ASV is a useful parameter for objective assessment of adaptability of the genotypes. Lower the magnitude of ASV, higher is the adaptability of the genotypes. In the present study in evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing, the estimates of ASV were lower in magnitude with respect to the LCA varieties and checks, LCA 206, G3 and KBCH-1 compared to those with respect to other genotypes for fruit width; LCA 960, LCA 334 and LCA 424 for green fruit yield plant$^{-1}$; LCA 334, LCA 655 and LCA 336 for red fruit yield plant$^{-1}$ (Syukur *et al.* 2013).

In the present study apart from evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing also evaluated for across location, the estimates of ASV were lower in magnitude with respect to the LCA varieties and checks, LCA 655, LCA 206 and LCA 336 compared to those with respect to other genotypes for average fruit width. LCA 336, LCA 206 and LCA 436 for green fruit yield plant$^{-1}$.

### 4.1.7 Stability Index (SI)

The estimate of SI is a useful parameter for objective assessment of adaptability of the genotypes based on both mean yield and adaptability. Low magnitude of SI indicates wide adaptability. In the present study in evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing, the estimates of SI were lower in magnitude with respect to the LCA varieties and checks, LCA 206, LCA 235 and LCA 625 for fruit width; LCA 334, LCA 336 and LCA424 for green fruit yield plant$^{-1}$; LCA 334, L336 and LCA 206 for red fruit yield plant$^{-1}$ (Table 7a).

In the present study apart from evaluation of Lam chilli varieties released from Lam research station Guntur across dates of sowing also evaluated for across location, the estimates of SI were lower in magnitude with respect to the LCA varieties and checks, LCA 206, LCA 235 and LCA 424 for average fruit width; LCA 336, LCA 235 and LCA206 for green fruit yield plant$^{-1}$ (Table 7b).

### 4.1.8 Identification of specifically/widely adapted genotypes based on ASV and SI

The Lam chilli varieties, LCA 206, LCA 235 and G3 were regarded as widely adaptable based on the lower estimates of ASV and SI for average fruit width (Table 7a and 8a). However, these genotypes were not the best performers for green fruit yield plant$^{-1}$. The Lam chilli varieties, LCA 334, LCA 424 and LCA 336 were regarded as widely adaptable based on the lower estimates of ASV and SI for green fruit yield plant$^{-1}$ (Table 7a and 8a). The Lam chilli varieties, LCA 334, LCA 336 and LCA 206 were regarded as widely adaptable based on the lower estimates of ASV and SI for red fruit yield plant$^{-1}$ (Table 7a and 8a). On the contrary, and as expected, the good performers such as Arka Meghana, Arka Haritha and US 341 exhibited poor adaptability. Wondimu and Aklilu (2018) have also reported that best yielders were not stable across different environments in chilli. Such negative relationship between performance levels and stability/adaptability could be attributed to the possible involvement of different sets of genes controlling *per se* performance and stability (Caligari and Mather, 1975) and trade-offs between performance and stability (Ludlow and Muchow, 1990). On location evaluation the Lam chilli varieties, LCA 206, LCA 424 and LCA 336 were regarded as widely adaptable based on the lower estimates of ASV and SI for average fruit width (Table 7b and 8b). The Lam chilli varieties, LCA 334, LCA 424 and LCA 336 were regarded as widely adaptable based on the lower estimates of ASV and SI for green fruit yield plant$^{-1}$ (Table 7b and 8b). The widely adaptable varieties are expected to contribute to sustainable chilli production. Also, breeding varieties and hybrids with high yield and wide adaptability is essential to increase economic returns to the farmers and hence maintain competitiveness of chilli with other commercial crops (Plate 3).

**Table 7a: Estimates of IPC scores and parameters to assess adaptability of 17 Lam chilli varieties released from Lam research station Guntur across dates of sowing**

| Genotype | Fruit width (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | RANK | IPCAg1 | IPCAg2 | ASI | RANK | SI | RANK |
| **LCA 206** | 0.86 | 2 | 0.03 | 0.07 | 0.08 | 1 | 3 | 1 |
| **LCA 235** | 0.8 | 1 | 0.08 | 0.01 | 0.12 | 4 | 5 | 2 |
| **LCA 305** | 0.97 | 7 | 0.07 | 0.27 | 0.29 | 17 | 24 | 13 |
| **LCA 333** | 0.99 | 10 | -0.02 | -0.36 | 0.36 | 19 | 29 | 16 |
| **LCA 334** | 0.97 | 8 | 0.10 | 0.14 | 0.20 | 9 | 17 | 6 |
| **LCA 336** | 0.98 | 9 | 0.05 | -0.11 | 0.14 | 6 | 15 | 5 |
| **LCA 353** | 0.93 | 4 | 0.10 | 0.06 | 0.17 | 8 | 12 | 4 |
| **LCA 424** | 1.03 | 14 | -0.16 | 0.04 | 0.25 | 15 | 29 | 17 |
| **LCA 436** | 0.96 | 6 | -0.18 | 0.01 | 0.27 | 16 | 22 | 8 |
| **LCA 620** | 1.01 | 12 | -0.07 | -0.18 | 0.21 | 10 | 22 | 9 |
| **LCA 625** | 0.92 | 3 | 0.09 | 0.04 | 0.14 | 7 | 10 | 3 |
| **LCA 639** | 1.01 | 13 | 0.09 | -0.19 | 0.23 | 13 | 26 | 15 |
| **LCA 655** | 1.2 | 17 | -0.11 | 0.160 | 0.23 | 14 | 31 | 18 |
| **LCA 960** | 1.24 | 18 | -0.41 | 0.27 | 0.68 | 20 | 38 | 21 |
| **G3** | 1.06 | 15 | 0.06 | -0.06 | 0.10 | 2 | 17 | 7 |
| **G4** | 1.07 | 16 | 0.45 | 0.08 | 0.70 | 21 | 37 | 20 |
| **G5** | 1.63 | 21 | -0.14 | -0.07 | 0.23 | 12 | 33 | 19 |
| **KBCH-1** | 1.28 | 19 | -0.03 | -0.10 | 0.11 | 3 | 22 | 10 |
| **Arka.Meghana** | 0.99 | 11 | -0.12 | -0.12 | 0.22 | 11 | 22 | 11 |
| **ArkaHaritha** | 0.95 | 5 | 0.20 | 0.13 | 0.34 | 18 | 23 | 12 |
| **US341** | 1.31 | 20 | -0.07 | -0.08 | 0.14 | 5 | 25 | 14 |
| **SE m** | 0.04 | | | | | | | |
| **CD @ p= 0.05** | 0.11 | | | | | | | |

**Table 7a: Contd…**

| Genotype | Green fruit yield (g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | RANK | IPCAg1 | IPCAg2 | ASI | RANK | SI | RANK |
| **LCA 206** | 172.8 | 7 | 0.46 | 2.22 | 2.24 | 5 | 12 | 4 |
| **LCA 235** | 114 | 1 | -2.3 | -1.01 | 3.55 | 11 | 12 | 5 |
| **LCA 305** | 145.3 | 5 | 2.29 | 0.02 | 3.80 | 13 | 18 | 7 |
| **LCA 333** | 186 | 8 | 4.10 | 5.91 | 7.62 | 19 | 27 | 14 |
| **LCA 334** | 119.1 | 2 | -0.60 | 0.49 | 1.40 | 2 | 4 | 1 |
| **LCA 336** | 133.5 | 3 | 0.02 | 2.10 | 2.05 | 4 | 7 | 2 |
| **LCA 353** | 278 | 14 | 1.93 | -2.03 | 2.48 | 6 | 20 | 9 |
| **LCA 424** | 142.6 | 4 | 1.21 | -0.46 | 1.76 | 3 | 7 | 3 |
| **LCA 436** | 216.3 | 10 | 5.91 | -0.14 | 9.79 | 20 | 30 | 16 |
| **LCA 620** | 253.6 | 13 | -0.32 | 6.83 | 3.73 | 12 | 25 | 11 |
| **LCA 625** | 165.1 | 6 | 1.00 | 2.83 | 2.90 | 8 | 14 | 6 |
| **LCA 639** | 244.9 | 12 | -9.41 | 2.63 | 15.77 | 21 | 33 | 19 |
| **LCA 655** | 354.3 | 19 | 0.04 | 3.68 | 2.71 | 7 | 26 | 12 |
| **LCA 960** | 301.8 | 17 | -1.28 | -2.23 | 0.20 | 1 | 18 | 8 |
| **G3** | 297.4 | 16 | 1.92 | 0.65 | 3.39 | 10 | 26 | 13 |
| **G4** | 222.8 | 11 | 3.30 | 0.05 | 5.48 | 16 | 27 | 15 |
| **G5** | 196.7 | 9 | -3.53 | -2.54 | 5.40 | 14 | 23 | 10 |
| **KBCH-1** | 448.1 | 21 | -2.53 | -4.16 | 3.042 | 9 | 30 | 17 |
| **Arka.Meghana** | 320.2 | 18 | -2.80 | 4.04 | 5.45 | 15 | 33 | 20 |
| **ArkaHaritha** | 292.2 | 15 | -3.66 | 3.00 | 6.54 | 17 | 32 | 18 |
| **US341** | 406.9 | 20 | 4.24 | -0.85 | 6.91 | 18 | 38 | 21 |
| **SE m** | 20.6 | | | | | | | |
| **CD @ p= 0.05** | 57.09 | | | | | | | |

**Table 7a: Contd…**

| Genotype | Red fruit yield (g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mean** | **RANK** | **IPCAg1** | **IPCAg2** | **ASI** | **RANK** | **SI** | **RANK** |
| **LCA 206** | 49.7 | 7 | 0.24 | -0.95 | 3.08 | 4 | 11 | 3 |
| **LCA 235** | 32.25 | 1 | -1.18 | 0.30 | 14.42 | 10 | 11 | 4 |
| **LCA 305** | 41.81 | 4 | 1.19 | 0.13 | 14.55 | 11 | 15 | 7 |
| **LCA 333** | 58.61 | 8 | 2.85 | -3.55 | 35.14 | 19 | 27 | 15 |
| **LCA 334** | 34.24 | 2 | -0.03 | -0.49 | 0.61 | 1 | 3 | 1 |
| **LCA 336** | 38.73 | 3 | 0.22 | -1.30 | 3.02 | 3 | 6 | 2 |
| **LCA 353** | 88.15 | 14 | 1.30 | 1.16 | 16.08 | 12 | 26 | 13 |
| **LCA 424** | 42.06 | 5 | 0.79 | 0.17 | 9.75 | 6 | 11 | 5 |
| **LCA 436** | 66.78 | 0 | 3.73 | 0.27 | 45.81 | 20 | 20 | 9 |
| **LCA 620** | 80.14 | 13 | -0.26 | 3.72 | 4.88 | 5 | 18 | 8 |
| **LCA 625** | 49.06 | 6 | 0.96 | -1.58 | 11.84 | 8 | 14 | 6 |
| **LCA 639** | 77.28 | 12 | -5.32 | -1.98 | 65.34 | 21 | 33 | 20 |
| **LCA 655** | 115.06 | 19 | 0.01 | 1.94 | 1.94 | 2 | 21 | 10 |
| **LCA 960** | 97.5 | 17 | -0.86 | 0.99 | 10.58 | 7 | 24 | 11 |
| **G3** | 95.09 | 16 | 1.34 | -0.38 | 16.37 | 13 | 29 | 16 |
| **G4** | 70.29 | 11 | 1.90 | -0.12 | 23.30 | 15 | 26 | 14 |
| **G5** | 60.37 | 9 | -1.97 | 1.21 | 24.16 | 16 | 25 | 12 |
| **KBCH-1** | 143.24 | 21 | -2.31 | 2.76 | 28.49 | 18 | 39 | 21 |
| **Arka.Meghana** | 103.52 | 18 | -1.48 | -2.55 | 18.28 | 14 | 32 | 18 |
| **ArkaHaritha** | 94.33 | 15 | -2.12 | -2.06 | 26.07 | 17 | 32 | 19 |
| **US341** | 121.47 | 20 | 0.98 | 2.32 | 12.30 | 9 | 29 | 17 |
| **SE m** | 6.83 | | | | | | | |
| **CD @ p= 0.01** | 24.9 | | | | | | | |

**Table 7b: Estimates of IPC scores and parameters to assess adaptability of seventeen Lam chilli varieties released from Lam research station Guntur for locations**

| Genotype | Average fruit width (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Rank | IPCAg1 | IPCAg2 | ASI | Rank | SI | Rank |
| **LCA 206** | 0.842 | 2 | 0.01 | 0.02 | 0.24 | 2 | 4 | 1 |
| **LCA 235** | 0.825 | 1 | 0.04 | -0.07 | 0.51 | 6 | 7 | 2 |
| **LCA 305** | 0.917 | 4 | 0.19 | -0.11 | 1.08 | 17 | 21 | 11 |
| **LCA 333** | 1.017 | 13 | 0.12 | 0.05 | 0.83 | 13 | 26 | 15 |
| **LCA 334** | 0.967 | 8 | 0.12 | -0.07 | 0.83 | 14 | 22 | 12 |
| **LCA 336** | 0.992 | 11 | 0.01 | 0.02 | 0.24 | 3 | 14 | 4 |
| **LCA 353** | 0.925 | 5 | 0.20 | -0.15 | 1.09 | 18 | 23 | 13 |
| **LCA 424** | 0.925 | 6 | 0.03 | -0.03 | 0.45 | 4 | 10 | 3 |
| **LCA 436** | 0.883 | 3 | 0.17 | 0.08 | 1.00 | 16 | 19 | 9 |
| **LCA 620** | 1.025 | 14 | 0.16 | 0.01 | 0.97 | 15 | 29 | 16 |
| **LCA 625** | 0.942 | 7 | 0.07 | -0.08 | 0.64 | 11 | 18 | 6 |
| **LCA 639** | 1.058 | 15 | 0.04 | 0.04 | 0.50 | 5 | 20 | 10 |
| **LCA 655** | 1.117 | 17 | 0.01 | -0.04 | 0.23 | 1 | 18 | 7 |
| **LCA 960** | 1.158 | 18 | 0.31 | -0.21 | 1.36 | 20 | 38 | 20 |
| **G3** | 1 | 12 | 0.07 | 0.15 | 0.66 | 12 | 24 | 14 |
| **G4** | 1.083 | 16 | 0.41 | 0.17 | 1.56 | 21 | 37 | 19 |
| **G5** | 1.583 | 21 | 0.29 | 0.27 | 1.32 | 19 | 40 | 21 |
| **KBCH-1** | 1.292 | 20 | 0.06 | -0.05 | 0.58 | 9 | 29 | 17 |
| **Arka.Meghana** | 0.983 | 10 | 0.04 | -0.22 | 0.53 | 8 | 18 | 8 |
| **ArkaHaritha** | 0.967 | 9 | 0.04 | 0.23 | 0.52 | 7 | 16 | 5 |
| **US 341** | 1.225 | 19 | 0.06 | -0.01 | 0.60 | 10 | 29 | 18 |
| **SE m** | 0.038 | | | | | | | |
| **CD @ p= 0.05** | 0.104 | | | | | | | |

**Table 7b: Contd…**

| Genotype | Green fruit yield plant$^{-1}$ (g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Rank | IPCAg1 | IPCAg2 | ASI | Rank | SI | Rank |
| **LCA 206** | 223.3 | 6 | -0.84 | -0.19 | 8.89 | 2 | 8 | 3 |
| **LCA 235** | 204.7 | 2 | -1.23 | 0.56 | 12.94 | 5 | 7 | 2 |
| **LCA 305** | 220.3 | 4 | -2.03 | -1.39 | 21.35 | 6 | 10 | 4 |
| **LCA 333** | 230.2 | 7 | -2.07 | 2.58 | 21.89 | 7 | 14 | 7 |
| **LCA 334** | 182.9 | 1 | 2.43 | 2.01 | 25.63 | 10 | 11 | 5 |
| **LCA 336** | 206.9 | 3 | -0.52 | 2.93 | 6.23 | 1 | 4 | 1 |
| **LCA 353** | 344.6 | 14 | 2.96 | -1.08 | 31.08 | 14 | 28 | 14 |
| **LCA 424** | 221.5 | 5 | 3.57 | 3.29 | 37.59 | 16 | 21 | 11 |
| **LCA 436** | 257.8 | 10 | 0.75 | -4.13 | 8.95 | 3 | 13 | 6 |
| **LCA 620** | 403.8 | 18 | -2.69 | -1.48 | 28.32 | 13 | 31 | 17 |
| **LCA 625** | 232.3 | 8 | 2.60 | 5.61 | 27.89 | 12 | 20 | 9 |
| **LCA 639** | 290.8 | 12 | -3.81 | -1.14 | 40.02 | 17 | 29 | 16 |
| **LCA 655** | 422.7 | 19 | 3.22 | -2.67 | 33.87 | 15 | 34 | 18 |
| **LCA 960** | 373.8 | 16 | 3.85 | 0.56 | 40.36 | 18 | 34 | 19 |
| **G3** | 376.8 | 17 | -2.14 | 0.01 | 22.47 | 8 | 25 | 13 |
| **G4** | 259.3 | 11 | 2.17 | -2.92 | 23.02 | 9 | 20 | 10 |
| **G5** | 252 | 9 | 4.71 | -0.95 | 49.46 | 19 | 28 | 15 |
| **KBCH-1** | 656.9 | 21 | -13.74 | 0.87 | 144.11 | 21 | 42 | 21 |
| **Arka.Meghana** | 354.1 | 15 | -0.86 | 0.72 | 9.11 | 4 | 19 | 8 |
| **ArkaHaritha** | 322.4 | 13 | -2.46 | -2.41 | 25.99 | 11 | 24 | 12 |
| **US 341** | 445.3 | 20 | 6.15 | -0.76 | 64.48 | 20 | 40 | 20 |
| **SE m** | 24.62 | | | | | | | |
| **CD @ p= 0.05** | 68.23 | | | | | | | |

**Table 8a: Stable and high yielding Lam chilli varieties for different dates of sowing for traits under consideration**

| Sl. No. | Trait | Lam chilli varieties |
|---|---|---|
| 01. | Average Fruit width (cm) | LCA 206, LCA 235, G3 |
| 02. | Green fruit yield plant$^{-1}$(g) | LCA 334, LCA 424, LCA336 |
| 03. | Red fruit yield plant$^{-1}$ (g) | LCA 334, LCA336, LCA 206 |

**Table 8b: Stable and high yielding Lam chilli varieties for different locations of sowing for traits under consideration**

| Sl. No. | Trait | Lam chilli varieties |
|---|---|---|
| 01. | Days to 50 per cent flowering | LCA 424, G5, LCA 206 |
| 02. | Average fruit width | LCA 206, LCA 424, LCA 336 |
| 02. | Green fruit yield plant$^{-1}$(g) | LCA 336, LCA 206, LCA 235 |


**LCA 334**


**LCA 336**


**LCA 206**


**LCA 424**

**Plate 3b: Identified stable and high yielding Lam chilli varieties**

# V SUMMARY

The present research programme was carried out at K block, Department of Genetics and Plant Breeding, UAS, G.K.V.K, Bengaluru in all three dates of sowing *viz*., July 15, September 15andNovember 15 were sown during 2017- 18. Whereas November 15 sowing was taken in farmers field Sidlaghatta (Chikkaballapur district) and Farmers field Srinivasapur (Kolar district) apart from K block, Department of Genetics and Plant Breeding, UAS, G.K.V.K, Bengaluru during 2017- 18. Study was done to know the adaptability patterns of selected Lam chilli varieties released from Lam research station Guntur. The objectives for the study consisted of identifing most promising Lam chilli varieties for yield and its component traits and to assess stability pattern of selectedLam chilli varieties across different dates of sowing and also for different locations of sowing.

The study comprised of total 17 Lam chilli varieties (LCA 206, LCA 235, LCA 305, LCA 333, LCA 334, LCA 336, LCA 353, LCA 424, LCA 436, LCA 620, LCA 625, LCA 639, LCA 655, LCA 960, G3, G4 and G5) along with 4 checks *viz*., KBCH-1, Arka Haritha, Arka Meghana and US 341.

The quantitative traits means of 21 genotypes were subjected to pooled ANOVA and Additive Main effects and Multiplicative Interaction (AMMI) model. AMMI analysis was used to detect and characterize the patterns genotype × environment interaction (GEI), Genotype + Genotype × Environment (GGE) bi-plot, AMMI stability value (ASV) and Stability Index (SI). These parameters were used to interpret GLI patterns of genotypes and identify those with specific/wide adaptation.

The stability analysis revealed that, percent variance attributed by genotype to total variance was greater than that of percent contribution by environment and interaction for both three dates of sowing and three locations of sowing. Variance attributed by both genotype, environment and interaction was found to be of considerable magnitude as indicated by the significance of variance for both three dates of sowing and three locations of sowing. Among the three dates of sowing November sowing was found to be most suitable for sowing for Lam chilli varieties for most of the characters especially for yield and its component traits. Among locations K block, Department of Genetics and Plant Breeding (GPB) was found to be the most suitable location for most of the characters particularly to obtain yield and its component trait

**The salient features of experimental findings are summarized as follows**

- The AMMI analysis of variance indicated significant variability attributable to GEI for all nine quantitative traits except for first fruit maturity and green fruit yield plant$^{-1}$ across dates of sowing and; days to 50% flowering and first fruit maturity across locations.

- The genotypes, LCA 334, LCA 424 and LCA336 with lowest estimate of ASV and SI for green fruit yield were widely adapted across three dates of sowing.

- The genotypes, LCA 336, LCA 206 and LCA 235with lowest estimate of ASV and SI for green fruit yield were widely adapted across three locations.

- The variety LCA 639 was specifically adapted for number of fruits plant$^{-1}$, green fruit yield plant$^{-1}$, red fruit yield plant$^{-1}$; the variety LCA 333 was specifically adapted for average fruit length, average fruit width; LCA 334 for plant height during July sowing.

- The variety LCA 334 was specifically adapted for number of fruits plant$^{-1}$, green fruit yield plant$^{-1}$, red fruit yield plant$^{-1}$; the variety LCA 655 and LCA 206 was specifically adapted for average fruit length; LCA 960 for average fruit width and KBCH-1 for plant height during September sowing.

- The variety LCA 620 was specifically adapted for green fruit yield plant$^{-1}$, red fruit yield plant$^{-1}$; LCA 655 for number of fruits plant$^{-}$1; the variety LCA 960 and US 341 was specifically adapted for average fruit length; G4 was specifically adapted for fruit width and Arka Meghana for plant height during November sowing.

- The variety LCA 234 was specifically adapted for days to 50 percent flowering; US 341 was specifically adapted for first fruit maturity, green fruit yield plant$^{-1}$, red fruit yield plant$^{-1}$; LCA 655 for number of fruits ; LCA 333 and LCA 336 was specifically adapted for plant height; LCA 655 was specifically adapted for number of fruits plant$^{-1}$; LCA 960 was specifically adapted for fruit length; G5 was specifically adapted for average fruit width and average fruit weight; US 341 was specifically adapted for green fruit yield plant$^{-1}$ and LCA 436 was specifically adapted for red fruit yield plant$^{-1}$ at GKVK sowing.

- The variety LCA 620 was specifically adapted for days to 50 percent flowering; G5 was specifically adapted for first fruit maturity; KBCH-1 was specifically adapted for plant height, number of fruits plant$^{-1}$, green fruit yield plant$^{-1}$ and red fruit yield plant$^{-1}$; LCA 655 for fruit length; G5 was specifically adapted for average fruit width; LCA 206 and LCA 235 was specifically adapted for average fruit weight at Siddalaghatta sowing.

- The variety LCA G5 was specifically adapted for days to 50 percent flowering, number of fruits plant$^{-1}$, average fruit width; LCA 424 was specifically adapted for first fruit maturity; LCA 655 was specifically adapted for plant height; LCA 625 was specifically adapted for green fruit yield plant$^{-1}$ and red fruit yield plant$^{-1}$; LCA 206 and G4 was specifically adapted for fruits length; G4 was specifically adapted for average fruit weight at Srinivasapura sowing.

**Future line of work**

- Identified Lam chilli varieties LCA 334, LCA 424 and LCA336suitable for different dates of sowing and LCA 336, LCA 206 and LCA 235different locations should be confirmed through multi season and multi-location trialsand can be either directly recommended as variety for cultivation or used as one of the parent in hybridization programme.

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