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## Genotype x environment interaction studies for earliness and grain yield in cowpea (*Vigna unguiculata* (L.) Walp.)

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### Abstract

The study was conducted to estimate the effects of genotype, environment, and genotype × environment interaction for earliness and grain yield in three different environments. Eighty genotypes comprising twelve lines, five testers, their resultants sixty F<sub>1</sub> crosses, and three checks were evaluated in randomized block design during the *Kharif*-2023 cropping season. Analysis of variance showed mean squares owing to environments (E) and genotypes (G) were extremely significant, indicating genotypes and settings under study were diverse. However, on the basis of earliness and stability parameters, the crosses Phule Sonali x SNAGR 12-33, Phule Vithai x EC 101998, and Phule Vithai x IC 326997 for days to 50% flowering; Phule Sonali x IC 329764 for days to maturity, Phule Vithai x IC 622602, GC 3 x IC 329764, Phule Sonali x EC 101958, and Phule Sonali x IC 329764 101958 for grain yield manifested stable performance in all three environments. Such crosses showing stable performance across the environments and may be useful in a breeding program for evolving early and high yielding cowpea hybrids for well adapted to varying environments.

**Keywords:** Cowpea, stability, G x E interaction, Eberhart and Russell, earliness and grain yield

### 1. Introduction

Cowpea is an annual herbaceous and self-pollinated grain legume crop that belongs to family Fabaceae and genus *Vigna*. It is a diploid species with  $2n = 2x = 22$  chromosomes (Ogbemudia *et al.* 2010) [26]. The precise primary center of origin and the exact center of diversity of cowpea is not known, but according to OECD, Ethiopia is the primary center of diversity of cowpea and more than 66.5% of the arable land is very suitable for cowpea production. Cowpea is drought resistant and adapted to marginal soil due to the nitrogen-fixing ability that makes it a useful staple crop for farmers in harsh environments under moisture stress and hot temperatures (Hill, 2015; Noubissietchiagm *et al.* 2010) [18, 23]. It is widely cultivated and consumed globally, especially in the arid and semiarid tropics and sub-Saharan Africa (Baidoo and Mochiah 2014) [5]. The crop is cultivated primarily for its edible seeds, young leaves (as a vegetable), pods seeds, soil improvement, and forage value (Mulugeta *et al.* 2017 and Alemu, 2015) [21, 3]. Despite the fact that cowpea is a multipurpose grain legume, its productivity is very low and unstable across environments and years due to biotic factors (weeds, insects, and diseases), abiotic factors (soil type, altitude, rainfall distribution, and intensity), and scarcity of widely adaptable and early-maturing varieties (Fonji, 2015, Horn *et al.* 2015) [13, 19]. The variability in environments, such as location effects, seasonal fluctuations, and their interactions, highly influences the production of cowpea in relation to yield potential (Adewale *et al.* 2011; Hall *et al.* 2003) [2, 15]. Genotype × environment interaction (GEI) is a challenge for plant breeders since it complicates variety recommendation because of the inconsistency of best-yielding genotypes across cropping environments and seasons. The effect of GEI is most commonly minimized by repeating the experiment at several sites in a single year, over several crop seasons in a single site, or both (Gauch *et al.* 1996 and Bandeira *et al.* 2018) [14, 6]. Even though there are many opportunities for breeders to develop cowpea varieties possessing different agronomic characteristics and inherent tolerance to a wide range of biotic and abiotic factors, progress in

cowpea breeding is very limited, either in exploiting the available genetic variability in the country or through the introduction of improved varieties. Moreover, information on the effect of genotype, environment, and their interaction and the performance stability of cowpea landraces is scanty. Therefore, evaluating cowpea genotypes in contrasting environments to generate such information is imperative. In view of this, this research was initiated with the following objectives: (i) To estimate the effects of genotype, environment, and genotype  $\times$  environment interaction on earliness and grain yield (ii) To assess the stability of cowpea genotypes for earliness and grain across environments.

## 2. Materials and Methods

### 2.1. Description of the Study Area

The experiment was conducted at three cowpea-growing environments during the *Kharif* 2023 main cropping season in Marathwada region of Maharashtra, India. The environments were Parbhani, Badnapur and Aurangabad. These three locations representing different agroecologies growing areas in Maharashtra and descriptions of the areas are presented in table 1.

**2.2. Experimental Materials and Design:** Female lines were the released cultivars and the donor lines were collected from NBPGR, New Delhi. The features of parental lines used in present study are presented in (Table 2). Sixty  $F_1$  crosses were generated from crossing five lines and twelve testers in a line  $\times$  tester mating system during *Kharif*-2022. Seventeen parents including lines and testers, sixty  $F_1$  crosses along with three check (PL 3, DC 15 and RC 10) were evaluated. The experiment was conducted using randomized block design with two replication each at three different locations and each genotype was assigned randomly. The seeds were planted with two rows, with an interrow spacing of 45 cm and 10 cm between seeds within the row. The length of row was 4.00 m<sup>2</sup>. All agronomic management practices were carried out equally and properly as per the recommendations.

### 2.3. Data Collection and Data Analysis.

Data for yield and yield related traits were collected on the basis of five sample plants which were randomly taken from the two central rows, and the average of five samples was used for analysis. The collected data were analyzed using R software, employing the linear regression model of stability proposed by Eberhart and Russell (1966) <sup>[11]</sup>.

## 3. Results and Discussion

### 3.1. Analysis of Variance for earliness and grain yield

An analysis of variance showed that the mean squares owing to environments (E) and genotypes (G) were determined to be extremely significant. (Table 3) for three characters under study. The findings showed that the genotypes and settings under study were diverse. Similar results are in agreement with those Nunes *et al.* (2014) <sup>[24]</sup>, El. shaieny *et al.* (2015) <sup>[12]</sup> and, Sharma *et al.* (2022) <sup>[31]</sup> in cowpea who reported large variation performance among different tested cowpea genotypes across environments. Mean square due to E + (G  $\times$  E) component was significant for days to 50% flowering and variations due to environment (linear) were significant for days to 50% flowering, days to maturity and grain yield/plant revealing the linear contribution of environmental effects and additive environment variance

(Patel and Jain 2012., Chaudhari *et al.* 2013., and Nassir *et al.* 2021) <sup>[28, 8, 22]</sup>. The majority of the overall variance could be explained by the environments' linear response, as seen by the larger magnitude of mean squares attributed to environments (linear) than genotypes  $\times$  environments (linear). The non-linear components of G  $\times$  E interaction (pooled deviation) were significant for days to 50% flowering, days to maturity and grain yield/plant. This implied that the differential response of stability comprised both predictable and unexpected components for this trait. (Ddmuliral *et al.* 2015., Aquino *et al.* 2016 and Manivannan *et al.* 2019) <sup>[10, 4, 20]</sup>.

### 3.2. Stability analysis earliness and grain yield:

According to Eberhart and Russell's model, a stable genotype should have high mean yield, the regression coefficient approximating to a unity ( $b_i = 1$ ), and deviation from regression ( $S^2_{di}$ ) nearly equal to zero. The regression coefficient ( $b_i$ ) measures the response of genotypes to environments. When the regression coefficient of the genotype is nonsignificantly different from unity ( $b_i = 1$ ), the genotype is said to have average response to environmental change and suitable to both poor and good environments, while if the  $b_i$  value of genotypes is significantly greater than unity ( $b_i > 1$ ), the genotype is highly responsive to environmental change and it is suitable only for a good environment. When the genotype  $b_i$  value is significantly less than unity ( $b_i < 1$ ), it indicates that the genotype is less responsive and it is suitable for poor environments. The stability parameters among all the experimental genotypes are presented in Table 4. In present study, the unit regression coefficient and non-significant value of departure from regression were shown for average stable parents and crosses. Because of their lower mean (preferred) and non-significant value of regression deviation, unit regression coefficient ( $b_i$ ) values are thought to be generally stable and adaptable to a variety of events in days to flowering parents (PL 4 and IC626138) and crosses were Phule Sonali  $\times$  SNAGR 12-33 (Mean 38.00 days,  $b_i = 1.09$ ,  $S^2_{di} = -0.52$ ), Phule Vithai  $\times$  EC 101998 (Mean = 45.50 days,  $b_i = 0.90$ ,  $S^2_{di} = 0.42$ ), and Phule Vithai  $\times$  IC 326997 (Mean 46.17 days,  $b_i = 1.01$ ,  $S^2_{di} = -0.66$ ), depicted stable performance and suitability to varied environments. The crosses showed earliness in 50% flowering with wider adaptability and it may be utilised for the development of early flowering improved varieties. The cross PL 4  $\times$  EC 738277 (Mean = 40.17 days,  $b_i = 1.21$ ,  $S^2_{di} = -0.15$ ) exhibited non-significant deviation from regression, mean value less than population mean (47.13 days), with regression coefficient more than unity appeared suitable for favourable environment for days to 50% flowering. These results confirmed the findings of Adewale *et al.* (2010) <sup>[1]</sup>. Pal *et al.* (2020) <sup>[27]</sup> who found that the genotype Paras was the most stable for days to 50% flowering across all environments. Sharma *et al.* (2022) <sup>[31]</sup> found that the genotype GC 1602 exhibited desirable stability parameters for days to 50% flowering in cowpea. For days to maturity, low mean value than population mean (73.32) and non-significant values of regression coefficient ( $b_i < 1$ ) and deviation from regression ( $S^2_{di} < 0$ ) were desirable. Among all the seventeen parents, none of line and tester exhibited stable performance across the three environments for days to maturity. However, the lines PL 4 (Mean = 57.33 days,  $b_i = -0.52$ ,  $S^2_{di} = 0.79$ ) and Phule Vithai (Mean = 68 days,  $b_i = -0.46$ ,  $S^2_{di} = -0.75$ ) exhibited low mean, coefficient less unity and least non-significant deviation from regression depicted suitability for low yielding environments. While, the cross Phule Sonali  $\times$  IC

329764 (Mean = 64.33 days,  $b_i = 0.99$ ,  $S^2d_i = -0.78$ ) expressed low mean coupled with  $b_i = 1$  and least non-significant deviation from regression showed its stability across the all types of environment. However, the cross PL 4 × EC 724805 (Mean = 65.50 days,  $b_i = 1.13$ ,  $S^2d_i = -0.09$ ) followed by GC 3 × EC 724805 (Mean = 66.17 days,  $b_i = 1.19$ ,  $S^2d_i = -0.72$ ) and Phule Sonali × IC 68786 (Mean = 69.83 days,  $b_i = 1.20$ ,  $S^2d_i = -0.70$ ) expressed low mean coupled with coefficient more than unity and least non-significant deviation from regression depicted below average stability to favourable environments. Further, the cross combination GC 3 × IC 202931 (Mean = 72.83 days,  $b_i = 0.86$ ,  $S^2d_i = -0.26$ ) had regression coefficient less than unity, and recommended to unfavourable environments only. These results were in consonance with the findings of Singh (2003) [33] who stability of 15 genotypes of cowpea lines regarding days to maturity. Similar results were also reported by Chauhan *et al.* (2004) [9], Adewale *et al.* (2010) [1], Patel and Jain (2012) [28], Simion *et al.* (2018) [32] and Sharma *et al.* (2022) [31] for days to maturity. In case of grain yield, the stability analysis evinced that crosses like Phule Vithai × IC 622602 (Mean 22.67 g,  $b_i = 1.08$ ,  $S^2d_i = -0.47$ ), GC 3 × IC 329764 (Mean 19.83 g,  $b_i = 0.97$ ,  $S^2d_i = -0.72$ ), Phule Sonali × EC 101958 (Mean 25.53 g,  $b_i = 0.91$ ,  $S^2d_i = -0.09$ ), Phule Sonali × IC 329764 101958 (Mean 27.87 g,  $b_i = 0.93$ ,  $S^2d_i = -0.72$ ) exhibited high mean value than population mean (16.69 g), regression coefficient near unity and minimum deviation from regression line manifested stable performance to all three environments. Such crosses showing stable performance across the environments may be useful in a breeding programme for evolving high yielding cowpea crosses well adapted to varying environments. Crosses showing stable performance across different environments may be advantageous in a breeding endeavour geared toward developing early, high-yielding cowpea crosses that are well-suited to various conditions. Furthermore, the crosses viz., Phule Rakhumai × SNAGR 12-33 (Mean = 17.85 g,  $b_i = 1.16$ ,  $S^2d_i = -0.63$ ), Phule Sonali × EC 724805 (Mean = 19.13 g,  $b_i = 1.30$ ,  $S^2d_i = -0.83$ ), Phule Sonali × IC 326997 (Mean = 19.63 g,  $b_i = 1.41$ ,  $S^2d_i = -1.04$ ), Phule Vithai × SNAGR 12-33 (Mean = 20.83 g,  $b_i = 1.63$ ,  $S^2d_i = -0.27$ ) and GC 3 × IC 326997 (Mean = 20.15 g,

$b_i = 1.71$ ,  $S^2d_i = -0.56$ ) had  $b_i$  values more than unity and minimum deviation from regression line indicated highly responsive to environmental change and are suitable only for favorable environments. Similarly, Rodriguez *et al.* (2007) [29] and Adewale *et al.* (2011) [2] reported differences in cowpea genotypes for their responsiveness and stability for grain yield tested at different environments. Chattopadhyay *et al.* (2001) [7] also reported EC 2543954, Sel-Tm1, and Sel-Tm3 emerged as relatively stable genotypes for yield in cowpea. Whereas, Henry *et al.* (2003) [17] noted that genotype V-585 exhibited consistent performance across varying environmental conditions, while genotype GC-3 was identified as well-suited for adverse environments. The harmony in results were reported by Patel and Jain (2012) [28] who revealed that for improvement of grain yield, the genotype GC-0121 was most stable and found 20% superior over the popular check variety GC-5. On another hand, El-shaieny *et al.* (2015) [12] reported stability parameters for genotypes Chinese Red, IT81D1064, IT85F2205 and Sudany were identified as stable for total dry grain yield. Likewise, Havaraddi and Deshpande (2018) [16] noted genotypes DC 15, DCS 47-1-1(F), C 152×IC 202872 (F) and C 152 IC 202860 (F) were identified as stable and well-adapted across environments for grain yield. In the present investigation, upon examining these factors for every genotype independently, it was found that none of the parents or hybrids demonstrated average stability across all features. Because the genotype for these traits may not display uniform responsiveness and stability patterns at the same time, it is impossible to generalize about the stability of the genotype for all of the characters. It is consequently advised that in order to develop stable hybrids, genuine hybrids would need to be tested in a variety of conditions, and the choice of parents should be made primarily on how well they combine. It has been found that the stability of its component features leads to the genotype stability for green pod yield per plant. Nunes *et al.* (2014) [24], Santos *et al.* (2015) [30], Manivannan *et al.* (2019) [20] and Sharma *et al.* (2022) [31] suggested incorporating stability into breeding operations by using prospective and stable genotypes.

**Table 1:** Description of the test environments

| Sr. No.                                                                   | Details        | Locations (Environments) |               |                     |
|---------------------------------------------------------------------------|----------------|--------------------------|---------------|---------------------|
|                                                                           |                | Parbhani (E1)            | Badnapur (E2) | Aurangabad (E3)     |
| 1                                                                         | Latitude       | 19.25° N                 | 19.86° N      | 18.72° N            |
| 2                                                                         | Longitude      | 75.76° E                 | 75.70° E      | 76.38° E            |
| 3                                                                         | Altitude       | 478.77 m                 | 586.65 m      | 637 m               |
| 4                                                                         | Soil type      | Black cotton             | Vertisol      | Medium black cotton |
| 5                                                                         | Date of sowing | 27/06/2023               | 01/07/2023    | 02/07/2023          |
| Location details:                                                         |                |                          |               |                     |
| E1: Experimental farm, Safflower Research Station, VNMKV, Parbhani.       |                |                          |               |                     |
| E2: Experimental farm, Agricultural Research Station, Badnapur            |                |                          |               |                     |
| E3: Experimental farm, National Agricultural Research Project, Aurangabad |                |                          |               |                     |

**Table 2:** Source and salient characteristics of the parents used present study.

| Sr. No  | Parents        | Source                           | Characteristics of parents                        |
|---------|----------------|----------------------------------|---------------------------------------------------|
| Females |                |                                  |                                                   |
| 1.      | PL 4           | ARS, Badnapur                    | Early                                             |
| 2.      | Phule Vithai   | MPKV, Rahuri                     | High yielding, indeterminate, dark purple flowers |
| 3.      | GC 3           | ARS, Badnapur                    | Light brown seed color                            |
| 4.      | Phule Rakhumai | MPKV, Rahuri                     | High yielding, indeterminate.                     |
| 5.      | Phule Sonali   | MPKV, Rahuri                     | High yielding.                                    |
| Males   |                |                                  |                                                   |
| 1.      | EC 101958      | Collection from NBPGR, New Delhi | White colored flowers                             |
| 2.      | IC 68786       |                                  | High yield and good number of pods                |
| 3.      | IC 329764      |                                  | Dark purple colored flowers                       |
| 4.      | IC 599262      |                                  | High yielder                                      |
| 5.      | SNAGR 12-33    |                                  | Long pod                                          |
| 6.      | IC 326997      |                                  | High 100 seed weight                              |
| 7.      | IC 202931      |                                  | High yielder                                      |
| 8.      | EC 724805      |                                  | High pod length                                   |
| 9.      | EC 738277      |                                  | Long pod                                          |
| 10.     | IC 622602      |                                  | Long pod                                          |
| 11.     | IC 626138      |                                  | Yellow colored flowers                            |
| 12.     | EC 724382      |                                  | High yielder                                      |
| Checks  |                |                                  |                                                   |
| 1.      | PL 3           | ARS, Badnapur                    | 50-55 cm tall, bush type, brown colored seeds     |
| 2.      | DC 15          | ARS, Badnapur                    | Wide adaptability                                 |
| 3.      | RC 101         | ARS, Badnapur                    | Early maturing                                    |

**Table 3:** Analysis of variance for phenotypic stability of yield and yield contributing characters in cowpea.

| Source                  | D.F. | Days to 50% flowering | Days to maturity | Grain yield/ plant |
|-------------------------|------|-----------------------|------------------|--------------------|
| Rep. within environment | 3    | 0.99                  | 0.90             | 0.94               |
| Genotypes               | 79   | 113.18**              | 223.36**         | 101.76**           |
| Environments            | 2    | 45.71**               | 87.99**          | 65.57**            |
| Geno. x Env.            | 158  | 3.39                  | 5.03             | 4.78               |
| Env. + (Geno. x Env.)   | 160  | 3.92*                 | 6.07             | 5.54               |
| Environments (Lin.)     | 1    | 91.43**               | 175.98**         | 131.15**           |
| Geno. x Env. (Lin.)     | 79   | 4.10*                 | 3.67             | 4.61               |
| Pooled deviation        | 80   | 2.65**                | 6.31**           | 4.89**             |
| Pooled error            | 237  | 0.65                  | 0.78             | 1.10               |

\*Significant at P = 0.05\*\* significant at P = 0.01

**Table 4:** Pooled mean and stability parameters for earliness and grain yield/ plant in cowpea.

| Sr. No. | Genotypes/crosses | Days to 50% flowering |       |                   | Days to maturity |       |                   | Grain yield |        |                   |
|---------|-------------------|-----------------------|-------|-------------------|------------------|-------|-------------------|-------------|--------|-------------------|
|         |                   | Mean                  | bi    | S <sup>2</sup> di | Mean             | bi    | S <sup>2</sup> di | Mean        | Bi     | S <sup>2</sup> di |
|         | Lines             |                       |       |                   |                  |       |                   |             |        |                   |
| 1.      | PL4               | 38.17                 | -0.28 | -0.58             | 57.33            | -0.52 | 0.79              | 14.33       | -0.99* | -1.09             |
| 2.      | Phule Vithai      | 47.33                 | 0.67  | 1.98 *            | 68.00            | -0.46 | -0.75             | 10.63       | 1.11   | -0.84             |
| 3.      | GC3               | 48.33                 | 1.97  | 3.09 *            | 77.33            | 1.25  | 0.96              | 12.78       | 1.31   | -1.08             |
| 4.      | Phule Rakhumai    | 49.17                 | 1.85  | 0.09              | 71.33            | 2.46  | 1.12              | 9.82        | 1.75   | -1.00             |
| 5.      | Phule Sonali      | 38.17                 | 2.16  | 4.18**            | 61.33            | 3.12  | 4.93 **           | 15.18       | 0.17   | 0.51              |
|         | Testers           |                       |       |                   |                  |       |                   |             |        |                   |
| 6.      | EC 101958         | 57.67                 | 0.81  | -0.25             | 87.83            | -0.39 | -0.46             | 9.17        | 0.32*  | -1.10             |
| 7.      | IC 68786          | 52.50                 | 1.29  | -0.56             | 92.33            | 1.25  | 0.96              | 13.38       | 2.35   | 0.45              |
| 8.      | IC 329764         | 52.83                 | 2.41  | 1.35              | 86.67            | 1.19  | -0.72             | 9.22        | 1.03   | -0.16             |
| 9.      | IC 599262         | 57.00                 | -1.24 | 4.09 **           | 97.67            | -0.58 | 4.64 **           | 12.62       | 1.07   | 5.45 *            |
| 10.     | SNAGR-12-33       | 67.67                 | -0.78 | 3.80 **           | 101.67           | -0.35 | 11.11 **          | 10.00       | 1.58   | -1.03             |
| 11.     | IC 326997         | 52.17                 | -1.23 | 6.27 **           | 86.33            | 1.25  | 0.96              | 8.43        | 0.46   | -0.27             |
| 12.     | IC 202931         | 65.67                 | -0.08 | -0.50             | 88.33            | -0.98 | 1.26              | 12.43       | 1.89   | -0.89             |
| 13.     | EC 724805         | 51.83                 | 3.56  | 0.01              | 81.67            | 2.32  | -0.43             | 14.37       | 1.88   | 5.19 *            |
| 14.     | EC 738277         | 52.50                 | 0.90  | 0.42              | 82.67            | 0.86  | -0.22             | 8.37        | 0.40   | 0.19              |
| 15.     | IC 622602         | 62.67                 | 2.69  | 2.21 *            | 92.50            | 1.85  | -0.28             | 8.90        | 0.76*  | -1.10             |
| 16.     | IC 626138         | 46.67                 | -0.93 | -0.47             | 87.50            | 0.85  | 4.14 *            | 9.22        | 0.99   | -0.94             |

|                |                              |       |         |          |       |         |           |       |        |          |
|----------------|------------------------------|-------|---------|----------|-------|---------|-----------|-------|--------|----------|
| 17.            | EC 724382                    | 66.83 | 0.67    | 1.98 *   | 92.67 | 0.98    | 1.26      | 10.78 | -1.32* | -1.10    |
| <b>Crosses</b> |                              |       |         |          |       |         |           |       |        |          |
| 18.            | PL 4 x EC 101958             | 46.17 | 3.79    | 1.11     | 71.33 | 2.51    | 0.58      | 16.64 | 0.87   | -0.16    |
| 19.            | PL 4 x IC 68786              | 42.33 | -3.34   | 2.76 *   | 63.50 | -1.85   | -0.28     | 12.40 | 3.05   | 10.74 ** |
| 20.            | PL 4 x IC 329764             | 44.83 | 4.15    | 0.80     | 69.83 | 0.81    | 9.92 **   | 18.08 | 3.10   | 37.77 ** |
| 21.            | PL 4 x IC 599262             | 39.00 | 3.17    | 6.34 **  | 61.00 | 3.52    | 2.52 *    | 13.87 | -1.87  | -0.44    |
| 22.            | PL 4 x SNAGR-12-33           | 52.50 | -1.24   | 4.09 **  | 74.83 | -1.11   | 3.67 *    | 23.48 | 0.15   | 22.39 ** |
| 23.            | PL 4 x IC 326997             | 44.83 | 1.23    | 6.27 **  | 72.83 | 0.74    | 1.19      | 16.03 | 0.71   | 4.44     |
| 24.            | PL 4 x IC 202931             | 45.67 | -0.93   | -0.47    | 68.00 | -0.13   | -0.32     | 17.25 | 0.82   | 21.19 ** |
| 25.            | PL 4 x EC 724805             | 40.50 | 0.20    | -0.20    | 65.50 | 1.13    | -0.09     | 30.05 | 5.13   | 28.25 ** |
| 26.            | PL 4 x EC 738277             | 40.17 | 1.21    | -0.15    | 68.50 | 0.72    | 1.59      | 25.77 | 1.89*  | -1.10    |
| 27.            | PL 4 x IC 622602             | 45.67 | -0.03   | 1.51     | 66.83 | -0.39   | -0.46     | 18.44 | 1.91   | 4.34     |
| 28.            | PL 4 x IC 626138             | 43.83 | 3.31    | -0.51    | 65.83 | 2.35    | 23.24 **  | 23.83 | 4.25   | 2.06     |
| 29.            | PL4 x EC 724382              | 48.83 | 0.98    | 1.41     | 72.83 | 1.87    | 4.22 *    | 23.92 | -1.83* | -1.10    |
| 30.            | Phule Vithai x EC 101958     | 45.50 | 0.90    | 0.42     | 65.33 | 0.40    | 0.03      | 18.07 | 0.31   | 7.47 **  |
| 31.            | Phule Vithai x IC 68786      | 43.67 | 3.20    | -0.17    | 65.83 | 2.38    | -0.55     | 10.80 | 0.86   | -0.84    |
| 32.            | Phule Vithai x IC 329764     | 41.00 | 0.14    | 5.81 **  | 68.83 | 0.79    | 0.53      | 12.00 | 0.44   | 13.00 ** |
| 33.            | Phule Vithai x IC 599262     | 43.17 | 2.05    | 1.71     | 64.00 | -0.28   | 8.54 **   | 13.17 | 2.27   | -0.59    |
| 34.            | Phule Vithai x SNAGR-12-33   | 45.83 | 1.57    | -0.31    | 69.67 | 0.73    | -0.78     | 20.83 | 1.63   | -0.27    |
| 35.            | Phule Vithai x IC 326997     | 46.17 | 1.01    | -0.66    | 75.33 | 0.91    | 2.54 *    | 15.57 | -2.89  | 15.85**  |
| 36.            | Phule Vithai x IC 202931     | 49.00 | 2.38*   | -0.65    | 75.83 | 3.48    | 15.77 **  | 14.37 | -0.93  | -1.07    |
| 37.            | Phule Vithai x EC 724805     | 45.83 | 1.63    | 0.99     | 72.67 | 0.01    | 1.38      | 12.40 | 0.36   | 1.56     |
| 38.            | Phule Vithai x EC 738277     | 49.33 | 1.27    | 12.68 ** | 74.33 | 1.38    | 3.22 *    | 12.73 | -1.44  | 6.26 *   |
| 39.            | Phule Vithai x IC 622602     | 43.67 | 6.23    | -0.30    | 69.83 | 3.05    | -0.51     | 22.67 | 1.08   | -0.47    |
| 40.            | Phule Vithai x IC 626138     | 44.00 | 1.94    | -0.44    | 65.67 | 0.65    | 2.95 *    | 22.50 | 2.11   | -1.01    |
| 41.            | Phule Vithai x EC 724382     | 46.00 | -1.04   | 1.61     | 67.67 | 0.06    | 0.38      | 11.92 | 0.98   | -0.35    |
| 42.            | GC3 x EC 101958              | 46.67 | 2.30    | -0.54    | 71.00 | 2.31    | 0.00      | 8.42  | -0.21  | -0.75    |
| 43.            | GC3 x IC 68786               | 48.17 | 1.01    | -0.66    | 76.50 | 2.44    | 1.66      | 15.93 | 2.04   | 7.94 **  |
| 44.            | GC3 x IC 329764              | 44.83 | 0.78    | 3.80 **  | 70.67 | 0.81    | 2.45 *    | 19.83 | 0.97   | -0.72    |
| 45.            | GC3 x IC 599262              | 46.33 | 2.22    | -0.11    | 67.17 | 0.19    | 2.30 *    | 12.37 | 0.16   | 1.91     |
| 46.            | GC3 x SNAGR-12-33            | 51.00 | 0.65    | -0.63    | 72.33 | 4.50    | 89.82 **  | 26.02 | 2.25   | 5.41 *   |
| 47.            | GC3 x IC 326997              | 47.33 | -0.17   | -0.02    | 76.33 | 1.25    | 0.96      | 20.15 | 1.71   | -0.56    |
| 48.            | GC3 x IC 202931              | 47.00 | 1.74    | -0.61    | 72.83 | 0.86    | -0.26     | 23.60 | 2.47   | 4.62 *   |
| 49.            | GC3 x EC 724805              | 42.83 | 0.42    | 7.30 **  | 66.17 | 1.19    | -0.72     | 31.33 | 5.36   | -0.13    |
| 50.            | GC3 x EC 738277              | 45.33 | 0.87    | 4.64 **  | 68.50 | -0.75   | 7.49 **   | 25.17 | -1.70  | 8.55 **  |
| 51.            | GC3 x IC 622602              | 53.50 | 2.58    | -0.27    | 75.83 | 1.99    | 1.64      | 17.10 | 3.20   | -0.83    |
| 52.            | GC3 x IC 626138              | 56.67 | 1.71    | 2.16 *   | 80.50 | 2.77    | 0.34      | 23.87 | 6.40   | 21.53 ** |
| 53.            | GC3 x EC 724382              | 54.00 | 2.38*   | -0.65    | 78.83 | 1.66    | 0.32      | 29.33 | 1.29   | 5.79 *   |
| 54.            | Phule Rakhumai x EC 101958   | 53.00 | 4.97    | -0.34    | 75.33 | 3.48    | 15.77 **  | 10.98 | 0.59   | -1.10    |
| 55.            | Phule Rakhumai x IC 68786    | 49.83 | -1.35   | 9.92 **  | 74.17 | 1.76    | 33.59 **  | 16.00 | 1.39   | 12.09 *  |
| 56.            | Phule Rakhumai x IC 329764   | 49.17 | -1.12   | 0.57     | 81.67 | 0.22    | 6.28 **   | 10.63 | 1.05   | 0.85     |
| 57.            | Phule Rakhumai x IC 599262   | 47.33 | 1.82    | -0.29    | 73.17 | 2.65    | 0.42      | 17.77 | 2.58   | -0.41    |
| 58.            | Phule Rakhumai x SNAGR-12-33 | 50.00 | -1.60   | 6.92 **  | 75.00 | 1.23    | 17.39 **  | 17.85 | 1.16   | -0.63    |
| 59.            | Phule Rakhumai x IC 326997   | 43.17 | 0.45    | 17.77 ** | 66.83 | -0.22   | 6.28 **   | 19.42 | 2.62   | -1.01    |
| 60.            | Phule Rakhumai x IC 202931   | 53.50 | 3.48    | -0.48    | 80.17 | 3.58    | -0.23     | 8.43  | -1.00  | -0.72    |
| 61.            | Phule Rakhumai x EC 724805   | 43.50 | 1.54    | 0.12     | 69.17 | 0.81    | 2.45 *    | 16.12 | -2.08  | 10.93 ** |
| 62.            | Phule Rakhumai x EC 738277   | 42.83 | 2.92    | 0.29     | 73.00 | 1.46    | 1.01      | 16.48 | 0.85   | 3.61 *   |
| 63.            | Phule Rakhumai x IC 622602   | 48.67 | 1.66    | -0.62    | 77.67 | 1.52    | -0.71     | 12.03 | -0.82  | 3.31 *   |
| 64.            | Phule Rakhumai x IC 626138   | 43.50 | 2.19    | -0.13    | 74.67 | 1.86    | -0.20     | 26.13 | 2.61   | 6.77 **  |
| 65.            | Phule Rakhumai x EC 724382   | 50.00 | -0.98   | 10.73 ** | 74.67 | 0.14    | -0.16     | 13.47 | -2.28  | 32.43 ** |
| 66.            | Phule Sonali x EC 101958     | 44.50 | 0.45    | -0.39    | 75.67 | 0.93    | 0.47      | 25.53 | 0.91   | -0.09    |
| 67.            | Phule Sonali x IC 68786      | 42.17 | 1.46    | -0.42    | 69.83 | 1.20    | 0.73      | 13.77 | 3.11   | 0.93     |
| 68.            | Phule Sonali x IC 329764     | 43.67 | -1.52   | 5.38 **  | 64.33 | 0.99    | -0.78     | 27.87 | 0.93   | -0.72    |
| 69.            | Phule Sonali x IC 599262     | 43.17 | 2.61    | 6.74 **  | 66.17 | 1.73    | 1.31      | 10.80 | 1.80   | 4.02 *   |
| 70.            | Phule Sonali x SNAGR-12-33   | 38.00 | 1.09    | -0.52    | 63.00 | -0.59   | -0.05     | 25.32 | 0.25   | 3.99 *   |
| 71.            | Phule Sonali x IC 326997     | 43.00 | 2.38*   | -0.65    | 69.50 | -1.13   | -0.09     | 16.93 | 1.41   | -1.04    |
| 72.            | Phule Sonali x IC 202931     | 47.17 | -2.665* | -0.61    | 70.00 | 0.80    | 136.30 ** | 14.32 | 1.18   | -1.10    |
| 73.            | Phule Sonali x EC 724805     | 48.67 | 1.21    | -0.15    | 70.00 | 0.00 ** | -0.78 **  | 19.13 | 1.30   | -0.83    |
| 74.            | Phule Sonali x EC 738277     | 44.17 | -2.41   | 1.35     | 67.33 | -0.47   | 0.90      | 15.35 | 0.35   | 6.15 *   |
| 75.            | Phule Sonali x IC 622602     | 46.83 | -1.01** | -0.66    | 71.00 | -0.26   | 1.07      | 15.28 | -1.74  | -0.33    |
| 76.            | Phule Sonali x IC 626138     | 44.33 | -2.05   | 1.71     | 69.50 | 0.67    | 0.24      | 21.12 | 0.89   | -0.76    |
| 77.            | Phule Sonali x EC 724382     | 43.67 | 1.71    | 2.16 *   | 70.50 | 1.34    | 3.29 *    | 18.52 | 0.10   | 3.11     |
| <b>Checks</b>  |                              |       |         |          |       |         |           |       |        |          |
| 78.            | DC15                         | 46.00 | 3.57    | 15.31 ** | 65.33 | 0.91    | 2.54 *    | 23.12 | 1.79   | -0.26    |
| 79.            | PL3                          | 39.17 | -4.80   | 1.20     | 64.83 | -1.32   | 0.07      | 16.85 | 0.12   | 1.91     |
| 80.            | RC101                        | 37.50 | 1.29    | -0.56    | 68.00 | -0.26   | 1.07      | 16.45 | -0.71  | -0.02    |

#### 4. Conclusion

On the basis of earliness and stability parameters over environments, the crosses Phule Sonali x SNAGR 12-33, Phule Vithai x EC 101998 and Phule Vithai x IC 326997 for days to 50% flowering, Phule Sonali x IC 329764 for days to maturity and Phule Vithai x IC 622602, GC 3 x IC 329764, Phule Sonali x EC 101958 and Phule Sonali x IC 329764 101958 for grain yield manifested stable performance to all three environments. Such crosses showing stable performance across the environments and may be useful in a breeding programme for evolving early and high yielding cowpea hybrids well adapted to varying environments.

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#### 6. Conflict of Interest: None

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