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Reproductive efficiency as a gateway trait for Chickpea improvement: Assessing genetic variability for flower drop, pod setting and seed yield

Bharath S R[1], Chaitanya Ghalagi[1], Afsanabanu Manik[2], Basavaraja B[3], Nanjareddy Y A[1], Nataraja Karaba N[1], Prasad T G[1], Mohan Raju B[1], Shankar A G[1], Geetha K N[4], Bhausaheb Tambat[1*]

[1] Department of Crop Physiology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka India

[2] Department of Crop Physiology, University of Agricultural Sciences, Raichur, Karnataka India

[3] Department of Seed Science and Technology, AICRP on Seed (Crops), GKVK, Bengaluru, Karnataka, India

[4] Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

Corresponding Author: Bhausaheb Tambat

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Abstract

Chickpea (*Cicer arietinum* L.) is an important pulse crop that contributes significantly to human nutrition due to its high protein content. However, its productivity is constrained by poor reproductive efficiency, particularly flower drop and reduced pod formation, especially under rainfed conditions. The present study was conducted to evaluate variability among chickpea genotypes for germination, physiological traits, reproductive efficiency, and yield performance. Ten chickpea genotypes were assessed for growth parameters, flowering behavior, flower drop, fruiting efficiency and yield-related traits under field conditions. Significant variability was observed among the genotypes for reproductive and yield attributes. Genotypes JG-14, KAK-2, ICCV-10, A-1, and BGD-103 exhibited higher fruiting efficiency and superior yield performance, whereas GKB-10, GBM-2, JAKI, and MNK-1 showed lower fruiting efficiency and yield. Fruiting efficiency showed a positive association with pod number and seed yield, while a negative association was observed with flower drop, indicating its importance as a selection criterion for improving chickpea productivity. JG-11 and JG-14 recorded better germination performance among the evaluated genotypes. The identified variability for fruiting efficiency, reproductive traits, and yield potential provides valuable genetic resources for chickpea improvement. Selection of genotypes with higher fruiting efficiency, reduced flower drop, and better pod-setting ability can contribute to the development of high-yielding and stable chickpea varieties adapted to stress-prone environments.

Keywords: Chickpea, fruiting efficiency, flower drop, pod number, seed yield

Introduction

Chickpea (*Cicer arietinum* L.) is a cool-season legume crop belonging to the family Fabaceae. It is one of the most important grain legumes, cultivated in more than 51 countries, covering an area of over 13.5 million hectares with an average global productivity of about 967.6 kg ha^{-1}. India is the largest producer and consumer of chickpea, contributing about 67.02% of the global production (Ghosh *et al*., 2014) [9]. The crop is generally sown during October–November and harvested from February to April in South India. The crop duration ranges from 90 to 110 days depending on the variety. Desi varieties are generally short-duration types, whereas Kabuli varieties require a longer period for maturity. Chickpea is predominantly cultivated in arid and semi-arid regions under rainfed conditions, utilizing stored soil moisture in subtropical environments or seasonal rainfall in Mediterranean-type environments. Under such conditions, yield losses frequently occur due to terminal drought stress (Yadav *et al*., 2006 [31]; Toker *et al*., 2009).

Chickpea productivity is affected by several constraints, among which flower drop is a major factor. Excessive flower abscission accounts for 65–70% loss in reproductive structures, resulting in reduced pod formation and yield (Shukla Niharika, 2013) [24]. Chickpea seeds are the edible part of the plant and are nutritionally rich, containing approximately 23% protein, 64% carbohydrates, and significant amounts of minerals such as iron (7 mg) and zinc (3 mg) (ICRISAT). In addition to its nutritional importance, chickpea contributes to soil fertility through biological nitrogen fixation by symbiotic association with *Rhizobium* species. It is also used as animal feed, supporting livestock production by improving egg and milk yield (Gaur *et al*., 2007) [8].

Although chickpea is considered relatively drought tolerant, it is sensitive to high temperature stress and waterlogging, which negatively affect reproductive development and increase flower drop. In legume crops, a large number of flowers are produced, but only a limited proportion develop into mature pods. Flower shedding varies from 60–92% in soybean (*Glycine max*) (Nahar and Ikeda, 2002; Saitoh *et al*., 2004) [19, 22], 70–90% in mungbean (*Vigna radiata*) (Kumari and Verma, 1983; Mondal *et al*., 2011) [16, 18], 80–91% in cowpea (*Vigna unguiculata*) (Hossain *et al*., 2006) [10], 80–95% in pigeonpea (*Cajanus cajan*) (Fakir et al., 1998) [6], and 80–95% in chickpea (*Cicer arietinum* L.) (Shukla Niharika, 2013) [24].

High reproductive abscission in legumes is mainly associated with late-formed flowers and pods. These reproductive structures may receive inadequate assimilates due to poor phloem development in the distal regions of racemes, resulting in flower and immature pod abortion (Mondal *et al*., 2011) [18]. Reduced assimilate supply to developing reproductive organs is one of the major causes of flower and pod abscission (Wiebold and Panciera, 1990) [29]. Therefore, improving flower retention and reducing reproductive abortion can contribute significantly to increasing yield in legume crops.

Drought, cold, and salinity are the major abiotic stresses affecting chickpea production, with drought being the most important constraint (Croser *et al*., 2003) [5]. Chickpea is exposed to two major types of drought stress: terminal drought, where soil moisture declines continuously towards the end of the growing season, and intermittent drought, where rainfall is irregular and insufficient. Vegetative growth is mainly affected by intermittent drought, whereas reproductive growth is severely influenced by terminal drought stress (Ganjeali *et al*., 2005) [7]. High temperature, drought, and photoperiod are major limitations affecting yield potential and harvest index in legumes (Khattak et al., 2001) [12].

Increasing fruiting efficiency is therefore a major focus for improving chickpea productivity. This can be achieved through the identification and selection of genotypes with higher flower-to-pod conversion efficiency. Hormonal regulation, particularly involving ethylene and abscisic acid (ABA), plays an important role in flower drop. In addition, source–sink relationships influence reproductive success; increasing photosynthetic source capacity and improving sink strength through enhanced pod setting can improve fruiting efficiency.

Hence, screening chickpea genotypes for variability in flowering pattern, flower production, flower drop, and fruiting efficiency is essential for crop improvement. Understanding the morpho-physiological basis of reproductive efficiency and its association with yield-related traits will support the development of high-yielding and stress-tolerant chickpea varieties. Therefore, the present study was undertaken to evaluate flower production, flowering behavior, reproductive efficiency (flower-to-pod ratio), nutritional traits, and abiotic stress tolerance among ten selected chickpea genotypes to identify key factors determining yield performance.

Material and Methods

Yield in leguminous crops is determined by the number of flowers per plant, percentage of pod set and number of seeds per pod. Although chickpea plants produce a large number of flowers, only a small proportion successfully develop into pods, resulting in reduced productivity. In addition, abiotic stresses such as drought and high temperature further limit crop performance. Chickpea, one of the important pulse crops, is also affected by these constraints. Therefore, understanding the variation in flowering behavior, pod setting, and fruiting efficiency among chickpea varieties is essential for evaluating their performance. The materials and methods followed to achieve the objective are described below.

Seed Materials Collection

Seeds of chickpea varieties were procured from the Agricultural Research Station (ARS), Gulbarga. These genotypes were used to assess fruiting efficiency and abiotic stress tolerance in chickpea.

Screening of chickpea varieties to assess the fruiting efficiency of leading chickpea varieties

A field experiment was conducted at the Department of Crop Physiology experimental plot, UAS, GKVK, Bengaluru-65, using ten chickpea varieties. The experiment was laid out in a randomized complete block design (RCBD), with the experimental area divided into blocks. Each plot measured 2.5 m × 2 m and was uniformly fertilized with the recommended dose of fertilizers during land preparation. The chickpea varieties were grown under field conditions following standard crop management practices to study fruiting efficiency. Prophylactic measures were adopted whenever required, and irrigation was provided at four-day intervals. Observations were recorded at different growth stages for plant height, number of branches, days to 50% flowering, number of flowers per plant, flower drop, number of pods per plant, fruiting efficiency, biomass, seed yield, and test weight.

Statistical Analysis

The field experiment was conducted using a randomized complete block design (RCBD), while the pot experiment was conducted using a completely randomized block design (CRBD). One-way analysis of variance (ANOVA) was performed for the field experiment, and factorial analysis was carried out for the pot experiment.

Results and Discussion

Pulses are rich in protein and are an important source of nutrition in the human diet. Most pulse crops are grown in marginal areas where they are frequently exposed to biotic and abiotic stresses, resulting in reduced growth and productivity. Among abiotic stresses, high temperature and drought are the major factors limiting crop yield. In addition, excessive flower drop is a common phenomenon in pulses, leading to poor pod set and reduced fruiting efficiency. Therefore, it is important to understand the factors influencing flower production, pod set, and fruiting efficiency to identify superior genotypes with better yield under moisture and heat stress. Hence, the present study was conducted in chickpea to identify genotypes with high fruiting efficiency, improved tolerance to abiotic stress, and better nutrient content.

Variability in growth parameters of ten chickpea varieties at 45 DAS

Growth parameters were also recorded at 45 days after sowing (DAS), and significant variability was observed among the genotypes. Plant height ranged from 36.67 to 54.00 cm, with a mean of 42.31 cm. The number of primary branches showed no significant increase compared to 30 DAS and ranged from 1.0 to 3.0. The number of secondary branches ranged from 4.0 to 7.2. Biomass accumulation increased significantly from 30 DAS and ranged from 10.2 to 28.4 g. As chickpea plants enter the reproductive stage around 45 DAS, the number of flowers and pods was also recorded. The number of flowers ranged from 9.40 to 15.57, with a mean of 12.94, while the number of pods ranged from 1.0 to 2.67 (Table 1).

The present study revealed significant variability among the chickpea genotypes for growth and reproductive traits at 45 days after sowing (DAS), indicating the presence of substantial genetic diversity. Significant variation was observed in plant height, secondary branches, biomass, flower production, and pod formation. The increased biomass at 45 DAS reflects active vegetative growth and the onset of the reproductive stage. Variation in secondary branching may contribute to improved canopy development and reproductive performance (Table 1).

Table 1: Variability in growth parameters of ten chickpea varieties at 45 DAS

Parameters	Minimum	Maximum	Mean	SD	SEM	CD@ 5%	CV (%)
Plant height(cms)	36.67	54.10	42.31	0.67	0.22	0.66*	18.01
Primary branches	1.00	3.00	1.67	0.02	0.01	0.029*	14.98
Secondary branches	4.00	7.20	5.11	0.09	0.03	0.09*	18.75
Biomass (g)	10.20	28.40	19.37	0.22	0.07	0.21*	19.24
Number of flowers	9.40	15.57	12.94	0.24	0.08	0.24*	15.72
Number of pods	1.00	2.67	0.25	0.24	0.08	0.24*	15.5

* Significant at 5% level

Flowering and early pod development are important determinants of fruiting efficiency and seed yield in chickpea. Genotypes with higher flower production and better pod set have greater yield potential. The observed variability provides opportunities for selecting superior genotypes for breeding programmes. Similar findings were reported by Burton and DeVane (1953) and Panse and Sukhatme (1985) [2, 20], who emphasized the importance of genetic variability for effective selection. Wang *et al*., (2025) and Varshney *et al*. (2013) [27, 28] also reported that variation in growth and reproductive traits contributes to improved productivity and adaptation in chickpea. The positive association of early plant height, branching, and biomass with crop productivity has also been reported in pulse crops by Singh *et al*. (2017) and Kumar *et al*. (2019) [14, 25].

Variability in growth parameters of ten chickpea varieties at 60 DAS.

Growth and yield parameters were recorded at 60 days after sowing (DAS), and significant variability was observed among the genotypes. Plant height ranged from 59.00 to 77.33 cm, with a mean of 67.86 cm. No significant difference was observed in the number of primary branches, whereas the number of secondary branches ranged from 5.00 to 8.13, with a mean of 7.01. The number of flowers ranged from 29.00 to 65.50, while the number of pods increased with crop age and ranged from 18.00 to 46.63, with a mean of 30.46 (Table 2).

Table 2: Variability in growth parameters of ten chickpea varieties at 60 DAS.

Parameters	Min	Max	Mean	SD	SEM	CD@ 5%	CV (%)
Plant height(cm)	59	77.33	67.86	0.97	0.32	0.96*	15.9
Primary branches	1.0	3.0	1.69	0.03	0.01	0.034*	17.30
Secondary branches	5.00	8.13	7.01	0.11	0.03	0.11*	19.88
Number of flowers	29	65.50	52.24	0.66	0.22	0.66*	18.44
Number of pods	18.00	46.63	30.46	0.83	0.27	0.82*	17.95
Biomass(g)	15.5	35.5	21.5	0.78	0.25	0.78	22.80

* Significant at 5% level

The present study revealed significant variability among chickpea genotypes for growth and reproductive traits at 60 days after sowing (DAS), indicating considerable genetic diversity. Variation in plant height, secondary branches, flower production, and pod formation reflects differences in vegetative growth and reproductive potential among the genotypes. The non-significant variation in primary branches suggests limited genetic influence on this trait at this stage. The variation in flower number and pod formation indicates differences in reproductive efficiency and yield potential among the genotypes (Table 2). Such variability provides opportunities for selecting superior genotypes for crop improvement. Similar findings were reported by Upadhyaya *et al*. (2007) [8], who observed significant genetic variability for yield-related traits in chickpea germplasm. Jha *et al*. (2015) [11] also reported considerable variation among chickpea genotypes for growth, flowering, and yield attributes, suggesting the potential for effective selection. Similarly, Kumar *et al*. (2018) [15] and Ali *et al*. (2020) emphasized that variability in branching pattern, reproductive traits, and pod formation contributes significantly to yield improvement in chickpea.

Variability in flowering yield parameters

Days to 50 per cent flowering

Days to 50% flowering ranged from 43 to 60 days, with a mean value of 52 days (Table 3). The varieties JG-11 and JG-14 were identified as early flowering types, attaining 50% flowering at 43 days after sowing (DAS). In contrast, GKB-10 and GBM-2 were late flowering varieties, reaching 50% flowering at 59 and 56.67 DAS, respectively (Table 3).

Table 3: Variability in the Reproductive and yield at 90 DAS

Varieties	Mean No. of Days to 50% flowering	Flower drop	Number of pods	Fruiting efficiency (%)
GBM-2	56.67	69.5	52.64	32.11
GKB-10	59.33	79.39	38.5	23.46
JAKI	54	72.61	39.92	29.84
A-1	49.33	66.17	57.5	40.24
ICCV-10	49	58.17	56.35	43
BGD-103	50.33	58.5	54.25	41.48
JG-11	43	56	42.17	25.81
JG-14	48	54.44	69.05	46.71
MNK-1	54	73	51.61	39.38

KAK-2	50	57.47	57.72	41.33
Mean	51.37	65.77	51.97	36.59
SD	0.6	1.03	1.13	0.858
SEM	0.2	0.34	0.37	0.286
CD @ 5%	0.59*	1.02*	1.12*	0.849*
CV (%)	12.11	18.01	19.81	18.8

* Significant at 5% level

Flower drop per plant

Flower drop was recorded daily from the initiation of flowering until maturity. The percentage of flower drop ranged from 54.44 to 79.39, with a mean of 65.77 (Table 3). The highest flower drop was recorded in GKB-10 and MNK-1, whereas the lowest was observed in JG-14 and JG-11 (Table 3). Flower and immature pod abscission are major constraints limiting chickpea productivity. Abiotic stresses, particularly heat stress and terminal drought, significantly affect reproductive development, resulting in reduced pod formation and increased reproductive abortion. Such stresses can cause substantial yield losses compared with irrigated conditions by reducing pod production and final seed yield (Shukla Niharika, 2013) [24].

Total number of flowers per plant

The total number of flowers per plant was calculated by considering both the flowers retained on the plant and the flowers that dropped. The number of flowers per plant ranged from 29.00 to 65.50, with a mean of 52.24 (**Table 3**). JG-11 and BGD-103 recorded the highest number of flowers, whereas GKB-10 and KAK-2 recorded the lowest. This indicates that inadequate assimilate supply to later-formed pods may be a major constraint affecting reproductive success. Genotypes that produce a higher number of flowers within a shorter flowering period have a greater probability of successful pod setting and retention until maturity (Fakir, 1997).

Fruiting efficiency (per cent)

Fruiting efficiency was calculated as the ratio of the number of pods formed to the total number of flowers produced per plant. The values ranged from 23.46 to 46.71, with a mean of 36.59 (Table 3). The highest fruiting efficiency was recorded in JG-14 (46.71), whereas the lowest was observed in GKB-10 (23.46).

Fruiting efficiency is an important trait that influences pod formation and seed yield in chickpea. A significant correlation between fruiting efficiency and pod number indicates that increased pod formation enhances fruiting efficiency through effective translocation of photosynthates from source to sink. Similarly, the positive association between fruiting efficiency and seed yield suggests that genotypes with higher fruiting efficiency produce greater yields.

Flower and immature pod abortion are major constraints limiting pulse productivity. Reduction in flower drop can improve pod setting and increase yield potential. Earlier studies have suggested that yield in legumes is often influenced by source–sink relationships, as assimilate availability plays a major role in the retention and development of reproductive structures (Fakir, 1997; Kuroda et al., 1998) [17].

In the present study, variability in flower drop and fruiting efficiency was assessed among chickpea genotypes. High-yielding genotypes exhibited higher fruiting efficiency, whereas low-yielding genotypes showed lower fruiting efficiency. The lower flower number in some genotypes may reduce competition for assimilates, resulting in better conversion of flowers into pods. Similar observations were reported by Xiangwen Fang *et al*. (2010) [30], who highlighted the importance of assimilate partitioning in determining reproductive success.

Therefore, improvement of fruiting efficiency through reduced flower drop, better assimilate translocation, and enhanced pod-setting ability can serve as an effective approach for developing high-yielding chickpea varieties.

Yield parameters

Significant variability was observed among chickpea varieties for yield and yield-related traits (**Table 3**). The number of pods per plant ranged from 38.50 to 69.05, with a mean of 51.97. JG-14 recorded the highest number of pods, whereas GKB-10 recorded the lowest. Pod weight varied from 9.20 to 48.63 g, with the maximum recorded in MNK-1 and the minimum in GKB-10. The Seed weight ranged from 6.22 to 36.74 g, with a mean of 17.22 g. The highest seed weight was recorded in MNK-1, while the lowest was observed in GKB-10. Shell weight showed significant variation, ranging from 1.7 to 10.4 g. Seed yield varied from 321.73 to 823.83 g, with JG-14 recording the highest yield and KAK-2 the lowest. Test weight ranged from 17.83 to 64.83 g, with the highest value recorded in MNK-1 and the lowest in GKB-10.

Significant correlation between the fruiting efficiency and number of flower indicates that if sink size increases there will be a competition for assimilates hence results in higher flower drop. Similarly, negative correlation between FE and flower drop indicates source sink relation is the important factor in pulse crop, Yield of the chickpea crop depend upon the fruiting efficiency of pulse (Shukla Niharika., 2013) [24].

Relationship between Fruiting efficiency and seed yield

Among the yield-attributing traits, fruiting efficiency is considered one of the most important components influencing seed yield in chickpea. The present study revealed a significant positive correlation between fruiting efficiency, seed yield, and the number of pods, indicating that genotypes with higher fruiting efficiency tend to produce more pods and achieve greater yield potential. Fruiting efficiency reflects the ability of plants to successfully convert flowers into pods, and therefore, it serves as an important indicator of reproductive success under field conditions.

A significant negative correlation was observed between fruiting efficiency and flower drop, suggesting that higher flower retention contributes to improved pod formation and increased seed yield. Flower drop is a major limiting factor affecting reproductive efficiency in chickpea, as a considerable proportion of flowers may fail to develop into mature pods due to genetic and environmental factors. Genotypes with reduced flower abscission and better flower-to-pod conversion ability are likely to exhibit higher fruiting efficiency and improved yield performance (Figure 1a).

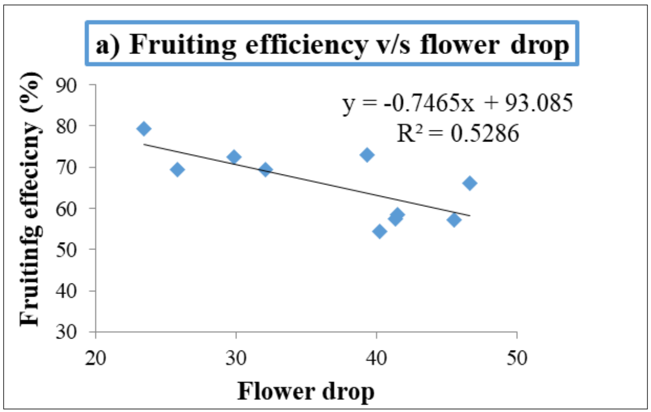

Fig 1a: Correlation analysis between different yield parameters in chickpea a) Fruiting efficiency and flower drop.

The relationship between fruiting efficiency and yield components highlights the importance of selecting genotypes with superior reproductive traits in chickpea breeding programmes. Improvement in fruiting efficiency through the identification of genotypes with reduced flower drop, enhanced pod setting, and better flower retention can contribute significantly to increasing yield stability, particularly under stress-prone environments. Since chickpea is often cultivated under rainfed conditions, maintaining reproductive success during flowering and pod development stages is crucial for achieving higher productivity (Figure 1b).

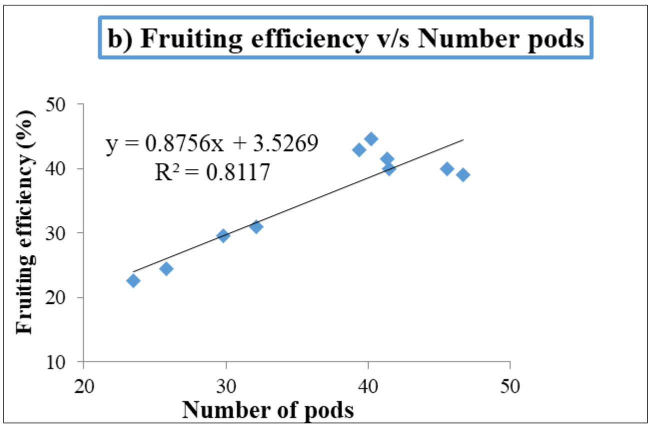

Fig 1b: Correlation analysis between different yield parameters in chickpea b) fruiting efficiency and number of pods.

The significant association of fruiting efficiency with pod number and seed yield observed in the present study suggests that this trait can be effectively used as a selection criterion in breeding programmes. Selection for higher fruiting efficiency may help in developing chickpea genotypes with improved reproductive capacity and greater yield potential (Figure 2a). Similar findings have been reported by several researchers, who emphasized that reproductive traits such as flower retention, pod setting ability, and harvest index play a vital role in determining yield performance in chickpea. The improvement of these traits, along with enhanced tolerance to abiotic stresses, will contribute to the development of high-yielding and stable chickpea varieties (Figure 2b).

Fruiting efficiency is an important reproductive trait that determines yield potential in chickpea by influencing the conversion of flowers into pods. The present study revealed a significant positive correlation between fruiting efficiency, pod number, and seed yield, indicating that genotypes with higher fruiting efficiency have better reproductive success and yield performance. The significant negative association between fruiting efficiency and flower drop suggests that reduced flower abscission and improved flower retention enhance pod formation and contribute to higher seed yield (Figure 2a and 2b).

Flower drop is a major constraint affecting yield realization in chickpea, as a large proportion of flowers may fail to develop into pods due to genetic limitations and environmental stresses. Therefore, genotypes with better flower retention, efficient flower-to-pod conversion, and higher fruiting efficiency are desirable for improving productivity. The strong relationship between fruiting efficiency and yield components highlights its potential as an important selection criterion in chickpea breeding programmes (Figure 2a and 2b).

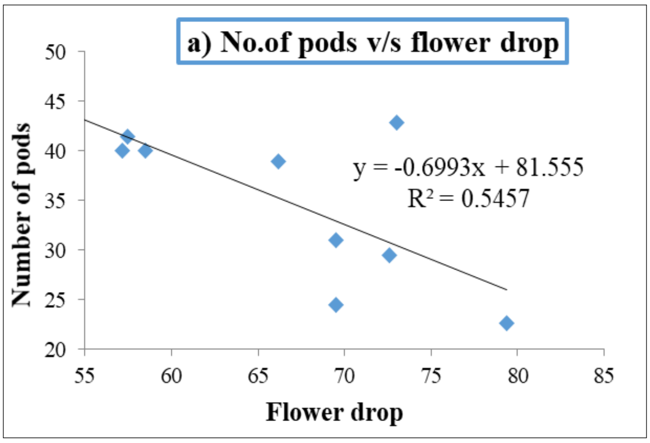

Fig 2a: Correlation analysis between different yield parameters in chickpea a) Number of pods v/s flower drop

Similar observations were reported by Sharma and Singh (2013) [23], who emphasized the importance of reproductive traits such as flower retention and pod-setting ability in improving chickpea yield. Kiran *et al*. (2016) [13] highlighted the importance of improving reproductive efficiency and stress tolerance for enhancing chickpea productivity. Therefore, selection for higher fruiting efficiency, reduced flower drop, and improved pod-setting ability can be effectively utilized for the development of high-yielding and stable chickpea varieties.

Conclusion

Chickpea production is largely affected by abiotic stresses and poor reproductive efficiency, particularly due to excessive flower drop and reduced pod formation. The present study revealed significant variability among chickpea genotypes for germination, flowering behaviour, fruiting efficiency, and yield-related traits. Genotypes JG-11 and JG-14 showed superior germination performance, while considerable differences were observed among varieties for flower drop, fruiting efficiency, and seed yield.

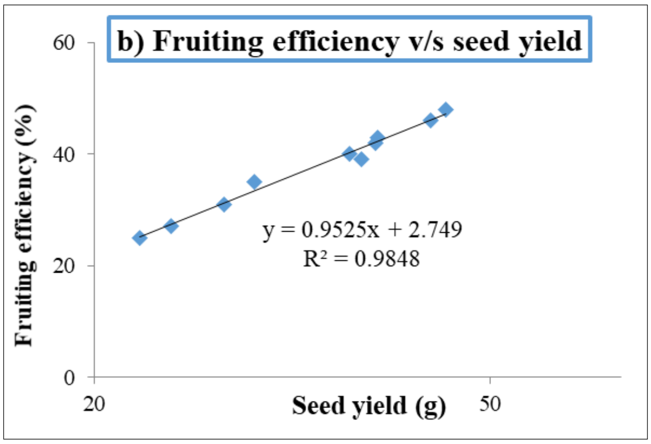

Fig 2b: Correlation analysis between different yield parameters in chickpea b) Fruiting efficiency v/s seed yield.

Fruiting efficiency exhibited a positive association with pod number and seed yield and a negative association with flower drop, indicating its importance as a key trait for yield improvement. Based on yield performance and reproductive efficiency, JG-14, KAK-2, ICCV-10, A-1, and BGD-103 were identified as high-yielding genotypes, whereas GKB-10, GBM-2, JAKI, and MNK-1 were classified as low-yielding types. The identified variability provides valuable opportunities for selecting and developing chickpea genotypes with improved fruiting efficiency, higher yield potential, and better adaptation to stress-prone environments. These superior genotypes can serve as useful genetic resources for future chickpea breeding programmes.

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Conflict of Interest

The authors disclose no conflict of interest

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