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Research Paper

Genotypic and phenotypic variability and identification of agro-morphological trait-specific donors, in a novel set of Kabuli chickpea germplasm

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ABSTRACT

In the present study, 101 accessions of Kabuli chickpea germplasm were evaluated for seven morpho agronomic, quantitative traits. The entries FLIP 09-104C, FLIP-11-164C-S1 and FLIP11-01C showed higher 100- seed wt > 50g, while DG 16-313 had the highest seed yield/plot and early maturity under late sown conditions. Entries FLIP09-346C and FLIP1189 C-S1 also had 100- seed wt > = 50 g. Entry K-328080 had the highest number of pods/plant and the highest seed yield /plant, however, its 100- seed wt was <50 g. Thus, based on wide variation, direct selection for number of pods per plant, seed yield and indirect selection for other traits can be done for development of high-yielding varieties using these donors.

Key words: Grid score, Genetic variability, Kabuli Chickpea, PCA, Seed weight

INTRODUCTION

The large-seeded Kabuli chickpea (*Cicer arietinum* L.) is important in the market for its premium price. It has a high level of protein in its seeds, the ability to fix atmospheric nitrogen to soil, and acts as a cover crop in sustainable agriculture (Ahmad *et al.* 2019, Soe *et al.* 2020). The domesticated chickpea known as “macrosperma” or “kabuli” does not possess pigment on the vegetative green parts and flowers and these plants generally produce larger cream and whitish-cream seeds. The seed size in chickpeas is referred to as the single seed weight (Abbo *et al.* 2000), 100-seed weight (Sundaram *et al.* 2019), and scale of the sieve size in mm (Bicer 2008). Seed size in chickpeas is not only governed by genetic factors but also affected by environment (Muehlbauer and Singh 1987), generally having a high heritability (Koseoglu *et al.* 2017). Large seed size has therefore been considered to be a noteworthy trait in breeding programs (Upadhyaya *et al.* 2006). To investigate the genetics of large seed size, several studies have been carried out starting from, 1950s to date, the inheritance of seed size was determined as monogenic, digenic and polygenic (Sharma *et al.* 2013). Seed size in chickpeas was mapped using recombinant inbred lines (RILs) and some quantitative trait loci (QTLs) and candidate genes were located on LG1, LG2, LG4, LG5, LG6, LG7 and LG8 (Hossain 2010, Cobos *et al.* 2007, Verma *et al.* 2015, Lal and Ravikumar 2018). Thus, some improved cultivars have been described for 100-seed weight (Singh *et al.* 2016) along with important agro-morphological traits.

India exported 1.21 lakh tonnes of Kabuli chickpeas, valued at ₹ 1,200 crore in 2022-23. However, India also imports Kabuli chickpea due to fluctuations in domestic production. Kabuli chickpea harvested in India in 2023 was below average despite a 30% increase in the sowing area due to unusually high temperatures in mid-December, affecting the grain size and yield. The total harvest was between 300- 350,000 MT, which was less than the expected 400 - 450,000 MT (APEDA & The Hindu Business Line 2024). In this background, there is a need to strengthen the Kabuli chickpea breeding program to address the domestic need and tap the export market as well to maximize the farmers’ profits. There are limited large/extra large kabuli chickpea varieties in the national seed chain and more promising Advanced Breeding Lines (ABLs) need to be brought under AICRP trials through different centers. The present study aims to identify novel trait-specific donors and develop potential large/extra large kabuli chickpea ABLs with enhanced grain quality (100-seed weight 40-55 g) with higher number of pods. Twenty-nine kabuli chickpea varieties have been developed from 2012 to 2023 by the NARS system, out of which only two varieties (JGK 5 and JGK 6) have a seed weight >45 g, which have export potential. In the breeder seed indent 2023-24 for 2024-25, KAK 2 (bred in 1999) is the only large-seeded (HSW >35 g) variety having a seed indent more than 10 q, which shows there is scope for more varietal development in large/extra large-seeded kabuli chickpea segment. There is a lack of large-seeded (>35 g HSW) Kabuli chickpea varieties with yield above 20 q/ha. Screening a diverse set of Kabuli chickpea genotypes over the seasons will identify stable and specifically adapted genotypes for the target traits (Lokare *et al.* 2007).

MATERIALS AND METHODS

Plant materials and growing conditions

The present study evaluated a set of 101 kabuli chickpea germplasm accessions (novel set) over two years (2022- 23 and 2023-24) for seven agro-morphological and quantitative traits i.e., plant height (cm), days to 50% flowering, primary branch, days to maturity, pods/plant, 100- seed weight (g) and seed yield/plant (g) along with checks, KRIPA and GOCKCEE (2022-23) and KRIPA, KAK-2 and JGK-5 (2023-24) in augmented design with paired rows. The selected top high-yielding entries from Rabi 2022-23 germplasm were also evaluated in Rabi 2023-24 in three different station trials, including bold seed size (10 entries), high seed yield (8 entries) and late sown conditions (12 entries). The late sown trial was sown on 25th December 2023 at IIPR- RS, Phanda, Bhopal Research Farm. Station trials were conducted in a randomized block design with three replications, with two checks, KRIPA and KAK-2, in each, with a plot size of 1.8 m^2. Evaluation in station trials was done for five agro-morphological and quantitative traits i.e., plant height (cm), days to 50% flowering, days to maturity, 100 seed weight (g) and seed yield/plot (q/ha).

Statistical analysis

The recorded data of both years were subjected to Grid score analysis @ 2024 James Hutton Institute, software by Raubach *et al.* (2022), for observing phenotypic variability of recorded traits. Recorded data were also statistically analysed for both years for genetic variability and also pooled average data were subjected to statistical analysis using SPAR-2 software for correlation and principal component analysis of the recorded traits.

RESULTS AND DISCUSSION

The phenotypic variability over the years (2022-23 and 2023-24) exhibited wide variability in four important morpho-agronomic traits, 100 seed weight, seed yield per plant, days to 50% flowering, and days to maturity (Figure 1). The pooled average data exhibited wide variability for days to 50% flowering (46 - 97), days to maturity (116 - 134), plant height (35.90 - 68.95 cm), number of pods per plant (13 - 242), seed yield per plant (SPP) (4.44 - 44.64 g) and 100 seed weight (7.90 - 52.50 g) (Table 1). The accession DG16-313 showed the earliest maturity (116 days) amongst the studied germplasm; this can facilitate breeders to develop varieties which could benefit short season window available between two crops (Devasirvatham and Tan 2018). The highest plant height was recorded in accession FLIP10-125C (68.95 cm) and the shortest in accession EC141718 (35.90 cm). The studied germplasm revealed an ample amount of genetic variation for the number of pods per plant, and the highest value was recorded for K-328080 (242). However, 24 accessions exhibited a higher number of pods per plant > 50 than the check KRIPA (32). The highest 100-seed weight (>50 g) was recorded for FLIP09-346C (52.50). Notably, 100-seed weight of two of the studied germplasm, FLIP09-104C (51.70) and FLIP1189 C-S1 (50.30), respectively, surpassed that of the check KRIPA (42.57). The highest seed yield/plant (g) was recorded for K-328080 (44.64). Notably, seed yield/plant (g) of three of the studied germplasm IC-267194 (41.56), EC498827 (36.34) and S-150203 (32.38) surpassed that of the check KRIPA (16.10). The lowest coefficient of variation for days to maturity (3.48%) showed its best genetic potential and genetic influence, whereas the highest coefficient of variation for number of pods per plant (71.33%) showed more influence of environmental fluctuations. Based on the wide variation in the germplasm, direct selection for the number of pods per plant, seed yield and indirect selection based on other traits can be done for the development of high-yielding varieties in Kabuli chickpea (Gaur *et al.* 2019).

The three station trials kabuli (bold seed, high seed yield and late sown conduction) exhibited wide variability for days to 50% flowering (46–56, 46–73 and 33-55), days to maturity (117-125, 115–126 and 85-96), plant height (45.47-58.00, 38.73-62.80 and 38.00-53.56 cm), seed yield per plot in q/ha (7.38- 15.53, 6.20-17.41 and 14.05-31.20) and 100 seed weight in g (23.93-51.27, 17.33-35.20 and 17.27-60.13) respectively (Table 2). The weather conditions (Figure 2) were favourable during late sowing (25th December), i.e., a spell of rain during vegetative growth and temperature favourable (cool), resulting in a higher plant stand, less flower drop, also two shower spells during the grain filling stage may have resulted in a higher yield. The impact of climate variability on chickpea production in the central highlands of Ethiopia using auto autoregressive distributed lag model was also studied (Tirfeessa *et al.* 2025). Their findings show that temperature and rainfall have a complex relationship with chickpea production. More rainfall is linked to higher yields, while temperature fluctuations generally have a negative effect over time.

The accession FLIP11-01C showed the earliest maturity (85 days) in late sown conditions, among the studied accessions in the three station trials and can be used in breeding programmes to develop varieties for the short season window available

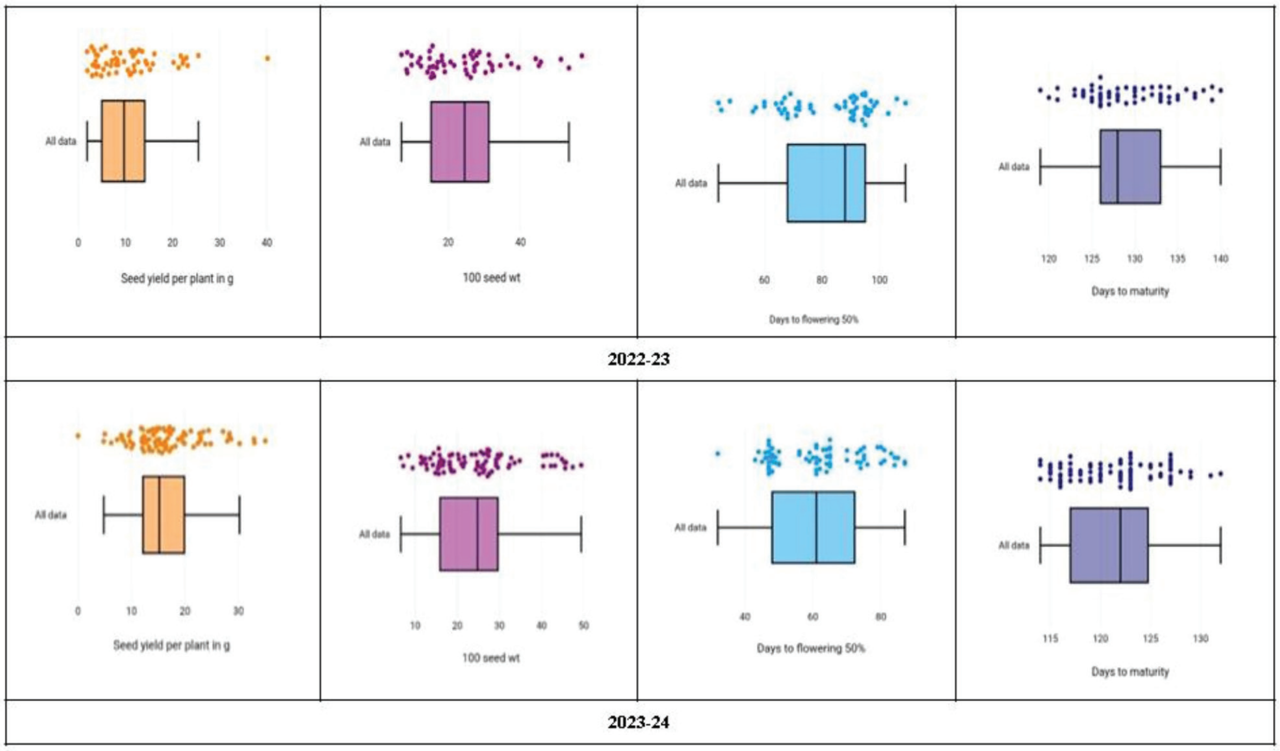

Fig. 1. Phenotypic variability of 100 seed weight and seed yield per plant as per Grid score @ 2024 of both years kabuli chickpea germplasm evaluations, 2022-23 & 2023-24

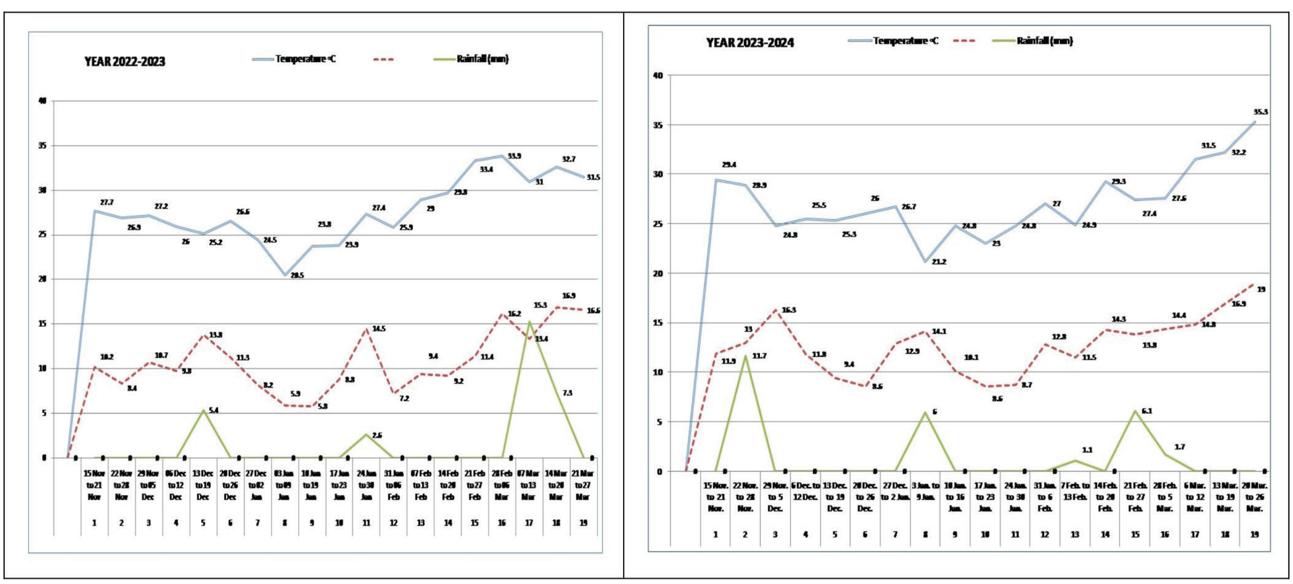

Fig. 2. Weather of both years during kabuli chickpea germplasm evaluations, 2022-23 & 2023-24

between two crops. A sudden rise in temperature near maturity adversely affects grain development and consequently grain yield. Therefore, genotypes with shorter duration may help in avoiding high-temperature-induced reduction in the yield (Guriqbal *et al.* 2017). The highest plant height in cm was recorded in IC490038 (62.80) and the shortest in EC-0026426 (38.00). The highest 100 seed weight was recorded for FLIP09-104C (60.13), also two other accessions, FLIP-11-164C-S1 (58.60) and FLIP11-01C (56.80), which surpassed checks KAK-2 (27.47) and KRIPA (31.07) in the late sown conditions trial. All the evaluated ten entries in bold seed trial showed higher 100 seed weight (g) and were found superior to the checks KAK-2 (23.93) and KRIPA (36.53). Entry FLIP 09-104C (55.20) showed the highest 100 seed weight along with FLIP09-346C (54.80), FLIP11-164C-S1 (51.27), FLIP11-01C (50.93) and FLIP1189C-S1 (49.87). Similarly, pooled average analysis of germplasm 2022-23 and 2023-24 revealed that 100-seed wt was >50 g in two entries, FLIP09-104C (51.70) and FLIP1189 C-S1 (50.30) and was higher than that of check KRIPA (42.57). The donor sources for the above traits are listed in Tables 3, 4 & 7. The highest seed yield/plot (q/ha) was recorded for DG 16-313 (31.20) in the late sown conditions trial. Also, higher seed yield/ plot (q/ha) was recorded for three entries ICCV211404 (15.53), FLIP1189 C-S1 (14.53) and FLIP11-94 C-S4 (12.81), respectively surpassing that of the check KAK-2 (12.16) and KRIPA (11.29) in the bold seed trial. Based on the wide variation in the germplasm, direct selection for 100 seed weight, seed yield per plot and indirect selection based on other traits can be done for the development of high-yielding varieties in kabuli chickpea (Dhuria and Babbar 2017). Also, late sown conditions were found highly

Table 3. Identified Donor sources based on Kabuli germplasm evaluation pooled average 2022-23 & 2023-24

Quantitative traits	Promising genotypes
Plant Height (cm)	FLIP10-125C
Days to 50% Flowering	PAO3616R
Primary Branch	IC223042, IC-267194, EC49767
Days to Maturity	DG 16-313
Pods/Plant	K-328080
100 Seed Weight (g)	FLIP09-346C, FLIP09-104C, FLIP1189 C-S1
Seed yield/plant (g)	K-328080, IC-267194, EC498827, S-150203

Table 4. Identified Donor sources based on 2023-24 three Kabuli chickpea Station trials

Quantitative traits	Station Trial (Bold Seed)	Station Trial (High Seed Yield)	Station Trial (Late Sown)
Plant Height (cm)	PAO8016R	IC490038	FLIP-11-164C-S1
Days to 50% Flowering	FLIP09-346C, FLIP11-164C-S1, FLIP11-01C	DG16-313	-
Days to Maturity	-	DG16-313	FLIP11-01C
100 Seed Weight (g)	FLIP11-164C-S1, FLIP11-01C, FLIP1189 C-S1, FLIP09-104C, FLIP11-94 C-S4, FLIP09-346C	PAO8016R	FLIP09-104C, FLIP-11-164C-S1, FLIP11-01C
Seed yield/plot (q/ha)	ICCV211404, FLIP1189 C-S1, FLIP11-94 C-S4	-	DG 16-313

Table 1. Genotypic variability of quantitative traits of both years 2022-23 & 2023-24 and pooled average of kabuli chickpea germplasm

Quantitative traits	2022-23			2023-24			Pooled Average 2022-23 & 2023-24			
	Range	Mean ± Std dev	Variance	Range	Mean ± Std dev	Variance	Range	Mean ± SE	Variance	CV
Plant Height (cm)	31.60 - 74.20	53.12± 7.74	59.97	21.80 - 72.60	51.34± 7.96	63.35	35.90 - 68.95	52.63± 0.64	39.64	11.96%
Days to 50% Flowering	45 - 109	79± 14.08	198.12	32 - 87	60 ± 12.53	157.02	46 - 97	69± 1.17	153.68	18.03%
Primary Branch	2 - 6	3± 0.67	0.44	1 - 4	3 ± 0.39	0.15	2 - 4	3± 0.05	0.15	14.18%
Days to Maturity	115 - 140	128± 5.63	31.73	116 - 132	123 ± 3.66	13.37	116 - 134	125± 0.41	18.93	3.48%
Pods/Plant	14 - 454	46± 53.27	2838.21	1 - 64	28 ± 12.30	151.35	13 - 242	38± 2.80	751.21	71.33%
100 Seed Weight (g)	7.00 - 55.20	24.93± 10.80	116.72	6.60 - 50.20	22.99± 9.87	97.42	7.90 - 52.50	24.74± 0.99	102.83	40.99%
Seed yield/plant (g)	1.93 - 75.20	11.09± 12.38	153.27	4.68 - 34.96	14.57± 5.57	30.99	4.44 - 44.64	13.80± 0.71	49.18	50.83%

Table 2. Genotypic variability of quantitative traits of 2023-24 three Kabuli chickpea Station trials

Quantitative traits	Station Trial Kabuli Bold Seed			Station Trial Kabuli High Seed Yield			Station Trial Kabuli Late Sown		
	Range	Mean± Std dev	Variance	Range	Mean± Std dev	Variance	Range	Mean ± Std Dev	Variance
Plant Height (cm)	45.47 - 58.00	52.07± 3.27	10.72	38.73 - 62.80	49.87± 7.06	49.79	38.00 - 53.56	46.74± 4.18	17.48
Days to 50% Flowering	46 - 56	48.00 ± 3.19	10.17	46 - 73	52± 9.29	86.31	33 - 55	41± 7.01	49.17
Days to Maturity	117 - 125	121± 2.62	6.85	115 - 126	121± 3.88	15.04	85 - 96	89± 3.34	11.12
100 Seed Weight (g)	23.93 - 51.27	39.74± 9.54	90.95	17.33 - 35.20	25.44± 4.94	24.36	17.27 - 60.13	37.61± 13.24	175.42
Seed Yield/Plot (q/ha)	7.38 - 15.53	11.00± 2.39	5.70	6.20 - 17.41	12.96± 3.18	10.09	14.05 - 31.20	22.87± 5.32	28.28

Table 5. Bi-Variate Correlation coefficients of quantitative traits of Kabuli germplasm evaluation pooled average 2022-23 & 2023-24

Quantitative traits	Days to 50% Flowering	Primary Branch	Days to Maturity	Pods /Plant	100 Seed Weight (g)	Seed Yield /plant (g)
Plant height (cm)	-0.26	-0.02	-0.17	0.00	0.42	0.33
Days to 50% Flowering		0.20	0.81**	0.01	-0.57	-0.24
Primary Branch			0.13	0.52	-0.24	0.39
Days to Maturity				-0.07	-0.45	-0.27
Pods /Plant					-0.23	0.70*
100 Seed Weight (g)						0.29

**Highly Significant, *Significant at $P < 0.05$.

suitable and gave better results, weather conditions of both years are presented in Figure 2 (Toker and Yadav 2011).

A positive and highly significant correlation of days to 50 per cent flowering with days to maturity (r=0.81**) and a positive and significant correlation of seed yield/plant with number of pods per plant (r=0.70*) were observed in the present study, which is similar to earlier studies (Geethanjali *et al.* 2018, Devi *et al.* 2024). Seed yield/plant showed a non-significant positive correlation with plant height, primary branch and 100 seed weight, and a negative correlation with days to 50% flowering and days to maturity, signifying that higher seed yield was linked to higher plant height, more branches and pods, early flowering, and maturity. 100 seed weight also showed a non-significant positive correlation with plant height, while a negative correlation with days to 50% flowering, primary branch, days to maturity and pods /plant. Pods/plant also showed a non-significant positive correlation with plant height, days to 50% flowering, and primary branch, while a negative correlation with days to maturity. Primary branch showed a non-significant positive correlation with days to 50% flowering, while a negative correlation with plant height also days to 50% flowering showed a negative correlation with plant height.

The principal component analysis is a multivariate statistical analysis technique. In the present investigation, the principal component analysis of seven quantitative agro-morphological traits data of 101 accessions of Kabuli chickpea revealed that three principal components (Table 6) had eigenvalue >1. Plant height contributed the maximum to the variation with eigenvalue = 2.18, explaining 31% of total variation. The 2nd principal component i.e., days to 50% flowering, had a value = 1.91 and explained 27% of the total variation. The principal component number of the primary branch had a value of 1.35, explaining 19% of the total variation. Similar results were also found by Arora *et al.* 2018.

Table 6. Principal component analysis of quantitative agro-morphological traits of Kabuli germplasm pooled average 2022-23 and 2023-24

Quantitative traits	Eigen Values	Proportion of Variance Explained / % Variability	Cumulative (%)
Plant height (cm)	2.18	31%	31%
Days to 50% Flowering	1.91	27%	58%
Primary Branch	1.35	19%	78%
Days to Maturity	0.21	3%	81%
Pods /Plant	0.60	9%	89%
100 Seed Weight (g)	0.55	8%	97%
Yield/plant (g)	0.19	3%	100%

Thus, it can be concluded that bi-variate correlation analysis revealed (Table 5) a positive and highly significant correlation of days to 50 per cent flowering with days to maturity and a positive and significant correlation of seed yield/ plant with number of pods per plant. Seed yield/ plant showed a positive correlation with plant height, primary branch, and 100-seed weight, and a negative correlation with days to 50% flowering and maturity. The 100 seed weight also showed a positive correlation with plant height, while a negative correlation with days to 50% flowering, primary branch, days to maturity, and pods /plant. The principal component analysis revealed that three principal components (Table 6) had eigenvalue >1, and plant height contributed the maximum (31%), days to 50% flowering (27%) and number of primary branches (19%) of the total variation.

Entry FLIP 09-104C (55.20), (60.13 Late sown), showed the highest 100-seed wt (Table 7) followed by FLIP09-346C (54.80), FLIP11-164C-S1 (51.27), FLIP11-01C (50.93), and FLIP1189C-S1 (49.87) in the bold seed trial and FLIP-11-164C-S1 (58.60) and FLIP11-01C (56.80) in the late sown trial. The highest seed yield/plot (q/ha) was recorded for DG 16-313 (31.20) in the late sown trial; also, this entry showed the lowest days to maturity in the pooled average of germplasm evaluation (116) and high seed yield station trials (115). Based on the wide variation in the germplasm, direct selection for the number of pods

Table 7. Top potential identified accessions of Kabuli Chickpea with 100 seed wt in g > 50; high seed yield (q/ha), Earliness, evaluated at IIPR-RS, Phanda Bhopal (2022-2024)

Accession no.	100 seed weight in g (trial)	Other potential trait / trial
FLIP09-104C	60.13 (Late sown), 55.20 (Germplasm 2022-23)	Low D/F (46) / Bold seed
FLIP11-164C-S1	58.60 (Late sown), 51.27 (Bold seed)	Low D/F (46) / Bold seed
FLIP11-01C	56.80 (Late sown), 50.93 (Bold seed)	lowest DM (85) / Late sown
FLIP09-346C	54.80 (Germplasm 2022-23), 52.50 (Pooled average germplasm)	Low D/F (46) / Bold seed
DG16-313	33.13(Late sown), 29.00 (Pooled average germplasm)	Highest seed yield/ plot (31.20) / Late sown Lowest DM (116) / Pooled average germplasm
K-328080	18.70 (Pooled average germplasm)	Highest no. of pods/plant (454 in 2022-23), (242) & Highest seed yield /plant (44.64) / Pooled average germplasm

Abbreviation: D/F: Days to 50% flowering, DM: Days to matur

per plant, seed yield, and indirect selection based on other traits can be done for the development of high-yielding varieties in kabuli chickpea. Also, the donors identified in the present investigation can be utilized in further breeding programmes.

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