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Evaluation of Global Composite Collection Reveals Agronomically Superior Germplasm Accessions for Chickpea Improvement

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Abstract: The rich genetic diversity existing within exotic, indigenous, and diverse germplasm lays the foundation for the continuous improvement of crop cultivars. The composite collection has been suggested as a gateway to identifying superior germplasm for use in crop improvement programs. Here, a chickpea global composite collection was evaluated at five locations in India over two years for five agronomic traits to identify agronomically superior accessions. The desi, kabuli, and intermediate types of chickpea accessions differed significantly for plant height (PLHT) and 100-seed weight (100 SW). In contrast, the intermediate type differed substantially from kabuli for days to maturity (DM). Several highly significant trait correlations were detected across different locations. The most stable and promising accessions from each of the five locations were prioritised based on their superior performance over the best-performing check cultivar. Accordingly, the selected germplasm accessions of desi type showed up to 176% higher seed yield (SY), 29% lower flowering time, 21% fewer maturity days, 64% increase in PLHT, and 183% larger seeds than the check cultivar JG11 or Annigeri. The prioritised kabuli accessions displayed up to 270% more yield, 13% less flowering time, 8% fewer maturity days, 111% increase in PLHT, and 41% larger seeds over the check cultivar KAK2. While the intermediate type accessions had up to 169% better yield, 1% early flowering, 3% early maturity, 54% taller plants, and 25% bigger seeds over the check cultivar JG 11 or KAK2. These accessions can be utilised in chickpea improvement programs to develop high-yielding, early flowering, short duration, taller, and large-seeded varieties with a broad genetic base.

Keywords: germplasm; yield; flowering time; genetic diversity; seed size

1. Introduction

Food grain legumes are a rich source of high-quality proteins, carbohydrates, dietary fibres, and minerals for millions of people in developing countries, especially in South Asia and sub-Saharan Africa [1]. Chickpea (*Cicer arietinum* L.) is one of the most important food grain legumes, widely grown on marginal lands in more than 56 countries. The world cropping area under chickpea cultivation is ~13.72 million hectares, with a total annual production of ~14.25 million tonnes, of which Asia contributes 83% of production [2]. The key chickpea-producing countries include India, Turkey, Russian Federation, Myanmar, and Pakistan. Cultivated chickpea can be classified into two distinct forms: desi types (characterised by purple flowers, small seed size, angular shape, and coloured seeds with a high level of fibre) and kabuli types (characterised by white flowers, large seed size, owl's head shape, and beige-coloured seeds possessing a low level of fibre).

Further, all desi types have anthocyanin pigmentation on other plant parts, whereas pigmentation is absent in kabuli chickpea. A third form, called intermediate type, is characterised by small- to medium-size round (pea)-shaped dark- or light-coloured seeds. The desi type chickpea is mainly cultivated in South Asia, while the kabuli type is primarily grown in the Mediterranean [2].

Although chickpea's productivity has continuously increased over the last six decades, its sensitivity to several biotic and abiotic stresses has also been enhanced simultaneously, leading to yield variations [3]. The major biotic stresses constraining chickpea production include the diseases Ascochyta blight (*Ascochyta rabiei* (Pass.) Labr.), fusarium wilt (*Fusarium oxysporum* f. sp. *Ciceris*), botrytis grey mould (*Botrytis cinerea* Pers. ex Fr.), collar rot (*Sclerotium rolfsii* Sacc.), and dry root rot (*Rhizoctonia bataticola* (Taubenhaus)); while pod borer or gram pod borer (*Helicoverpa armigera* (Hübner)), leaf miner (*Liriomyza cicerina* Rondani), aphid (*Aphis craccivora* Koch.), and bruchid (*Callosobruchus chinensis* L.) are among the important pests [4]. In addition, drought, heat, cold, and salinity stress, among abiotic factors, represent key constraints to chickpea productivity [5,6]. Worldwide, these stresses result in potential yield losses costing over USD 2559 million annually. About 46% of losses are projected to be recovered by developing improved chickpea cultivars with multiple resistance/tolerance to these stresses [7]. However, improved genotypes are hampered primarily because of the limited genetic diversity available in the modern crop gene pools [8]. Extensive use of limited and closely associated germplasm/improved breeding accessions in chickpea improvement programs has led to a plateau in genetic improvements of target traits. Therefore, the newly developed cultivars display increased susceptibility to pests, diseases, and unstable yields under changing environments. To this end, using exotic and diverse genetic resources in breeding is the key to boosting the productivity and diversity of chickpea cultivars [9,10].

One of the major reasons for the limited utilisation of germplasm accessions in breeding efforts is the lack of knowledge of economically important traits, which often display genotype $\times$ environment interactions and need multi-environment testing [11–14]. Apart from higher yields, early maturity, taller plants, and large seed size represent some key agronomic traits of economic importance. Developing high-yielding and early-maturing chickpea to escape terminal drought is important in breeding programs targeted at semi-arid tropical environments [15]. Varieties with tall and erect growth habits are suitable for mechanical harvesting and help minimise labour costs [16]. Chickpea seed size is a crucial trait for international trade, with the large-seeded desi and kabuli types receiving a premium price in the markets. For instance, the large-seeded (>50 g 100-seed^{-1}) kabuli cultivars receive a premium that is thrice the cost of desi and two times the cost of kabuli types, having a 100 SW of 25–40 g [17]. For developing improved chickpea cultivars for a target environment, identifying superior germplasm/parental accessions is a prerequisite. Different genetic backgrounds among parental accessions will offer the genetic diversity required to generate desired allelic combinations, which will increase the possibility of developing unique cultivars in proportion to the number of alleles by which the parents vary.

To increase the use of chickpea germplasm accessions in breeding programs, a composite collection of 3000 accessions represented variation in gene diversity ranging from 53% to 97% of the entire collection [18,19]. This global composite collection has been sequenced using whole-genome sequencing, and extensive analysis has been undertaken [10]. Evaluating such composite collections under multi-environmental trials is a promising approach to determining trait-specific promising germplasm accessions. The present study evaluated a composite collection under multi-environment field trials to identify agronomically superior germplasm accessions for increasing chickpea's genetic potential.

2. Materials and Methods

2.1. Plant Material

The chickpea composite collection comprised 3000 (desi (1714), kabuli (1196), intermediate (70), and wild (20)) accessions [18]. The 1714 desi accessions included traditional cultivars (10), advanced cultivars (35), breeding lines (206), and landraces (1463). The 1196 kabuli accessions included advanced cultivars (16), breeding lines (47), traditional cultivars (423), landraces (459), and unknown types (251). In comparison, 70 intermediate type accessions consisted of breeding lines (8), traditional cultivars (17), landraces (42), and unknown types (3). Geographically, accessions of the composite collection originate from about 58 countries. These accessions' flower colours vary from blue, light blue, pink, dark pink, light pink, and very light pink to white with pink stripes and white. These accessions had angular, owl's head, and pea-shaped seeds. The presence of high anthocyanin, low anthocyanin, and no anthocyanin content produced different seed coat colours. The classification of 3000 accessions from the chickpea composite collection based on biological status, source country, flower colour, pigmentation, seed shape, and seed coat colour is provided in Table 1.

2.2. Experimental Design, Target Traits, and Experiment Locations

The entire composite collection and very promising checks include four desi (Annigeri, G130, ICCV10, and JG11) and two kabuli (KAK2 and L550) accessions, which were grown in 2 m single-row plots in an augmented block design. The experiment was conducted at Patancheru, Amlaha, Junagadh, and Sehore during the 2014–15 and 2015–16 years post-rainy season (between October–November). The experiment was conducted at Kanpur for two years during the 2015–16 and 2016–17 years post-rainy season (during November). The meteorological conditions during the experiment were recorded for field trials conducted at Patancheru, India. During the 2014–15 crop season, the average day/night temperature recorded was 35.4/5.2 °C with a relative humidity of 18.0/98.0% and an average rainfall of 0–33.8 mm. While during the 2015–16 crop season, the average day/night temperature and relative humidity were 37.8/6.6 °C and 20.0/98.0%, respectively, and the average rainfall ranged between 0 and 40 mm. The agronomic data were recorded for days to 50% flowering (DF; days counted from sowing up to 50% of plants producing their first flower), DM (DM; days counted from sowing to the appearance of golden colour pods), plant height (PLHT; measured in centimetre from the soil surface to the tip of the plant foliage), 100-seed weight (100 SW; measured by taking a random sample of 100 seeds from a single row and by weighing them), and seed yield (SY).

Table 1. Classification of a chickpea composite collection based on biological status, source country, flower colour, pigmentation, seed shape, and seed coat colour.

Type (Number of Accessions)	Biological Status	Source Country	Flower Colour	Pigmentation	Seed Shape	Seed Coat Colour
Desi type (1714)	Traditional cultivar/ Landrace (10)	Jordan (1); Portugal (1); Tajikistan (1); Ukraine (1); Australia (1); Pakistan (2); Turkey(1); Romania (1); and Chile (1)	Pink (2) and White (8)	Low anthocyanin (2) and without anthocyanin (8)	Angular	Brown beige (1); Light yellow (2); Yellow beige (2); Yellow (1); Yellow brown (1); and Orange (3)
	Advanced cultivar (35)	ICRISAT (20); India (14); and Australia (1)	Pink (34) and White (1)	Low anthocyanin (34) and without anthocyanin (1)	Angular	Dark brown (1); Green (1); Light brown (5); Yellow (4); Yellow beige (1); and Yellow brown (23)
	Breeding material (206)	Bangladesh (1); Chile (1); Ethiopia (5); ICRISAT (103); India (90); Malawi (1); Myanmar (1); Turkey (1); United States of America (2); and Iran (1)	Blue (4); Dark pink (1); Light pink (1); Pink (193); White (6); and Light blue (1)	High anthocyanin (8); Low anthocyanin (188); and without anthocyanin (10)	Angular	Black (4); Brown beige (1); Dark brown (7); Green (3); Light brown (23); Light green (2); Light yellow (10); Yellow (1); Yellow beige (2); and Yellow brown (153)
	Landrace (1463)	Afghanistan (33); Algeria (2); Bangladesh (31); Cyprus (4); Egypt (3); Ethiopia (108); France (1); Germany (3); Greece (2); Hungary (1); India (649); Iran (377); Iraq (3); Israel (4); Italy (4); Jordan (1); Lebanon (1); Malawi (15); Mexico (43); Morocco (19); Myanmar (21); Nepal (17); Nigeria (2); Pakistan (43); Portugal (1); Russian Federation (12); Spain (2); Sri Lanka (2); Syrian Arab Republic (4); Tanzania (2); Turkey (19); Uganda (1); United States of America (9); Unknown (23); and Yugoslavia (1)	Blue (1); Dark pink (4); Light blue (1); Light pink (105); Pink (1320); Very light pink (4); White (25); and White with pink strips (3)	High anthocyanin (36); Low anthocyanin (1271); and without anthocyanin (156)	Angular	Beige (1); Black (187); Brown beige (115); Dark brown (50); Green (13); Greyish brown (1); Light brown (108); Light green (2); Light orange (8); Light yellow (67); Orange (1); Orange brown (4); Reddish brown (2); Yellow (19); Yellow beige (7); and Yellow brown (878)

Table 1. *Cont.*

Type (Number of Accessions)	Biological Status	Source Country	Flower Colour	Pigmentation	Seed Shape	Seed Coat Colour
Kabuli type (1196)	Advanced cultivar (16)	ICRISAT (10); India (2); Mexico (1); Morocco (1); Turkey (1); and USA (1)	White	No anthocyanin	Owl's head	Beige
	Breeding material (47)	Chile (3); Egypt (9); ICRISAT (18); India (8); Mexico (5); and Syrian Arab Republic (4)	White (46) and Pink (1)	No anthocyanin	Owl's head	Beige
	Traditional cultivar/Landrace (423)	Afghanistan (62); Algeria (12); Azerbaijan (6); Bulgaria (4); Chile (3); Cyprus (9); Czechoslovakia (1); Ecuador (1); Egypt (1); Ethiopia (1); Georgia (1); Greece (3); India (3); Iran (19); Iraq (9); Italy (5); Jordan (27); Kazakhstan (2); Kyrgyzstan (2); Lebanon (6); Libyan Arab Jamahiriya (2); Mexico (2); Moldova, Republic of (2); Morocco (25); Pakistan (32); Palestine (2); Peru (2); Portugal (3); Romania (1); Russian Federation (6); Spain (8); Sudan (4); Syrian Arab Republic (57); Tajikistan (1); Tunisia (9); Turkey (80); Ukraine (4); United Kingdom (1); United States of America (1); and Uzbekistan (4)	Light pink (6) and white (417)	No anthocyanin	Owl's head	Beige (418); Ivory white (1); Orange (1); and Orange brown (3)
	Landrace (459)	Afghanistan (38); Algeria (3); Australia (1); Bulgaria (3); Chile (17); China (7); Colombia (1); Cyprus (5); Czechoslovakia (4); Egypt (2); Ethiopia (8); Greece (2); India (27); Iran (153); Iraq (3); Israel (6); Italy (7); Jordan (3); Kenya (1); Lebanon (4); Malawi (2); Mexico (8); Morocco (17); Myanmar (3); Nepal (3); Pakistan (20); Peru (1); Portugal (12); Russian Federation (13); Spain (10); Sudan (1); Syrian Arab Republic (17); Tunisia (5); Turkey (38); United States of America (7); Yugoslavia (1); and Unknown (6)	Light pink (9); Pink (3); White (446); and white with pink strips (1)	Low anthocyanin (5) and without anthocyanin (454)	Owl's head	Beige (445); Brown (7); Ivory white (1); Light yellow (1); Orange (1); Orange brown (2); and Salmon brown (2)

Table 1. *Cont.*

Type (Number of Accessions)	Biological Status	Source Country	Flower Colour	Pigmentation	Seed Shape	Seed Coat Colour
	Unknown (251)	Algeria (3); Armenia (2); Bulgaria (8); Chile (20); China (7); Cyprus (1); Egypt (3); Ethiopia (1); France (11); Georgia (1); Greece (2); Hungary (1); ICARDA (1); India (1); Iran (2); Italy (2); Lebanon (1); Mexico (5); Morocco (2); Palestine (2); Portugal (6); Russian Federation (6); Spain (21); Syrian Arab Republic (101); Tajikistan (1); Tunisia (21); Turkey (2); Ukraine (1); United States of America (10); and Unknown (6)	White	No anthocyanin	Owl's head	Beige
Intermediate type (70)	Unknown (3)	Bulgaria (2) and Moldova, Republic of (1)	White	No anthocyanin	Pea-shaped	Light yellow (1) and Beige (2)
	Breeding material (8)	ICRISAT (2); Syrian Arab Republic (1); and India (5)	Blue (2); Light pink (1); and white (5)	No anthocyanin	Pea-shaped	Brown (1); Light yellow (1); Beige (1); Orange (3); and Salmon brown (2)
	Traditional cultivar/ Landrace (17)	Afghanistan (5); India (1); Kyrgyzstan (1); Republic of Moldova (1); Morocco (1); Pakistan (1); Russian Federation (1); Ukraine (2); Uzbekistan (3); and Yugoslavia (1)	Light pink (4); Pink (1); Very light pink (1); white (11)	Low anthocyanin (1) and without anthocyanin (16)	Pea-shaped	Beige (3); Light yellow (1); Orange brown (6); Salmon brown (1); and Yellow (6)
	Landrace (42)	Afghanistan (9); Czechoslovakia (1); Ethiopia (1); India (20); Iran (1); Mexico (1); Morocco (3); and Russian Federation (6)	Blue (1); Dark pink (1); Light blue (3); Light pink (15); Pink (6); White (15); and White with pink strips (1)	Low anthocyanin (8) and without anthocyanin (34)	Pea-shaped	Beige (3); Black brown mosaic (2); Brown (10); Light brown (1); Light green (1); Light orange (1); Light yellow (3); Orange (4); Orange brown (2); Reddish brown (2); Salmon brown (7); and Yellow (6)
Wild (20)	Wild	Turkey	Pink	Low anthocyanin	Angular	Brown (8); Dark brown (6); Greyish brown (4); Light green (1); and Orange brown (1)

2.3. Statistical Analysis

The statistical analyses were performed using GenStat 19th edition [20]. Analysis of variance was performed for the phenotyping data collected from all the locations over two years and for all five traits by considering block as random and entry as fixed effects using the restricted maximum likelihood (REML) estimation procedure. Further entry effect was partitioned to examine the differences among checks, differences among tests, and differences between checks and tests. The least-square means were calculated for all entries and used separately for three different sets (desi, kabuli, and intermediate type). Ranking biplots [21] were constructed to examine the discriminating ability and representativeness of the entries in individual test environments (location and year combination) and an ideal test environment. The total number of ranking biplots at individual test environments was 150 (3 sets × 5 locations × 2 years × 5 traits). It was difficult to present all 150 ranking biplots in this article; therefore, the relevant information for desi type is shown in Supplemental Table S1. For kabuli and intermediate types, the information is presented in Supplemental Table S2. A flow chart depicting the selection of germplasm accessions at each level is provided in Table 2.

Table 2. Flow chart for selection of the germplasm accessions at each level.

Level	Number of Accessions	Selection Procedure of Potential Elite Accessions
1	3000 composite collection (1714 desi + 1196 kabuli + 70 intermediate type + 20 wild type)	➢ A chickpea composite collection and 6 checks (4 desi and 2 Kabuli) were evaluated in augmented design at five locations (Patancheru, Amlaha, Kanpur, Junagadh, and Sehore) in India over 2 years. ➢ The data were recorded for DF (days), DM (days), PLHT (cm), 100 SW (g), and SY (g).
2	(1162 desi + 336 kabuli + 35 intermediate type)	➢ The data for wild type accessions were not received from all the locations; therefore, it was not considered for further analysis. ➢ Common accessions were selected based upon data availability from different locations and across 2 years for all five traits. ➢ A total of 1162 desi accessions, 336 kabuli accessions, and 35 intermediate type accessions were used for developing ranking biplots for all five traits. ➢ To rank accessions based on the performance of one environment, a ranking biplot was developed where a line is drawn that passes through the biplot origin and the environment. Hence, 150 ranking biplots were developed (5 traits × 2 years × 5 locations × 3 types as desi, kabuli, and intermediate type).
3	(150–200 desi + 50–100 kabuli + 15–20 intermediate type for each trait)	➢ Firstly, all the accessions were shortlisted for early flowering and early maturity by using ranking biplots. Here the accessions that were opposite to the direction of AEC and far off from AEA seem to have less than average and unstable performance for PLHT and 100 SW, while accessions having more than average value in a positive direction towards AEC and closer to AEA, i.e., stable, were selected.
4	(40–50 desi + 25–30 kabuli + 8–10 intermediate type for each trait)	➢ Accessions selected at level 3 were further shortlisted based on yield performance. The accessions exhibiting the best performance in the ranking biplot of yield (in the direction of AEC and closer to AEA) were selected.
5	(0–20 desi + 0–10 kabuli + 0–3 intermediate type for each trait)	➢ Accessions selected at level 4 were further shortlisted based upon superior performance than check cultivars in yield. Here a maximum of top 20 accessions were selected for desi, a maximum of top 10 accessions were selected for kabuli, and a maximum of top 3 accessions were selected for intermediate type over the respective check cultivars for each location.

3. Results

3.1. Variation in Agronomic Traits among Desi, Kabuli, and Intermediate Type Accessions

Chickpeas are classified into three types based on seed shape—desi, kabuli, and intermediate. We observed significant differences among the means of desi, kabuli, and intermediate types of chickpea accessions for five traits phenotyped at five different locations in India for two years (Supplementary Tables S3 and S4). The three types of chickpeas showed significant variation for PLHT, 100 SW, and DM. For instance, the desi and kabuli chickpeas varied substantially for PLHT and 100 SW. The kabuli accessions were taller and possessed a higher 100 SW than desi. The intermediate types differed from desi types for PLHT and 100 SW and had taller plants with greater 100 SW.

Furthermore, a significant difference was observed for DM, PLHT, and 100 SW between the intermediate and kabuli chickpeas. Compared to intermediate types, the kabuli were later in maturity, taller in height, and had higher 100 SW. No significant differences were detected among the means of three types of chickpeas for DF and SY.

3.2. Correlation among Traits Evaluated at Five Locations

A Pearson correlation analysis was conducted to identify the correlations between agronomic traits within and between experimental trials. The correlation coefficients among the five traits evaluated for two years across five different locations revealed the presence of significant and meaningful correlations ($0.50 \leq r \leq -0.50$) (Supplementary Table S5). For instance, 100 SW measured across two years at Amlaha (Madhya Pradesh) displayed a significant positive correlation. At Patancheru (Telangana), significant positive correlations were detected between the following pairs of traits: DF and DM, DF and PLHT, and DM and PLHT. The 100 SW evaluated for two years at Kanpur (Uttar Pradesh) showed a substantial positive correlation. At Junagadh (Gujarat), DF was significantly and positively correlated with DM, while DF and 100 SW showed a significant positive correlation across years. Furthermore, at Sehore (Madhya Pradesh), DF, PLHT, and 100 SW showed a significant correlation across two years. Several other traits displayed a low to moderate correlation ($r = \pm 0.01$ to $r = \pm 0.49$) across years at different locations evaluated.

3.3. Selection of Stable and Promising Elite Accessions for Amlaha, Madhya Pradesh

3.3.1. Desi Type

During the 2014–15 year, the best check JG11 had a seed yield (SY) of 16 g plant^{-1}, DF of 83 days (d), DM of 119 d, PLHT of 48 cm, and 100 SW of 23 g. Based on DF, 16 elite accessions were selected with a flowering time of 75–90 d and SY in the range of 16–37 g plant^{-1}. Of these 16 accessions, 6 (ICCV91902, ICC14881, ICC14014, ICC16076, ICC16166, and ICC11046) produced a 50–131% higher yield than the check cultivar JG11 (Table 3). Based on DM, 20 elite accessions were identified with maturity days ranging from 108 d to 117 d and SY in the 16–42 g plant^{-1}. Of these 20 accessions, 9 (ICC14014, ICC16076, ICC13107, ICC5878, ICC11091, ICC14507, ICC8366, ICC10953, and ICC4074) produced an SY in the range of 50–163% over the check cultivar JG11 (Table 3). Furthermore, 20 germplasm accessions were selected based on PLHT, whose height ranged from 48 cm to 62 cm, and SY ranged from 27 to 36 g plant^{-1}. The PLHT of all the accessions was at par or more than JG11, and the accessions displayed a yield gain of up to 125% over the check cultivar JG11 (Table 3). Twenty accessions prioritised based on 100 SW had seed weight values ranging from 18 to 65 g 100-seeds^{-1} and SY ranging from 20 to 37 g plant^{-1}. Of these, ten accessions (ICC12452, ICCV88202, ICC8474, ICC14385, ICC11903, ICCV91902, ICC1000, ICC15540, ICC3164, and ICC16903) produced SY in the range of 50–131% more than JG11 (Table 3).

During the 2015–16 year, JG11 was selected as the best check and possessed an SY of 8 g plant^{-1}, DF of 56 d, DM of 112 d, PLHT of 40 cm, and 100 SW of 24 g. Here, 12 accessions were selected based on flowering time (48–62 d), producing SY in the 6–12 g plant^{-1}. Eight accessions were selected based on DM (91–116 d), which yielded in the range of 6–12 g plant^{-1}; three accessions were selected based on PLHT (31–46 cm), which produced a yield of 6–7 g plant^{-1}, and two accessions were selected based on 100 SW (15–24 g), having an SY of 6–7 g plant^{-1}. Notably, one accession (ICC5710), with a flowering time of 52 d and DM of 101 d, produced about 50% higher yield over the check cultivar JG11 (Table 3).

Table 3. Shortlisted germplasm accessions based on ranking biplot for five traits across two years for Amlaha, Madhya Pradesh.

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY
1	ICCV91902	75	37	ICC14014	108	25	ICC13285	62	32	ICC12452	65	29	ICC7470	48	6	ICC8190	91	7	ICC7554	46	7	ICC15065	24	7
2	ICC14014	79	25	ICC8950	109	23	ICC5472	61	25	ICC8348	49	22	ICC16145	50	6	ICC515	91	6	ICC13895	44	7	ICC5593	15	6
3	ICC7302	82	20	ICC12527	110	18	ICC8474	58	25	ICC8474	35	25	ICC9499	50	8	ICC1097	100	6	ICC16841	31	6	NA	NA	NA
4	ICC16166	82	36	ICC13107	110	33	ICC4074	57	34	ICC15762	29	21	ICC15065	51	7	ICC5710	101	12	NA	NA	NA	NA	NA	NA
5	ICC9100	83	19	ICC8332	110	23	ICC13874	57	25	ICCV88202	29	29	ICC5710	52	12	ICC15065	104	7	NA	NA	NA	NA	NA	NA
6	ICC14881	83	37	ICC1560	110	24	ICC15540	55	26	ICC11903	29	27	ICC16841	55	6	ICC342	108	7	NA	NA	NA	NA	NA	NA
7	ICC8522	84	22	ICC15851	110	19	ICC13694	54	25	ICCV93958	28	21	ICC8190	55	7	ICC14495	111	8	NA	NA	NA	NA	NA	NA
8	ICC14519	84	23	ICC5878	111	26	ICC3164	54	28	ICCV91902	26	37	ICC13895	56	7	ICC5593	116	6	NA	NA	NA	NA	NA	NA
9	ICC8332	85	23	ICC8556	112	16	ICC6973	53	32	ICC12458	24	22	ICC6120	58	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	ICC16706	85	21	ICC14176	112	22	ICC3766	53	36	ICC1000	23	35	ICC11507	58	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	ICC11046	86	31	ICC16076	113	25	ICC9636	53	23	ICC1240	23	22	ICC513	61	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	ICC8950	87	23	ICC9100	114	19	ICC13696	52	35	ICC6793	22	24	ICC342	62	7	NA	NA	NA	NA	NA	NA	NA	NA	NA
13	ICC8556	87	16	ICC228	114	20	ICCV95705	51	22	ICCL82108	22	24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
14	ICC1052	89	20	ICC11091	114	36	ICCL82108	49	24	ICC1402	20	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15	ICC10457	90	22	ICCV95705	114	22	ICC4168	49	27	ICC15540	20	26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16	ICC16076	90	25	ICC14507	116	27	ICC1817	48	26	ICC3164	19	28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
17	NA	NA	NA	ICC12273	116	19	ICC14385	48	25	ICC1560	19	24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	NA	NA	NA	ICC10953	116	42	ICC1240	48	22	ICC16903	19	31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	NA	NA	NA	ICC4074	117	34	ICC8366	48	27	ICC14385	18	25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	NA	NA	NA	ICC8366	117	27	ICC16400	48	27	ICCV95705	18	22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	Annigeri (C)	84	17	Annigeri (C)	123	17	Annigeri (C)	42	17	Annigeri (C)	18	17	Annigeri (C)	60	7	Annigeri (C)	111	7	Annigeri (C)	31	7	Annigeri (C)	19	7
2	G130 (C)	89	16	G130 (C)	120	16	G130 (C)	46	16	G130 (C)	12	16	G130 (C)	65	6	G130 (C)	111	6	G130 (C)	36	6	G130 (C)	14	6
3	ICCV10 (C)	84	16	ICCV10 (C)	119	16	ICCV10 (C)	48	16	ICCV10 (C)	17	16	ICCV10 (C)	63	7	ICCV10 (C)	110	7	ICCV10 (C)	36	7	ICCV10 (C)	19	7
4	**JG11 (C)**	**83**	**16**	**JG11 (C)**	**119**	**16**	**JG11 (C)**	**48**	**16**	**JG11 (C)**	**23**	**16**	**JG11 (C)**	**56**	**8**	**JG11 (C)**	**112**	**8**	**JG11 (C)**	**40**	**8**	**JG11 (C)**	**24**	**8**
	Kabuli type chickpea accessions tested in the year 2014–15												**Kabuli type chickpea accessions tested in the year 2015–16**											
1	ICC11879	75	32	ICC16644	112	20	ICC16659	64	21	ICC8483	39	16	IG70436	50	11	IG71993	98	6	IG73294	49	8	ICC10778	30	7
2	IG73331	87	22	IG71878	115	20	IG72021	60	18	ICC6355	33	16	IG7732	51	8	IG6401	101	6	ICC6140	47	9	ICC8527	29	11
3	ICC15518	87	30	ICC6831	118	19	ICC11879	55	32	IG70815	32	26	IG10569	53	6	ICC15823	107	8	ICC8527	46	11	ICC6246	26	8
4	ICC16659	88	21	IG73242	122	18	IG73242	52	18	IG73286	32	15	IG71993	53	6	IG7732	107	8	IG6401	44	6	IG71993	24	6
5	IG10187	89	25	ICC12428	123	20	ICC2496	51	28	IG6078	31	24	ICC6140	54	9	ICC8527	107	11	ICC8510	43	6	NA	NA	NA
6	ICC7676	90	16	ICC15812	123	22	IG9312	50	18	IG72021	30	18	IG6401	54	6	IG71878	107	6	IG10569	43	6	NA	NA	NA
7	ICC12428	90	20	IG9668	124	21	ICC14190	50	18	ICC7676	29	16	ICC10778	56	7	ICC6140	108	9	ICC4899	41	17	NA	NA	NA
8	IG71878	93	20	ICCV2	127	17	ICC8483	48	16	IG73331	29	22	IG71946	57	8	IG73242	109	8	NA	NA	NA	NA	NA	NA
9	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICCV2	27	17	NA	NA	NA	IG10569	110	6	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA	NA	NA	NA	IG70746	26	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	**KAK2 (C)**	**79**	**16**	**KAK2 (C)**	**119**	**16**	**KAK2 (C)**	**50**	**16**	**KAK2 (C)**	**35**	**16**	**KAK2 (C)**	**55**	**9**	**KAK2 (C)**	**111**	**9**	**KAK2 (C)**	**38**	**9**	**KAK2 (C)**	**37**	**9**
2	L550 (C)	90	16	L550 (C)	130	16	L550 (C)	47	16	L550 (C)	21	16	L550 (C)	65	6	L550 (C)	115	6	L550 (C)	37	6	L550 (C)	20	6
	Intermediate type chickpea accessions tested in the year 2014–15												**Intermediate type chickpea accessions tested in the year 2015–16**											
1	ICC5955	78	22	ICC5955	115	22	ICC7574	54	20	ICC7574	33	20	ICC5879	56	6	ICC5879	110	6	NA	NA	NA	NA	NA	NA
2	ICC5980	83	32	ICC5727	131	41	ICC5616	51	28	ICC12431	20	43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	IG7555	87	22	NA	NA	NA	ICC12118	45	27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 3. *Cont.*

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**	**Accession Name**	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	Annigeri (C)	84	17	Annigeri (C)	123	17	Annigeri (C)	42	17	Annigeri (C)	18	17	Annigeri (C)	60	7	Annigeri (C)	111	7	Annigeri (C)	31	7	Annigeri (C)	19	7
2	G130 (C)	89	16	G130 (C)	120	16	G130 (C)	46	16	G130 (C)	12	16	G130 (C)	65	6	G130 (C)	111	6	G130 (C)	36	6	G130 (C)	14	6
3	ICCV10 (C)	84	16	ICCV10 (C)	119	16	ICCV10 (C)	48	16	ICCV10 (C)	17	16	ICCV10 (C)	63	7	ICCV10 (C)	110	7	ICCV10 (C)	36	7	ICCV10 (C)	19	7
4	JG11 (C)	83	16	JG11 (C)	119	16	JG11 (C)	48	16	JG11 (C)	23	16	JG11 (C)	56	8	JG11 (C)	112	8	JG11 (C)	40	8	JG11 (C)	24	8
5	**KAK2 (C)**	**79**	**16**	**KAK2 (C)**	**119**	**16**	**KAK2 (C)**	**50**	**16**	**KAK2 (C)**	**35**	**16**	**KAK2 (C)**	**55**	**9**	**KAK2 (C)**	**111**	**9**	**KAK2 (C)**	**38**	**9**	**KAK2 (C)**	**37**	**9**
6	L550 (C)	90	16	L550 (C)	130	16	L550 (C)	47	16	L550 (C)	21	16	L550 (C)	65	6	L550 (C)	115	6	L550 (C)	37	6	L550 (C)	20	6

The check cultivars are highlighted in bold.

3.3.2. Kabuli Type

During the 2014–15 year, KAK2 was the best check cultivar, with an SY of 16 g plant^{-1}, DF of 79 d, DM of 119 d, PLHT of 50 cm, and 100 SW of 35 g. Eight accessions selected based on flowering time had DF in the range of 75–93 d and SY in the range of 16–32 g plant^{-1}. Three accessions (ICC11879, ICC15518, and IG10187) were prioritised, and SY was 56–100% more than the check cultivar KAK2 (Table 3). Furthermore, eight germplasm accessions were selected based upon DM (112–127 d), whose SY varied from 17–22 g plant^{-1}. None of these eight accessions produced a yield with a 50% increase over KAK2. Based on PLHT, eight accessions were selected whose height ranged between 48 and 64 cm, with a yield of 16–32 g plant^{-1}. Two of these eight accessions (ICC11879 and ICC2496) produced SY with a 75–100% increase over KAK2 (Table 3). Further, ten accessions were selected based upon 100 SW (26–39 g), whose SY ranged between 16–26 g. Two (IG70815 and IG6078) out of ten accessions had a 50–62% yield advantage compared to KAK2 (Table 3).

KAK2 was designated the best check during 2015–16, with an SY of 9 g plant^{-1}, a flowering time of 55 d, DM of 111 d, PLHT of 38 cm, and 100 SW of 37 g. Eight accessions were selected based on DF (50–57 d), which produced an SY of 6–11 g plant^{-1}. Ten accessions were prioritised based on maturity days (98–110 d), with a yield ranging between 6 and 11 g plant^{-1}. Further, seven accessions were selected based on PLHT (41–49 cm), yielding between 6 and 17 g plant^{-1}. Based on 100 SW, seven accessions were prioritised whose seed weight was 24–30 g and whose yield varied between 6 and 11 g plant^{-1}. Interestingly, during 2015–16, none of the accessions produced more than 50% over the check cultivar (Table 3).

3.3.3. Intermediate Type

During 2014–15, the check cultivar KAK2 produced a yield of 16 g plant^{-1}, DF of 79 d, DM of 119 d, PLHT of 50 cm, and 100 SW of 35 g. One accession (ICC5980) was selected based on DF (83 d), which yielded over 32 g plant^{-1} (>100% over KAK2); one accession (ICC5727) was selected based on DM (131 d), which produced an SY of 41 g plant^{-1} (>156% over KAK2). Further, two accessions (ICC5616 and ICC12118) were prioritised based on PLHT, which produced up to 75% higher yield when compared with KAK2. One accession (ICC12431) was selected based on 100 SW (20 g), producing up to 169% more yield than KAK2. During 2015–16, KAK2 was considered the best check, with an SY of 9 g plant^{-1}, DF of 55 d, DM of 111 d, PLHT of 38 cm, and 100 SW of 37 g. Here, none of the accessions was found to be agronomically superior to KAK2 (Table 3).

3.4. Selection of Stable and Promising Elite Accessions for Patancheru, Telangana

3.4.1. Desi Type

During the 2014–15 year, the check cultivar JG11 produced an SY of 15 g plant^{-1}, DF of 41 d, DM of 100 d, PLHT of 42 cm, and 100 SW of 25 g (Table 4). A total of 18 accessions were selected based upon flowering time (35–52 d), which produced an SY in the range of 14–23 g plant^{-1}. One accession (ICC8348) having DF of 38 d and a yield of 23 g plant^{-1} (>53% over JG11) was selected (Table 4). Seventeen accessions were selected based on maturity days (99–110 d), producing an SY of 14–26 g plant^{-1}. Further, two accessions (ICC8348 and ICC5003HN) with DM of 100–108 d and producing a yield of up to 73% higher than the check cultivar JG11 were prioritised (Table 4). Based on PLHT, 13 accessions were selected whose height ranged between 40 and 56 cm and whose SY ranged from 15 to 26 g plant^{-1}. Two accessions (ICC5003HN and ICC8348) having an average height in the range of 45–47 cm and SY up to 73% higher than JG11 were selected (Table 4). A total of 15 accessions were prioritised based on 100 SW (16–32 g), whose SY ranged between 14 and 26 g plant^{-1}. One accession (ICC5003HN) was selected, with a seed weight of 29 g and about 73% higher SY over JG11 (Table 4).

Table 4. Shortlisted germplasm accessions based on ranking biplot for five traits across two years for Patancheru, Telangana.

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY
1	ICCV92503	35	15	ICC3539	99	14	ICC9139	56	15	ICC5003LN	32	20	ICC8474	37	28	ICCV88202	91	16	ICC9307	64	24	ICC12159	30	17
2	ICC8348	38	23	ICC299	100	17	ICC643	51	17	ICC5003HN	29	26	ICC12159	41	17	ICC8318	97	15	ICC12993	61	20	ICC8474	29	28
3	ICC5934	41	15	ICC273	100	17	ICC4418	51	15	ICCV93958	29	18	ICC16841	42	19	ICC4918NN	99	16	ICC5472	55	17	ICC15762	25	16
4	ICC15065	41	19	ICC8348	100	23	ICC15376	48	15	ICC9139	25	15	ICCL85222	45	16	ICC12159	102	17	ICC16234	52	22	ICC15427	23	18
5	ICC5593	42	20	ICC12159	100	15	ICC5003HN	47	26	ICC1338	24	19	ICC4918NN	45	16	ICC5710	103	20	ICC1817	51	16	ICC15445	22	27
6	ICC3539	43	14	ICC11040	101	17	ICC13042	46	19	ICC7554	23	19	ICC10942	49	17	ICC10942	104	17	ICC5722	50	19	ICC4918NN	21	16
7	ICC12159	43	15	ICC5934	102	15	ICC8348	45	23	ICC15065	23	19	ICC2664	54	17	ICC10945	105	15	ICC2356	49	27	ICC15213	19	21
8	ICC14356	45	15	ICC7470	103	17	ICC15585	43	16	ICC15376	21	15	ICCL82108	54	20	ICC2938	107	17	ICC10197	49	25	ICCV88202	19	16
9	ICC15585	46	16	ICC5003LN	104	20	ICC5009	41	14	ICC11040	20	17	NA	NA	NA	ICC1097	108	19	ICC12463	48	20	IG70447	18	16
10	ICC16682	47	14	ICC5593	106	20	ICC11504	40	18	ICC1560	19	17	NA	NA	NA	ICC12337	109	16	IG70353	46	21	ICC15186	18	23
11	ICC5003LN	48	20	ICC12267	106	14	ICC299	40	17	ICC5593	18	20	NA	NA	NA	ICC8950	110	15	ICCL82108	46	20	ICC1560	18	18
12	ICC11040	48	17	ICC1392	107	19	ICC1124	40	18	ICC3539	18	14	NA	NA	NA	ICC1560	110	18	ICC15427	45	18	IG70353	17	21
13	ICC273	49	17	ICC1402	107	18	ICC1338	40	19	ICCV92503	18	15	NA	NA	NA	ICC6571	112	16	ICC1201	40	23	ICC2664	16	17
14	ICC1896	50	21	ICC5003HN	108	26	NA	NA	NA	ICCV95605	16	20	NA	NA	NA	ICC14495	117	16	ICC8474	36	28	ICCV95705	16	32
15	ICC342	52	16	ICC10945	109	15	NA	NA	NA	ICC1402	16	18	NA	NA	NA	ICC9499	118	16	NA	NA	NA	ICC1201	15	23
16	NA	NA	NA	ICC1124	109	18	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC1594	121	15	NA	NA	NA	ICC3440	15	20
17	NA	NA	NA	ICC2072	110	21	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC273	121	24	NA	NA	NA	ICCV95605	15	18
18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC513	122	19	NA	NA	NA	ICCL82108	15	20
19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	Annigeri (C)	45	14	Annigeri (C)	102	14	Annigeri (C)	39	14	Annigeri (C)	23	14	Annigeri (C)	40	15	Annigeri (C)	103	15	Annigeri (C)	37	15	Annigeri (C)	22	15
2	G130 (C)	57	15	G130 (C)	110	15	G130 (C)	41	15	G130 (C)	11	15	G130 (C)	68	17	G130 (C)	123	17	G130 (C)	43	17	G130 (C)	11	17
3	ICCV10 (C)	49	14	ICCV10 (C)	102	14	ICCV10 (C)	41	14	ICCV10 (C)	19	14	ICCV10 (C)	54	18	ICCV10 (C)	106	18	ICCV10 (C)	39	18	ICCV10 (C)	17	18
4	**JG11 (C)**	**41**	**15**	**JG11 (C)**	**100**	**15**	**JG11 (C)**	**42**	**15**	**JG11 (C)**	**25**	**15**	**JG11 (C)**	**38**	**15**	**JG11 (C)**	**101**	**15**	**JG11 (C)**	**39**	**15**	**JG11 (C)**	**24**	**15**
	Kabuli type chickpea accessions tested in the year 2014–15												**Kabuli type chickpea accessions tested in the year 2015–16**											
1	ICC5811	48	15	ICC12961	100	14	ICC9330	63	15	ICC15812	33	23	ICC5811	53	13	ICCV2NN	85	14	IG72070	76	26	ICC14220	45	10
2	ICC6355	50	15	ICC14913	102	14	ICC2496	63	16	ICC15823	31	13	ICC8864	58	15	IG10360	109	17	IG10370	67	16	IG70466	38	23
3	ICC16206	53	15	IG5868	108	18	ICC6140	56	14	ICC7259	31	19	ICC5899	59	23	ICC14913	111	12	ICC16637	62	24	ICC6239	35	26
4	ICC12961	53	14	ICC16206	110	15	ICC2503	55	13	ICC10778	31	14	IG7458	59	14	IG7427	111	12	IG70429	62	13	ICC10749	33	21
5	ICC6140	54	14	ICC14436	112	16	ICC10778	55	14	IG10956	29	17	ICC15834	59	18	IG71728	115	19	ICC11738	61	30	ICC8527	33	19
6	IG73294	54	18	ICC15812	114	23	IG73286	55	21	IG73286	29	21	ICC10749	62	21	ICC15834	119	18	ICC8527	60	19	IG71950	32	16
7	ICC14436	56	16	ICC15823	114	13	IG10569	54	21	IG6078	29	23	IG71946	62	13	IG71946	121	13	ICC8027	59	15	ICC15406	32	12
8	IG10569	58	21	ICC10747	115	14	ICC6355	54	15	ICC9330	23	15	ICC8527	62	19	IG71878	122	14	ICC13187	59	25	ICC7654	31	11
9	ICC15812	59	23	NA	NA	NA	ICC10747	54	14	ICC6246	21	15	IG71728	63	19	ICC8864	122	15	IG69692	57	15	IG72070	30	26
10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC5122	63	20	IG7458	123	14	IG10240	57	21	ICC16637	27	24
1	**KAK2 (C)**	**37**	**13**	**KAK2 (C)**	**93**	**13**	**KAK2 (C)**	**40**	**13**	**KAK2 (C)**	**37**	**13**	**KAK2 (C)**	**39**	**10**	**KAK2 (C)**	**90**	**10**	**KAK2 (C)**	**36**	**10**	**KAK2 (C)**	**35**	**10**
2	L550 (C)	61	15	L550 (C)	114	15	L550 (C)	40	15	L550 (C)	20	15	L550 (C)	70	21	L550 (C)	127	21	L550 (C)	46	21	L550 (C)	19	21
	Intermediate type chickpea accessions tested in the year 2014–15												**Intermediate type chickpea accessions tested in the year 2015–16**											
1	ICC5923	48	14	ICC5901	104	20	ICC9778	50	26	ICC8921	22	16	ICC5879	39	14	ICC4878	102	26	ICC7574	60	30	ICC4878	23	26
2	ICC5955	49	14	ICC5923	109	14	NA	NA	NA	NA	NA	NA	ICC4878	54	26	ICC5727	107	26	ICC8930	56	21	ICC12431	19	28
3	ICC9778	51	26	ICC9778	111	26	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC15234	119	14	ICC5616	55	18	ICC8930	18	21

Table 4. *Cont.*

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**	**Accession Name**	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	Annigeri (C)	45	14	Annigeri (C)	102	14	Annigeri (C)	39	14	Annigeri (C)	23	14	Annigeri (C)	40	15	Annigeri (C)	103	15	Annigeri (C)	37	15	Annigeri (C)	22	15
2	G130 (C)	57	15	G130 (C)	110	15	G130 (C)	41	15	G130 (C)	11	15	G130 (C)	68	17	G130 (C)	123	17	G130 (C)	43	17	G130 (C)	11	17
3	ICCV10 (C)	49	14	ICCV10 (C)	102	14	ICCV10 (C)	41	14	ICCV10 (C)	19	14	ICCV10 (C)	54	18	ICCV10 (C)	106	18	ICCV10 (C)	39	18	ICCV10 (C)	17	18
4	**JG11 (C)**	**41**	**15**	**JG11 (C)**	**100**	**15**	**JG11 (C)**	**42**	**15**	**JG11 (C)**	**25**	**15**	**JG11 (C)**	**38**	**15**	**JG11 (C)**	**101**	**15**	**JG11 (C)**	**39**	**15**	**JG11 (C)**	**24**	**15**
5	KAK2 (C)	37	13	KAK2 (C)	93	13	KAK2 (C)	40	13	KAK2 (C)	37	13	KAK2 (C)	39	10	KAK2 (C)	90	10	KAK2 (C)	36	10	KAK2 (C)	35	10
6	L550 (C)	61	15	L550 (C)	114	15	L550 (C)	40	15	L550 (C)	20	15	L550 (C)	70	21	L550 (C)	127	21	L550 (C)	46	21	L550 (C)	19	21

The check cultivars are highlighted in bold.

The best check cultivar, JG11, possessed an SY of 15 g plant^{-1}, a flowering time of 38 d, DM of 101 d, PLHT of 39 cm, and 100 SW of 24 g during 2015–16 (Table 4). Eight accessions were selected based upon DF (37–54 d), which produced a yield between 16 and 28 g plant^{-1}. Of these, one accession (ICC8474) having a flowering time of 37 d produced up to 87% higher SY over JG11 (Table 4). Furthermore, 18 accessions were selected based on maturity days (91–122 d), with SY ranging between 15 and 24 g plant^{-1}. One accession (ICC273) with a DM of 121 d produced a 60% greater yield than JG11 (Table 4). Based on PLHT, 14 accessions were selected whose height was 36–64 cm and whose yield varied between 16 and 28 g plant^{-1}. Out of 14, 5 accessions (ICC9307, ICC2356, ICC10197, ICC1201, and ICC8474) were found to have a more than 50% yield potential of JG11 (Table 4). Eighteen accessions were selected based upon 100 SW (15–30 g), which yielded between 16 and 32 g plant^{-1}. Five accessions (ICC8474, ICC15445, ICC15186, ICCV95705, and ICC1201) were found to have yielded more than 50% over the best check JG11 (Table 4).

3.4.2. Kabuli Type

During 2014–15, the best check cultivar KAK2 had an SY of 13 g plant^{-1}, a flowering time of 37 d, DM of 93 d, PLHT of 40 cm, and 100 SW of 37 g (Table 4). Nine accessions were selected based on flowering time (48–59 d), producing a yield of 14–23 g plant^{-1}. Two of these nine accessions (IG10569 and ICC15812) yielded up to 72% higher than KAK2 (Table 4). Based on DM, eight selected accessions had maturity days between 100 and 115 d and yields in the range of 13–23 g plant^{-1}. Here, one accession (ICC15812) produced about 77% higher yield than the best check KAK2. Nine accessions selected based on PLHT (54–63 cm) had SY in the 13–21 g plant^{-1}. Two accessions (IG73286 and IG10569) produced about 62% higher yields than KAK2. Further, nine accessions selected based on 100 SW (21–33 g) produced yields in the 13–23 g plant^{-1}. Three accessions (ICC15812, IG73286, and IG6078) were prioritised based on SY, ranging between 62 and 77% more than check cultivar KAK2 (Table 4).

During 2015–16, KAK2 had an average yield of 10 g plant^{-1}, DF of 39 d, DM of 90 d, PLHT of 36 cm, and 100 SW of 35 g (Table 4). Ten accessions were prioritised based on flowering time (53–63 d), producing a yield of 13–23 g plant^{-1}. Seven out of ten accessions yielded between 50 and 130% more than KAK2 (Table 4). Ten accessions were selected based on maturity days (85–123 d), producing 12–19 g plant^{-1}. Four accessions (IG10360, IG71728, ICC15834, and ICC8864) were selected, producing a 50–90% higher yield over KAK2. Furthermore, ten accessions were selected based on PLHT (57–76 cm), which had a yield of 13–30 g plant^{-1}. Eight of ten accessions produced a 50–200% greater yield than KAK2 (Table 4). Ten accessions were selected based upon 100 SW (27–45 g), having a yield of 10–26 g plant^{-1}. Seven accessions produced up to 60–160% more yield than the check cultivar KAK2 (Table 4).

3.4.3. Intermediate Type

The check cultivar JG11 yielded 15 g plant^{-1}, DF of 41 d, DM of 100 d, PLHT of 42 cm, and 100 SW of 25 g during 2014–15 (Table 4). One accession (ICC9778) was selected based on flowering time (51 d), which produced a 73% increase in yield over JG11. In addition, one accession (ICC9778) with a DM of 111 d had a yield gain of >73% over the check cultivar JG11. An accession (ICC9778) was prioritised based on PLHT (50 cm), producing more than 73% greater yield than JG11. During 2015–16, JG11 had an SY of 15 g plant^{-1}, days to flowering of 38 d, DM of 101 d, PLHT of 39 cm, and 100 SW of 24 g. One accession (ICC4878) was selected based upon flowering time (54 d) and produced about 73% more yield than JG11. Further, two (ICC4878 and ICC5727) accessions were selected based on maturity days (102–107 d) and produced more than 73% higher yield than JG11. One accession (ICC7524) was prioritised, with a PLHT of 60 cm yield gain of more than 100% over JG11. The two accessions (ICC4878 and ICC12431) selected based on 100 SW produced a 73–86% yield over the check cultivar JG11 (Table 4).

3.5. Selection of Stable and Promising Elite Accessions for Kanpur, Uttar Pradesh

3.5.1. Desi Type

During the 2015–16 season, JG11 was the best check cultivar and had an SY of 16 g $plant^{-1}$, DF of 64 d, DM of 117 d, PLHT of 45 cm, and 100 SW of 24 g (Table 5). Fourteen accessions were selected based upon DF (54–74 d), which produced 15–24 g $plant^{-1}$. One accession (ICC16734) was found to possess a flowering time of 62 d and yielded 24 g $plant^{-1}$ (>50% over JG11) (Table 5). Based on DM, 13 accessions were selected with maturity days in the 112–120 d and produced a yield between 16 and 28 g $plant^{-1}$. One accession (ICC299) with days of maturity of 112 d had more than 75% yield over the check JG11 (Table 5). Further, 11 accessions were selected based on PLHT (44–67 cm), which yielded 15–43 g $plant^{-1}$. Three accessions (ICC2766, ICC9139, and ICC2878) were detected to produce a 94–169% higher yield than JG11 (Table 5). Thirteen accessions were selected with 100 SW in the 12–31 g and had a yield of 15–41 g $plant^{-1}$. Notably, two accessions (ICC9139 and ICC15610) had 94–156% more yield than the JG11 check (Table 5).

During 2016–17, JG11 outperformed other checks by producing a yield of 16 g $plant^{-1}$, DF of 76 d, DM of 120 d, PLHT of 51 cm, and 100 SW of 24 g. Ten accessions were selected based upon flowering time (70–79 d), and these accessions had yields in the range of 17–30 g $plant^{-1}$. Of these, one accession (ICC15081) with a flowering time of 74 d and an SY of 30 g $plant^{-1}$ produced 88% more yield than the JG11 check. Based on DM, 15 accessions were selected that matured in 112–122 d and produced yield in the range of 17–27 g $plant^{-1}$. Of these 15 accessions, 4 (ICC12878, ICC1594, ICC12273, and ICC4478) were selected, as they produced 56–69% higher yield than the check cultivar JG11. Nineteen accessions were selected based on PLHT (45–68 cm), which yielded 16–28 g $plant^{-1}$. A total of five accessions (ICC15427, ICC3126, ICCL82108, ICC7054, and ICC796) outperformed JG11 by producing a 50–75% higher yield. Seventeen accessions were prioritised based on 100 SW (15–28 g), and these accessions had SY in the range of 16–28 g $plant^{-1}$. Four accessions (ICC2086, ICC10393, ICC1510, and ICC15427) out of seventeen produced about 50–75% greater yield than JG11 (Table 5).

3.5.2. Kabuli Type

The cultivar KAK2 was the best check during 2015–16 and had an SY of 15 g $plant^{-1}$, a flowering time of 59 d, DM of 116 d, PLHT of 44 cm, and 100 SW of 37 g (Table 5). Here, nine accessions were selected based upon days to flowering (56–73 d), which yielded 14–17 g $plant^{-1}$. Five accessions were prioritised based upon maturity days (111–121 d), which produced a yield range of 14–17 g $plant^{-1}$ (Table 5). Based on PLHT, six accessions were selected with a height of 55–71 cm and a yield of 16–24 g $plant^{-1}$. One accession (ICC16637) with 71 cm PLHT produced >60% yield over the check KAK2 (Table 5). Seven accessions were selected based on 100 SW (25–38 g), whose yield varied in the range of 14–24 g $plant^{-1}$. Two accessions produced about 53–60% higher yield than the check cultivar (Table 5).

During 2016–17, the check cultivar KAK2 yielded 14 g $plant^{-1}$, DF of 85 d, DM of 119 d, PLHT of 51 cm, and 100 SW of 37 g (Table 5). Nine accessions were selected based on flowering time (74–83 d), which produced a yield of 13–25 g $plant^{-1}$. Of these, an accession (ICC15060) with a DF of 80 d produced ~67% higher yield than KAK2 (Table 5). Ten accessions were prioritised based on maturity days (110–121 d) and had SY in the 14–22 g $plant^{-1}$. Furthermore, ten accessions were selected based on PLHT (54–78 cm) and produced 13–27 g $plant^{-1}$. One accession (ICC12031) having 57 cm PLHT was found to produce >80% yield over the check cultivar (Table 5). Ten accessions were also selected based on 100 SW, and these accessions had seed weight in the range of 28–52 g and produced a yield of 13–20 g $plant^{-1}$ (Table 5).

Table 5. Shortlisted germplasm accessions based on ranking biplot for five traits across two years for Kanpur, Uttar Pradesh.

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2015–16												Desi Type Chickpea Accessions Tested in the Year 2016–17											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**	**Accession Name**	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	ICCV92503	54	20	ICC14710	112	19	ICC2766	67	31	ICC15065	31	21	ICCV91902	70	23	ICC12878	112	27	ICC3164	68	16	ICCV91902	28	23
2	ICC12159	56	17	ICC15081	112	20	ICC643	60	17	ICC9139	29	31	ICC10963	73	19	ICC1205	116	17	ICC4418	68	20	ICC15510	24	20
3	ICC8348	57	19	ICC9030	112	16	ICC4250	57	18	ICC15610	23	41	ICC403	74	17	ICC13219	118	23	ICC1102	66	18	ICC1338	22	23
4	ICCV88503	60	21	ICC299	112	28	ICC3776	57	16	ICCV92503	22	20	ICC15081	74	30	ICC14098	118	20	ICC4036	65	16	ICC3164	20	16
5	ICC11009	62	23	ICC11372	112	19	ICC16841	55	16	ICC1634	21	20	ICC5951	75	20	ICC95	118	20	ICC1338	60	23	ICC15186	20	16
6	ICC15081	62	20	ICC8950	112	18	ICC9139	55	31	ICC15213	20	18	ICC1896	76	22	ICC10953	119	17	ICC4233	59	17	ICC10963	19	19
7	ICC16734	62	24	ICC11040	113	20	ICC4333	53	16	ICC5593	19	15	ICC14881	78	19	ICC10963	119	19	ICC14976	58	19	ICC7593	19	16
8	ICC11040	65	20	ICC14083	113	19	ICC2878	53	43	ICC11040	19	20	ICCV91106	78	20	ICC1594	119	27	ICC14176	57	23	ICC5593	18	21
9	ICC15065	68	21	ICC2072	114	19	ICC5491	49	20	ICC5491	18	20	ICC15595	79	23	ICC4478	119	25	ICC15427	57	28	ICC2086	18	24
10	ICC10898	68	18	ICC9541	114	20	ICC8348	45	19	ICC10898	18	18	ICC2023	79	18	ICC5593	119	21	ICC13696	56	22	ICC1510	18	26
11	ICC4250	70	18	ICCL83149	114	23	ICC6569	44	15	ICC1913	15	15	NA	NA	NA	ICC12267	121	18	ICC3126	56	28	ICC435NN	18	16
12	ICC45	71	15	ICC11944	120	18	NA	NA	NA	ICCV95605	15	20	NA	NA	NA	ICC14976	121	19	ICCL82108	56	26	ICC14852	17	20
13	ICC403	72	22	ICC12768	120	16	NA	NA	NA	ICC7441	12	18	NA	NA	NA	ICC6445	121	18	ICC7054	55	24	ICC1205	17	17
14	ICC16841	74	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC12273	122	27	ICC796	55	25	ICC10393	16	24
15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC13696	122	22	ICC95	53	20	ICC12458	15	16
16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC9676	50	17	ICC15427	15	28
17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICCV89314	50	17	IG70353	15	21
18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC14098	47	20	NA	NA	NA
19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ICC4024	45	19	NA	NA	NA
20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	Annigeri (C)	67	15	Annigeri (C)	116	15	Annigeri (C)	43	15	Annigeri (C)	13	15	Annigeri (C)	77	16	Annigeri (C)	118	16	Annigeri (C)	49	16	Annigeri (C)	13	16
2	G130 (C)	70	16	G130 (C)	120	16	G130 (C)	45	16	G130 (C)	12	16	G130 (C)	80	16	G130 (C)	122	16	G130 (C)	51	16	G130 (C)	13	16
3	ICCV10 (C)	67	17	ICCV10 (C)	117	17	ICCV10 (C)	44	17	ICCV10 (C)	19	17	ICCV10 (C)	77	18	ICCV10 (C)	118	18	ICCV10 (C)	45	18	ICCV10 (C)	18	18
4	**JG11 (C)**	**64**	**16**	**JG11 (C)**	**117**	**16**	**JG11 (C)**	**45**	**16**	**JG11 (C)**	**24**	**16**	**JG11 (C)**	**76**	**16**	**JG11 (C)**	**120**	**16**	**JG11 (C)**	**51**	**16**	**JG11 (C)**	**24**	**16**
	Kabuli type chickpea accessions tested in the year 2015–16												**Kabuli type chickpea accessions tested in the year 2016–17**											
1	ICCV2NN	56	17	ICC7272	111	14	ICC16637	71	24	IG70872	38	16	IG70872	74	19	ICC14190	110	16	IG72073	78	13	IG70872	52	19
2	IG70872	59	16	ICCV2NN	115	17	IG70321	60	16	IG6325	37	14	ICC12496	75	20	ICC13357	117	14	IG75637	66	13	IG6325	36	18
3	ICC12497	61	15	ICC6831	116	14	ICC14190	55	17	ICC16637	31	24	IG75637	77	13	IG70389	117	19	ICC16206	62	16	ICC10353	36	15
4	IG74018	65	16	ICC15060	117	15	ICC9464	47	17	IG6078	30	23	ICC10353	78	15	ICC10778	118	20	IG6448	61	15	ICC6355	34	14
5	ICC15060	65	15	IG71878	121	16	IG70321	60	16	IG70436	29	22	ICC7676	78	15	ICC2496	119	17	ICC7676	60	15	ICC10778	34	20
6	IG7446	65	17	NA	NA	NA	NA	NA	NA	IG70815	28	20	ICC15060	80	25	IG11161	119	14	IG69441	58	15	IG75637	34	13
7	ICC16206	72	14	NA	NA	NA	NA	NA	NA	ICC13816	25	17	ICC6355	81	14	IG73286	119	17	ICC12031	57	27	IG5872	33	14
8	ICC6831	73	14	NA	NA	NA	NA	NA	NA	NA	NA	NA	IG5872	81	14	IG75637	119	13	ICC4853	54	18	ICC7676	31	15
9	IG71878	73	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	IG69441	83	15	IG9330	120	22	ICC10778	54	20	IG70746	30	17
10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	IG6325	121	18	ICC13357	54	14	IG73286	28	17
1	**KAK2 (C)**	**59**	**15**	**KAK2 (C)**	**116**	**15**	**KAK2 (C)**	**44**	**15**	**KAK2 (C)**	**37**	**15**	**KAK2 (C)**	**85**	**14**	**KAK2 (C)**	**119**	**14**	**KAK2 (C)**	**51**	**14**	**KAK2 (C)**	**37**	**14**
2	L550 (C)	74	14	L550 (C)	120	14	L550 (C)	44	14	L550 (C)	20	14	L550 (C)	80	12	L550 (C)	120	12	L550 (C)	47	12	L550 (C)	21	12
	Intermediate type chickpea accessions tested in the year 2015–16												**Intermediate type chickpea accessions tested in the year 2016–17**											
1	NA	NA	NA	ICC5923	122	26	ICC8930	55	14	ICC8930	22	14	ICC15234	79	17	ICC15234	117	17	ICC7574	61	27	ICC7574	30	27
2	NA	NA	NA	ICC5879	124	17	ICC9821	41	21	NA	NA	NA	ICC8407	81	20	ICC7574	117	27	IG7555	45	13	ICC8930	22	29
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 5. *Cont.*

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2015–16												Desi Type Chickpea Accessions Tested in the Year 2016–17											
	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY
1	Annigeri (C)	67	15	Annigeri (C)	116	15	Annigeri (C)	43	15	Annigeri (C)	13	15	Annigeri (C)	77	16	Annigeri (C)	118	16	Annigeri (C)	49	16	Annigeri (C)	13	16
2	G130 (C)	70	16	G130 (C)	120	16	G130 (C)	45	16	G130 (C)	12	16	G130 (C)	80	16	G130 (C)	122	16	G130 (C)	51	16	G130 (C)	13	16
3	ICCV10 (C)	67	17	ICCV10 (C)	117	17	ICCV10 (C)	44	17	ICCV10 (C)	19	17	ICCV10 (C)	77	18	ICCV10 (C)	118	18	ICCV10 (C)	45	18	ICCV10 (C)	18	18
4	**JG11 (C)**	**64**	**16**	**JG11 (C)**	**117**	**16**	**JG11 (C)**	**45**	**16**	**JG11 (C)**	**24**	**16**	**JG11 (C)**	**76**	**16**	**JG11 (C)**	**120**	**16**	**JG11 (C)**	**51**	**16**	**JG11 (C)**	**24**	**16**
5	KAK2 (C)	59	15	KAK2 (C)	116	15	KAK2 (C)	44	15	KAK2 (C)	37	15	KAK2 (C)	85	14	KAK2 (C)	119	14	KAK2 (C)	51	14	KAK2 (C)	37	14
6	L550 (C)	74	14	L550 (C)	120	14	L550 (C)	44	14	L550 (C)	20	14	L550 (C)	80	12	L550 (C)	120	12	L550 (C)	47	12	L550 (C)	21	12

The check cultivars are highlighted in bold.

3.5.3. Intermediate Type

The best check JG11 displayed an SY of 16 g plant^{-1}, DF of 64 d, DM of 117 d, PLHT of 45 cm, and 100 SW of 24 g during 2015–16 (Table 5). One accession (ICC5923) with a DM of 122 d produced about 63% higher yield than check JG11. During 2016–17, JG11 displayed a yield of 16 g plant^{-1}, DF of 76 d, DM of 120 d, PLHT of 51 cm, and 100 SW of 24 g (Table 5). One accession (ICC7574) with 61 cm PLHT produced about 69% higher yield than JG11. Further, two accessions were selected based upon 100 SW, which displayed superior yield performance over JG11 (Table 5).

3.6. Selection of Stable and Promising Accessions for Junagadh, Gujarat

3.6.1. Desi Type

During the 2014–15 year, Annigeri was the best check and had an SY of 23 g plant^{-1}, DF of 54 d, DM of 104 d, PLHT of 41 cm, and 100 SW of 22 g (Table 6). Eight accessions were selected based on DF (46–65 d), which produced a yield of 19–27 g plant^{-1}. A total of 16 accessions were prioritised based on DM (82–110 d), which yielded in the range of 19–31 g plant^{-1}. Based on PLHT, 12 accessions were selected whose height ranged from 37 cm to 59 cm, and whose yield ranged from 19 to 31 g plant^{-1}. Fifteen accessions were selected based on 100 SW (14–30 g), having an SY of 19–36 g plant^{-1}. One accession (ICCV95605), having a 100 SW of 16 g, produced about 57% higher yield than Annigeri (Table 6).

During the 2015–16 year, the best check Annigeri produced a yield of 17 g plant^{-1}, a flowering time of 50 d, DM of 102 d, PLHT of 47 cm, and 100 SW of 21 g (Table 6). Twenty accessions were selected based on flowering time (47–62 days), producing a yield between 20 and 47 g plant^{-1}. Of these 20 accessions, six (ICC5934, ICC14550, ICC2072, ICC45, ICC494, and ICC273) produced about 59–176% higher yield over Annigeri. Twenty accessions were prioritised based on crop duration, whose DM ranged between 86 and 108 d, and SY varied between 21 and 47 g plant^{-1}. Of these 20 accessions, 10 produced more than 50% compared with the check Annigeri (Table 6). Nineteen accessions were selected based upon PLHT (44–76 cm) with an SY of 22–37 g plant^{-1}. Of these, nine accessions showed about 50% higher yield over Annigeri. Based on 100 SW, 20 accessions were selected whose seed weight values ranged between 17 and 33 g, and whose SY ranged from 17 to 34 g plant^{-1}. Out of 20 accessions, 5 accessions produced an SY of 53–100% more than the check cultivar Annigeri (Table 6).

3.6.2. Kabuli Type

The best check cultivar, KAK2, had an SY of 23 g plant^{-1}, a flowering time of 48 d, DM of 86 d, PLHT of 42 cm, and 100 SW of 36 g (Table 6). Ten accessions were selected based on flowering time (51–67 d), producing yields in the range of 21–32 g plant^{-1}. Eight accessions were selected based upon DM (81–110 d), having a yield of 18–31 g plant^{-1}. Ten accessions were selected based on PLHT, whose height ranged from 51 to 57 cm and whose yield spanned from 22 to 46 g plant^{-1}. One accession (IG6401) was identified with a height of 57 cm and a yield of 46 g plant^{-1}, which was about 100% more than KAK2. Further, eight accessions selected based upon 100 SW (28–38 g) had an SY in the range of 19–31 g plant^{-1} (Table 6). During the 2015–16 year, KAK2 yielded 10 g plant^{-1}, a flowering time of 50 d, DM of 96 d, PLHT of 50 cm, and 100 SW of 37 g (Table 6). Ten accessions were selected based on flowering time (58–68 d), with SY in the range of 16–37 g plant^{-1}. All the accessions produced about 60–270% higher yield over the check KAK2 (Table 6). Ten accessions selected based upon maturity days (91–108 d) yielded in the range of 14–37 g plant^{-1}, and all the accessions, excluding one, yielded more than 50% of the check cultivar. Similarly, ten accessions selected based on PLHT (53–61 cm) had SY in the range of 18–29 g plant^{-1}; all these accessions produced more than 50% high yield over the check KAK2. Ten accessions were prioritised based upon 100 SW (29–40 g) and yielded 13–19 g plant^{-1}. Seven of these ten accessions (ICC8483, ICC14220, ICC7654, ICC10747, IG72070, IG69692, and IG70436) exhibited more than 50% yield gain over KAK2 (Table 6).

Table 6. Shortlisted germplasm accessions based on ranking biplot for five traits across two years for Junagadh, Gujarat.

Ranking of Accessions	**Desi Type Chickpea Accessions Tested in the Year 2014–15**											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	ICC15065	46	22	ICC1560	82	25	ICC15585	59	19	ICC5003HN	30	22
2	ICC15585	49	19	ICC8366	84	19	ICC13726	57	19	ICCV93958	28	24
3	ICCL85222	50	19	ICC8950	86	21	ICC3890	53	20	ICC15762	27	21
4	ICC15081	50	22	ICC8931	88	21	ICC9307	52	22	ICC13726	22	19
5	ICC273	57	22	ICC6384	88	25	ICC5491	48	23	ICC15540	22	21
6	ICC1629	63	24	ICC4526	89	24	ICC3776	45	29	ICC15065	21	22
7	ICC10629	63	27	ICC95	93	24	ICC14176	42	21	IG70447	20	28
8	ICC15221	65	23	ICC15585	93	19	ICC16320	41	23	ICC5491	19	23
9	NA	NA	NA	ICC15954	93	19	ICC11707	41	21	ICC5639	17	19
10	NA	NA	NA	ICC16841	96	31	ICC5003HN	39	22	ICC1560	17	25
11	NA	NA	NA	ICC14495	96	29	ICC95	37	24	ICCV95605	16	36
12	NA	NA	NA	ICC2072	97	20	ICC16841	37	31	ICC11510	16	27
13	NA	NA	NA	ICC8556	99	19	NA	NA	NA	ICC1629	15	24
14	NA	NA	NA	ICC11322	99	28	NA	NA	NA	ICCV89314	15	19
15	NA	NA	NA	ICC5003HN	101	22	NA	NA	NA	ICC10629	14	27
16	NA	NA	NA	ICC14519	110	26	NA	NA	NA	NA	NA	NA
17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	**Annigeri (C)**	**54**	**23**	**Annigeri (C)**	**104**	**23**	**Annigeri (C)**	**41**	**23**	**Annigeri (C)**	**22**	**23**
2	G130 (C)	64	20	G130 (C)	105	20	G130 (C)	37	20	G130 (C)	11	20
3	ICCV10 (C)	56	22	ICCV10 (C)	91	22	ICCV10 (C)	37	22	ICCV10 (C)	18	22
4	JG11 (C)	51	19	JG11 (C)	89	19	JG11 (C)	38	19	JG11 (C)	21	19
	Kabuli type chickpea accessions tested in the year 2014–15											
1	ICC16644	51	23	ICC16644	81	23	IG6401	57	46	ICC8483	38	23
2	IG7446	55	23	ICC16206	101	19	ICC16659	56	24	IG6098	35	19
3	ICC6831	59	22	ICC5644	102	25	IG9668	56	22	ICC7259	33	31
4	ICC7259	59	31	IG5868	105	31	ICC9330	56	24	IG70436	32	19
5	ICCV91302	61	24	IG9668	108	22	IG5868	54	31	ICC6355	30	22
6	IG7253	62	26	ICC7272	109	21	ICC8527	53	21	ICC8527	28	21
7	ICC8527	65	21	ICCV91302	110	24	IG73294	52	24	IG9668	28	22
8	ICC12961	66	32	ICC14436	110	23	ICC12961	51	32	ICC15823	28	24
9	ICC5644	67	25	NA	NA	NA	ICC6355	51	22	NA	NA	NA
10	ICC14436	67	23	NA	NA	NA	IG73242	51	23	NA	NA	NA
1	**KAK2 (C)**	**48**	**23**	**KAK2 (C)**	**86**	**23**	**KAK2 (C)**	**42**	**23**	**KAK2 (C)**	**36**	**23**
2	L550 (C)	66	19	L550 (C)	110	19	L550 (C)	41	19	L550 (C)	20	19
	Intermediate type chickpea accessions tested in the year 2014–15											
1	ICC5879	53	17	ICC15234	85	23	ICC5616	42	21	ICC8407	22	23
2	ICC8407	66	23	ICC8407	88	23	NA	NA	NA	NA	NA	NA
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Ranking of Accessions	**Desi Type Chickpea Accessions Tested in the Year 2015–16**											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	ICC8348	47	23	ICC5934	86	32	ICC9307	76	23	ICC10301	33	17
2	ICC5934	48	32	ICCV88202	99	24	ICC5491	65	23	ICC15762	29	18
3	ICC10629	48	24	ICC11040	101	29	ICC3558	60	25	ICC5003LN	27	34
4	ICCV88503	48	20	ICC8348	101	23	ICC9261	57	26	ICC15376	26	17
5	ICC14550	49	47	ICC14495	102	22	ICC2878	57	28	ICC9139	26	32
6	ICCV88202	49	24	ICC10629	102	24	ICC12888	55	22	ICC5003HN	24	22
7	ICC6120	49	22	ICC2938	103	47	ICC6617	54	37	ICC9261	24	26
8	ICC4984	51	21	ICC1392	103	26	ICC6900	54	23	ICC1338	23	21
9	ICCL85222	55	25	ICCL85222	104	25	ICC4333	54	24	ICCV92503	22	20
10	GG2	56	21	ICC10651	105	23	ICC11300	53	28	ICC2356	22	23
11	ICC10651	57	23	ICC1891	106	23	ICC9541	52	32	ICCV93958	22	18
12	ICCV92503	58	20	ICC5003LN	106	34	ICC7744	50	30	ICC1505	21	24
13	ICC2072	58	28	ICC2072	106	28	ICC2500	49	27	ICCV88202	20	24
14	ICC45	59	27	ICC494	106	37	ICC5003HN	49	22	ICC15213	20	29
15	ICC4680	60	21	ICC10945	107	21	ICC9139	49	32	ICC11040	19	29
16	ICC494	60	37	ICC1097	107	25	ICC643	47	22	ICC1634	19	21
17	ICC342	61	25	ICC9541	107	32	ICC299	47	22	ICC5491	18	23
18	ICC5613	61	23	ICC45	108	27	ICC14385	47	24	ICC8318	18	23
19	ICC273	62	30	ICC5003HN	108	22	ICC45	44	27	ICC946	17	18
20	ICC12159	62	23	ICC14550	108	47	NA	NA	NA	ICC6793	17	19
1	**Annigeri (C)**	**50**	**17**	**Annigeri (C)**	**102**	**17**	**Annigeri (C)**	**47**	**17**	**Annigeri (C)**	**21**	**17**
2	G130 (C)	65	17	G130 (C)	107	17	G130 (C)	49	17	G130 (C)	11	17
3	ICCV10 (C)	59	22	ICCV10 (C)	105	22	ICCV10 (C)	49	22	ICCV10 (C)	17	22
4	JG11 (C)	49	18	JG11 (C)	97	18	JG11 (C)	49	18	JG11 (C)	23	18
	Kabuli type chickpea accessions tested in the year 2015–16											
1	ICC14220	58	16	ICCV2NN	91	16	IG69746	61	28	ICC8483	40	18
2	IG10000	60	27	IG7427	105	21	ICC13187	58	19	ICC14220	40	16
3	ICC7668	61	37	IG71878	106	15	IG6044	57	29	ICC7654	37	17
4	IG10240	62	19	ICC10747	107	16	ICC7654	57	17	ICC10747	35	16
5	IG7427	65	21	ICC14220	107	16	IG69446	57	23	ICC10749	34	14
6	ICC8483	66	18	IG7458	107	16	IG69692	57	19	ICC16637	33	14
7	ICC6140	67	22	ICC8864	108	15	IG72140	55	18	ICC15406	32	13
8	IG71993	68	18	ICC7668	108	37	IG71917	55	18	IG72070	30	17
9	ICC10740	68	29	IG71917	108	18	IG7427	53	21	IG69692	29	19
10	ICC14739	68	24	IG6367	108	14	ICC6140	53	22	IG70436	29	18
1	**KAK2 (C)**	**50**	**10**	**KAK2 (C)**	**96**	**10**	**KAK2 (C)**	**50**	**10**	**KAK2 (C)**	**37**	**10**
2	L550 (C)	69	16	L550 (C)	110	16	L550 (C)	50	16	L550 (C)	19	16
	Intermediate type chickpea accessions tested in the year 2015–16											
1	ICC5923	59	16	ICC15234	108	18	ICC5616	61	19	ICC8930	23	14
2	IG7555	60	22	ICC5879	106	18	ICC8930	56	14	NA	NA	NA
3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 6. *Cont.*

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY	Accession Name	DF	SY	Accession Name	DM	SY	Accession Name	PLHT	SY	Accession Name	100 SW	SY
1	Annigeri (C)	54	23	Annigeri (C)	104	23	Annigeri (C)	41	23	Annigeri (C)	22	23	Annigeri (C)	50	17	Annigeri (C)	102	17	Annigeri (C)	47	17	Annigeri (C)	21	17
2	G130 (C)	64	20	G130 (C)	105	20	G130 (C)	37	20	G130 (C)	11	20	G130 (C)	65	17	G130 (C)	107	17	G130 (C)	49	17	G130 (C)	11	17
3	ICCV10 (C)	56	22	ICCV10 (C)	91	22	ICCV10 (C)	37	22	ICCV10 (C)	18	22	ICCV10 (C)	59	22	ICCV10 (C)	105	22	ICCV10 (C)	49	22	ICCV10 (C)	17	22
4	JG11 (C)	51	19	JG11 (C)	89	19	JG11 (C)	38	19	JG11 (C)	21	19	JG11 (C)	49	18	JG11 (C)	97	18	JG11 (C)	49	18	JG11 (C)	22	18
5	**KAK2 (C)**	**48**	**23**	**KAK2 (C)**	**86**	**23**	**KAK2 (C)**	**42**	**23**	**KAK2 (C)**	**36**	**23**	**KAK2 (C)**	**50**	**10**	**KAK2 (C)**	**96**	**10**	**KAK2 (C)**	**50**	**10**	**KAK2 (C)**	**37**	**10**
6	L550 (C)	66	19	L550 (C)	110	19	L550 (C)	41	19	L550 (C)	20	19	L550 (C)	69	16	L550 (C)	110	16	L550 (C)	50	16	L550 (C)	19	16

The check cultivars are highlighted in bold.

3.6.3. Intermediate Type

During the 2014–15 year, none of the accessions was found to have yielded higher than that of the check cultivar KAK2. However, during 2015–16, about five accessions with DF in the range of 59–60 d, DM in the range of 106–108 d, and PLHT of 61 cm were found to produce a 60–120% higher yield than KAK2 (Table 6).

3.7. Selection of Stable and Promising Accessions for Sehore, Madhya Pradesh

3.7.1. Desi Type

The cultivar JG11 was the best check and had an SY of 12 g plant^{-1}, a flowering time of 75 d, DM of 120 d, PLHT of 38 cm, and 100 SW of 20 g (Table 7). Twenty accessions selected based on flowering days (67–79 d) had yields in the range of 10–29 g plant^{-1}. Of the 20 accessions, 5 (ICC15065, ICC257, ICC1629, ICC2023, and ICC2664) showed more than 50% yield gain over the check cultivar JG11 (Table 7). Further, 20 accessions selected based upon maturity days (109–122 d) produced a 10–37 g plant^{-1}. Four out of twenty accessions (ICC12159, ICC16841, ICC1896, and ICC8366) were found to have a 58–208% higher yield than the check cultivar (Table 7). Twenty accessions selected based on PLHT (36–57 cm) produced a yield of 10–24 g plant^{-1}. Three accessions (ICC9636, ICC16841, and ICC16269) grew 100% more yield over the JG11 check. Based on 100 SW, 20 accessions were selected having seed weight of 12–41 g 100-seeds^{-1}, which produced yield in the range of 10–24 g plant^{-1}. Three promising accessions (ICCV95605, ICC8318, and ICC15065) showed 50–100% more yield than JG11 (Table 7).

The cultivar JG11 outperformed other checks during 2015–16 and had a yield of 6 g plant^{-1}, a flowering time of 66 d, DM of 109 d, PLHT of 35 cm, and 100 SW of 19 g (Table 7). Twenty accessions were selected based upon flowering time (47–71 d), which displayed a yield variation of 4–13 g plant^{-1}. Seven accessions (ICCV92503, ICC4984, ICC10018, ICC95, ICC12159, ICC3406, and ICC5593) produced a 50–117% higher yield than the check cultivar JG11 (Table 7). Twenty accessions were selected based on maturity days (103–111 d) and produced yields in the 4–13 g plant^{-1}. Three accessions (ICC10947, ICC5593, and ICC12159) showed a 67–117% increase in SY over the check cultivar JG11 (Table 7). Furthermore, 20 accessions were prioritised based on PLHT (33–52 cm), which displayed a yield variation of 4–9 g plant^{-1}. One accession (ICC95) having a PLHT of 34 cm and more than 50% yield gain over JG11 was selected. Nineteen accessions were selected based on 100 SW (12–29 g), producing a yield in the 4–13 g plant^{-1}. Three promising accessions (ICCV92503, ICC5639, and ICC5593), having yielded more than 50% over the best check cultivar, were identified (Table 7).

3.7.2. Kabuli Type

During the 2014–15 year, the best check cultivar KAK2 displayed a yield of 12 g plant^{-1}, a flowering time of 64 d, DM of 122 d, PLHT of 38 cm, and 100 SW 36 g (Table 7). Ten accessions with DF in the range of 58–79 d were selected, producing a yield of 12–23 g plant^{-1}. Three out of ten accessions (ICC16644, ICCV92311, and ICC8584) had yielded 50–92% more yield over the check KAK2. Further, ten accessions were selected based on maturity days (120–123 d), which produced a yield of 12–23 g plant^{-1}. Four accessions (ICC16644, ICC8584, ICCV92311, and IG72140) were prioritised with a 50–92% yield higher than KAK2. Ten accessions selected based on PLHT (44–52 cm) had yields in the range of 11–23 g plant^{-1}. One accession (ICC11879), among the ten accessions selected, had a height of 48 cm and showed up to 92% more yield over the best check cultivar. Ten accessions were selected based on 100 SW, having a seed weight of 22–33 g 100-seeds^{-1} and an SY of 10–20 g plant^{-1}. Two accessions produced a 50–67% higher yield over the check KAK2 (Table 7).

Table 7. Shortlisted germplasm accessions based on ranking biplot for five traits across two years for Sehore, Madhya Pradesh.

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**	**Accession Name**	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	ICC15065	67	20	ICCV88202	109	11	ICC4233	57	15	ICCV95605	41	18	ICCV92503	47	9	ICC1097	103	6	ICC2500	52	8	ICC15762	29	5
2	ICC14564	69	15	ICC5710	115	10	ICC5541	54	13	ICCV88202	26	11	ICC8332	63	6	ICC11040	104	6	ICC4233	49	5	ICCV88202	22	5
3	ICCV88202	70	11	ICC11040	115	13	ICC4459	47	12	ICC5003HN	24	10	ICC4984	63	9	ICC5710	107	6	ICC1817	43	8	ICCV92503	19	9
4	ICC15562	73	10	ICC15081	117	10	ICC4418	47	10	ICC12458	24	10	ICC10651	64	6	ICC11046	107	5	ICC10197	43	6	ICC8318	19	6
5	ICC5593	73	12	ICC14385	118	10	ICC9636	43	24	ICC7554	21	17	ICC7470	65	6	ICC10942	107	6	ICC13895	43	7	ICC435NN	18	5
6	ICC15081	74	10	ICC13890	118	14	ICC13895	43	15	ICC8318	20	24	ICC15081	65	5	ICC15081	107	5	ICC26	43	4	ICC14390	18	4
7	ICCL85222	75	13	ICC12159	119	37	ICC991	42	14	ICC6671	18	15	ICC16841	65	8	ICCV88202	108	5	ICC16841	42	8	ICC10898	16	5
8	ICC7302	75	14	ICC299	119	10	ICC3558	41	13	ICC15065	18	20	ICC14391	65	5	ICC12273	109	5	ICC3558	41	5	ICC11040	16	6
9	ICC8931	76	17	ICC2220	119	16	ICC7554	41	17	ICC1560	18	13	ICC10018	65	9	ICC2220	109	4	ICC1122	41	5	ICC1634	16	4
10	ICC10629	76	11	ICC16841	119	19	ICC6900	41	12	ICC3539	16	11	ICC10386	66	6	ICC10947	109	13	ICC14385	39	4	ICC3331	15	6
11	ICC257	77	29	ICC1896	119	22	ICC5003HN	40	10	ICC11040	16	13	ICC16076	66	6	ICC8556	109	5	ICC643	39	6	ICC7277	15	4
12	ICC8474	77	10	ICC10629	120	11	ICC5009	40	11	ICC1634	16	14	ICC10629	67	4	ICC5593	109	13	ICC5472	39	7	ICC15080	15	5
13	ICC1629	78	25	ICCL85222	120	13	ICC8348	40	16	ICC1201	16	16	ICC8474	67	6	ICC11322	109	7	ICC4418	38	5	ICC12273	15	5
14	ICC14176	78	11	ICC1097	120	12	ICC14385	39	10	ICC1205	15	14	ICCV96970	67	6	ICC1315	109	8	ICC9636	37	5	ICC5639	15	11
15	ICC3539	78	11	ICC12259	120	10	ICCV89314	38	15	ICC15080	15	12	ICC12159	68	10	ICC14391	110	5	ICCV95705	35	8	ICC16076	14	6
16	ICC3406	79	13	ICC8366	120	20	ICC4359	38	14	ICC5639	13	15	ICC95	68	9	ICC12159	111	10	ICC1272	35	4	ICC26	14	4
17	ICC16682	79	17	ICC14495	121	10	ICC16841	38	19	ICC10629	13	11	ICC15080	69	5	ICC7470	111	6	ICC7541	35	4	ICC10629	13	4
18	ICC10898	79	13	ICC1891	121	11	ICC16269	38	19	ICC5593	13	12	ICC3406	70	12	ICC14507	111	6	ICC6900	35	5	ICC1272	13	4
19	ICC2023	79	19	ICC2072	122	14	ICC8314	36	10	ICC7302	12	14	ICC11040	70	6	ICC16733	111	5	ICC95	34	9	ICC5593	12	13
20	ICC2664	79	23	ICC1201	122	16	ICC5391	36	13	ICC1272	12	11	ICC5593	71	13	ICCL82108	111	5	ICC455	33	5	NA	NA	NA
1	Annigeri (C)	77	10	Annigeri (C)	121	10	Annigeri (C)	35	10	Annigeri (C)	17	10	Annigeri (C)	68	5	Annigeri (C)	111	5	Annigeri (C)	32	5	Annigeri (C)	15	5
2	G130 (C)	78	9	G130 (C)	122	9	G130 (C)	37	9	G130 (C)	11	9	G130 (C)	71	4	G130 (C)	113	4	G130 (C)	36	4	G130 (C)	11	4
3	ICCV10 (C)	75	11	ICCV10 (C)	119	11	ICCV10 (C)	38	11	ICCV10 (C)	16	11	ICCV10 (C)	67	5	ICCV10 (C)	110	5	ICCV10 (C)	35	5	ICCV10 (C)	16	5
4	**JG11 (C)**	**75**	**12**	**JG11 (C)**	**120**	**12**	**JG11 (C)**	**38**	**12**	**JG11 (C)**	**20**	**12**	**JG11 (C)**	**66**	**6**	**JG11 (C)**	**109**	**6**	**JG11 (C)**	**35**	**6**	**JG11 (C)**	**19**	**6**
	Kabuli type chickpea accessions tested in the year 2014–15												**Kabuli type chickpea accessions tested in the year 2015–16**											
1	ICC16644	58	18	ICC16644	120	18	ICC8483	52	11	ICC12497	33	20	IG7446	65	4	IG73242	102	6	IG72070	53	8	ICC14220	33	7
2	ICCV2	65	13	IG5868	121	13	ICC10778	51	17	ICC10778	31	17	ICC5811	67	8	IG7446	107	4	ICC10778	51	5	ICC10747	32	9
3	ICCV92311	71	23	ICC5122	122	17	IG73286	51	16	ICC16637	31	12	IG71993	68	5	IG71993	108	5	IG73294	51	7	ICC10778	30	5
4	ICC8584	74	18	ICC16206	123	16	ICC4899	49	17	ICC8483	31	11	ICC6831	68	5	ICC2489	111	4	ICC13690	50	4	IG72070	29	8
5	ICC8527	76	14	ICCV2	123	13	ICC11879	48	23	IG70746	28	12	ICC14220	69	7	IG72070	112	8	IG73242	50	6	ICCV89509	24	5
6	ICC6831	77	12	ICC8584	123	18	ICC2496	47	12	ICCV2	28	13	IG71728	69	4	IG7458	113	8	ICC15545	50	5	ICC6246	22	8
7	ICC5122	78	17	ICCV92311	123	23	IG5868	46	13	IG10956	26	10	IG7458	69	8	ICC14220	113	7	ICC16659	49	5	IG71993	22	5
8	ICC16206	79	16	ICC8527	123	14	ICC15802	45	17	IG72021	26	14	ICC6140	70	4	ICC6831	114	5	ICC4899	49	5	ICC4928	20	4
9	ICC15518	79	17	ICC14436	123	12	ICC8527	44	14	ICC15823	24	18	ICC2489	70	4	ICC15823	114	10	ICC14220	43	7	ICC15823	20	10
10	ICC14436	79	12	IG72140	123	21	ICC16206	44	16	IG71993	22	12	ICC6246	74	8	IG71980	115	5	ICC15306	40	5	NA	NA	NA
1	**KAK2 (C)**	**64**	**12**	**KAK2 (C)**	**122**	**12**	**KAK2 (C)**	**38**	**12**	**KAK2 (C)**	**36**	**12**	**KAK2 (C)**	**57**	**7**	**KAK2 (C)**	**116**	**7**	**KAK2 (C)**	**35**	**7**	**KAK2 (C)**	**34**	**7**
2	L550 (C)	80	10	L550 (C)	123	10	L550 (C)	37	10	L550 (C)	19	10	L550 (C)	72	4	L550 (C)	118	4	L550 (C)	36	4	L550 (C)	18	4
	Intermediate type chickpea accessions tested in the year 2014–15												**Intermediate type chickpea accessions tested in the year 2015–16**											
1	ICC5879	75	11	ICC8407	118	16	ICC7574	50	13	ICC12431	22	13	IG7555	65	5	ICC8407	110	4	ICC8930	42	5	ICC8407	21	4
2	ICC4878	79	18	ICC12431	121	13	ICC5616	40	19	ICC8407	20	16	ICC5923	69	6	ICC5923	113	6	IG7555	37	5	ICC8930	15	5
3	NA	NA	NA	ICC5616	123	19	ICC8930	37	14	ICC8930	18	14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 7. *Cont.*

Ranking of Accessions	Desi Type Chickpea Accessions Tested in the Year 2014–15												Desi Type Chickpea Accessions Tested in the Year 2015–16											
	Accession Name	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**	**Accession Name**	**DF**	**SY**	**Accession Name**	**DM**	**SY**	**Accession Name**	**PLHT**	**SY**	**Accession Name**	**100 SW**	**SY**
1	Annigeri (C)	77	10	Annigeri (C)	121	10	Annigeri (C)	35	10	Annigeri (C)	17	10	Annigeri (C)	68	5	Annigeri (C)	111	5	Annigeri (C)	32	5	Annigeri (C)	15	5
2	G130 (C)	78	9	G130 (C)	122	9	G130 (C)	37	9	G130 (C)	11	9	G130 (C)	71	4	G130 (C)	113	4	G130 (C)	36	4	G130 (C)	11	4
3	ICCV10 (C)	75	11	ICCV10 (C)	119	11	ICCV10 (C)	38	11	ICCV10 (C)	16	11	ICCV10 (C)	67	5	ICCV10 (C)	110	5	ICCV10 (C)	35	5	ICCV10 (C)	16	5
4	JG11 (C)	75	12	JG11 (C)	120	12	JG11 (C)	38	12	JG11 (C)	20	12	JG11 (C)	66	6	JG11 (C)	109	6	JG11 (C)	35	6	JG11 (C)	19	6
5	**KAK2 (C)**	**64**	**12**	**KAK2 (C)**	**122**	**12**	**KAK2 (C)**	**38**	**12**	**KAK2 (C)**	**36**	**12**	**KAK2 (C)**	**57**	**7**	**KAK2 (C)**	**116**	**7**	**KAK2 (C)**	**35**	**7**	**KAK2 (C)**	**34**	**7**
6	L550 (C)	80	10	L550 (C)	123	10	L550 (C)	37	10	L550 (C)	19	10	L550 (C)	72	4	L550 (C)	118	4	L550 (C)	36	4	L550 (C)	18	4

The check cultivars are highlighted in bold.

During the 2015–16 year, the best check KAK2 produced a yield of 7 g plant^{-1}, DF of 57 d, DM of 116 d, PLHT of 35 cm, and 100 SW of 34 g (Table 7). Ten accessions selected based upon flowering time (65–74 d) produced yield in the 4–8 g plant^{-1}. Furthermore, ten accessions were selected based on maturity days (102–115 d) and showed a yield variation of 4–10 g plant^{-1}; 10 accessions were selected based on PLHT (40–53 cm) and produced a yield of 4–8 g plant^{-1}. Based on 100 SW, nine accessions were selected with seed weight values in 20–33 g 100-seeds^{-1} and yield variation in the 4–10 g plant^{-1} (Table 7).

3.7.3. Intermediate Type

During the 2014–15 year, KAK2 was the best check cultivar that produced a yield of 12 g plant^{-1}, DF of 64 d, DM of 122 d, PLHT of 38 cm, and 100 SW of 36 g (Table 7). One accession (ICC4878) with DF of 79 d and producing SY of 18 g plant^{-1} (>50% over KAK2) was selected. In addition, one accession (ICC5616) with a PLHT of 40 cm and a yield of 19 g plant^{-1} displayed ~58% yield gain over the check cultivar KAK2 (Table 7).

3.8. Selection of Short Duration Desi, Kabuli, and Intermediate Type Accessions

3.8.1. Desi Type

Early flowering and maturing desi type cultivars were selected for each of the five locations evaluated based on their superior performance across two years. For Amlaha, four accessions (ICCV91902, ICC14014, ICC5710, and ICC9499) were selected based on the flowering response evaluated over two years. These accessions displayed an 11% decrease in DF and a 131% increase in SY over the check cultivar JG11. Further, 11 accessions (ICC14014, ICC8950, ICC12527, ICC13107, ICC8332, ICC1560, ICC15851, ICC5878, ICC8556, and ICC14176) were selected based on early maturity, which showed up to a 10% decrease in crop duration and up to a 106% increase in yield over JG11 (Table 3). For Patancheru, two accessions (ICCV92503 and ICC8348) were prioritised based on early flowering, displaying up to a 15% decrease in flowering time and a 53% increase in yield over the check cultivar JG11. Only one accession (ICCV88202) was selected based on DM, which showed a 10% decrease in maturity days and a 7% higher yield over JG11 (Table 4). For Kanpur, six promising accessions (ICCV92503, ICC12159, ICC8348, ICCV88503, ICCV91902, and ICC10963) were selected for early flowering, which indicated up to 16% reduction in flowering time and up to 44% increase in SY over the check cultivar JG11. One accession (ICC12878) was prioritised based on DM, which revealed a 7% early maturity and a 69% yield increase over JG11 (Table 5). For Junagadh, one accession (ICC8348) was selected that showed a 6% decrease in flowering time and yield performance of 35% over check cultivar Annigeri. Based on DM, seven accessions (ICC1560, ICC6384, ICC4526, ICC95, ICC16841, ICC14495, and ICC5934) were selected, with up to 21% early maturity producing up to 88% higher yield over Annigeri (Table 6). For Sehore, five accessions were selected based on DF, which revealed a 29% decrease in flowering time and a 67% increase in yield over JG11 (Table 7).

3.8.2. Kabuli Type

The kabuli type chickpea, having both early flowering and maturity and producing higher/similar yields over the best check cultivar of the respective location, was selected based on two years' evaluation. For the Amlaha location, two accessions (ICC11879 and IG70436) were selected based on DF, which displayed a 9% decrease in flowering time and up to 100% yield gain over the check cultivar KAK2. Four accessions (ICC16644, IG71878, ICC6831, and ICC8527) were selected based on maturity days, which matured up to 6% early and produced up to 25% greater yield than KAK2 (Table 3). For Patancheru, only one accession (ICCV2NN) was selected based on maturity days, which showed 6% early maturity and a 40% yield increase over KAK2 (Table 4). At Kanpur, eight accessions showed up to 13% early flowering and 79% higher yield over KAK2. Six accessions were prioritised based on early maturity, which showed an 8% decrease in crop duration and a 43% increase in yield over KAK2 (Table 5). Two accessions for the Junagadh location were selected based on early maturity, indicating a 6% decrease in maturity days and up to 60% yield advantage over KAK2 (Table 6). At Sehore, one accession (ICC16644) with 9% early flowering and 50% yield gain over KAK2 was found. Six accessions (ICC16644, IG5868, IG72070, IG7458, ICC14220, and ICC15823) were selected based on early maturity that showed a 3% decrease in DM and up to a 50% increase in yield over the check cultivar KAK2 (Table 7).

3.8.3. Intermediate Type

Like desi and kabuli types, intermediate type cultivars that displayed early flowering and maturity and higher/similar yield over the check cultivar were selected for each of the evaluated locations. For Amlaha, one accession (ICC5955) with 1% early flowering and 3% early maturity with 38% higher yield than KAK2 was selected (Table 3). For Patancheru, none of the accessions was superior to JG11 (Table 4). For the Kanpur location, two accessions (ICC15234 and ICC7574) with early maturity showed a 3% decrease in maturity days and up to 69% yield gain over JG11 (Table 5). For Junagadh, one accession (ICC15234) with 1% early maturity and SY similar to KAK2 was selected (Table 6). For Sehore, two accessions (ICC8407 and ICC12431) were selected based on early maturity, which indicated a 3% decrease in crop duration and up to 33% yield advantage over KAK2 (Table 7).

3.9. Selection of Mechanically Harvestable Desi, Kabuli, and Intermediate Type Accessions

3.9.1. Desi Type

Desi accessions displaying at least a 10 cm increase in the PLHT over the check cultivar and having a higher/similar yield than the best check were selected. For Amlaha, three accessions (ICC13285, ICC5472, and ICC8474) were found to have a 29% increase in PLHT and up to 100% yield gain over the check cultivar JG11 (Table 3). For Patancheru, eight accessions (ICC9139, ICC9307, ICC12993, ICC5472, ICC16234, ICC1817, ICC5722, ICC2356, and ICC10197) were prioritised that had up to 64% taller plants and up to 60% higher yield over JG11 (Table 4). The selected ten accessions displayed up to 49% tall plants for the Kanpur location and 94% yield gain over the check JG11 (Table 5). For Junagadh, five accessions (ICC9307, ICC5491, ICC3558, ICC9261, and ICC2878) showed a 62% increase in height and up to 65% yield advantage when compared to Annigeri (Table 6). For the Sehore location, three accessions (ICC4233, ICC5541, and ICC2500) were selected based on the above-defined criteria, demonstrating up to 50% gain in PLHT and up to 33% increase in yield over JG11 (Table 7).

3.9.2. Kabuli Type

Kabuli accessions showing a minimum of 10 cm increase in PLHT over the best check and those having a higher/similar yield than the check cultivar KAK2 were selected. For Amlaha, two accessions (ICC16659 and IG72021) display up to a 28% increase in PLHT and up to a 31% yield advantage over KAK2 (Table 3). For Patancheru, 19 accessions revealed up to 111% taller plants and a 200% higher yield over the check cultivar KAK2 (Table 4). Furthermore, five accessions (ICC16637, ICC14190, IG70321, ICC16206, and IG6448) had more than 10 cm taller plants and produced up to 60% higher yield for the Kanpur location over the check cultivar KAK2 (Table 5). In the Junagadh location, six accessions (IG6401, ICC16659, ICC9330, IG69746, IG73294, and IG5868) were found to have up to a 36% increase in PLHT and up to 180% yield increase over the check cultivar KAK2 (Table 6). Sehore's seven accessions (ICC8483, ICC10778, IG73286, ICC4899, ICC11879, IG72070, and IG73294) showed a 51% increase in PLHT and up to 92% increase in SY over KAK2 (Table 7).

3.9.3. Intermediate Type

Intermediate type accessions with at least a 10 cm increase in PLHT and having higher/similar yield over the check cultivar were selected. Accordingly, for Amlaha, none of the accessions was superior in height and yield performance over the best check KAK2 (Table 3). For Patancheru, three accessions (ICC7574, ICC8930, and ICC5616) were found to have a minimum of 10 cm increase in PLHT and a 100% increase in yield over the check

JG11 (Table 4). One accession (ICC7574) with 61 cm PLHT and 69% higher yield than JG11 was detected for Kanpur (Table 5). For Junagadh, one accession (ICC5616) with a PLHT of 61 cm and a yield of 19 g plant^{-1}, 90% higher than the KAK2 check, was selected (Table 6). Sehore prioritised one accession (ICC7574) with a 32% increase in PLHT and an 8% higher yield than KAK2 (Table 7).

3.10. Selection of Large-Seeded Desi, Kabuli, and Intermediate Type Accessions

3.10.1. Desi Type

Desi accessions displayed an increase of at least 3 g 100-seeds^{-1} over the best check and a higher/similar yield than the selected check cultivar. For Amlaha, eight accessions (ICC12452, ICC8348, ICC8474, ICC15762, ICCV88202, ICC11903, ICCV93958, and ICCV91902) were selected that showed up to 183% increase in 100 SW and up to 131% increase in yield over JG11 (Table 3). For Patancheru, five accessions (ICC5003LN, ICC5003HN, ICCV93958, ICC12159, and ICC8474) increased the 100 SW by up to 28% and produced up to 87% higher yield than JG11 (Table 4). For the Kanpur location, three accessions (ICC15065, ICC9139, and ICCV91902) were found to have up to 29% bigger seeds and up to 94% greater yield than the check cultivar JG11 (Table 5). For the Junagadh location, eight accessions (ICCV93958, ICC10301, ICC15762, ICC5003LN, ICC15376, ICC9139, ICC5003HN, and ICC9261) were detected to possess up to a 57% increase in 100 SW and up to 100% yield advantage over Annigeri (Table 6). Sehore identified one accession (ICCV95605) with a 100 SW of 41 g and a 50% higher yield than the JG11 check (Table 7).

3.10.2. Kabuli Type

Kabuli accessions showing higher/similar 100 SW than best check and greater/similar yield over the check cultivar were selected. For Amlaha, one accession (ICC8483) with an 11% increase in 100 SW and yield similar to KAK2 was detected (Table 3). For Patancheru, three accessions (ICC14220, IG70466, and ICC6239) were found to have up to a 29% increase in 100 SW and up to 160% higher yield over KAK2 in the year 2015–16 (Table 4). Furthermore, only one accession (IG70872) was selected from the Kanpur location, with up to 41% bigger seeds and up to 27% greater yield over the check cultivar KAK2 (Table 5). For the Junagadh location, three elite accessions (ICC8483, ICC14220, and ICC7654) with up to 8% bigger seeds and 80% higher yield than the check KAK2 were detected (Table 6). At the Sehore location, none of the accessions was superior in seed weight and yield than the check KAK2 (Table 7).

3.10.3. Intermediate Type

Intermediate type accessions having higher/similar 100 SW than the best check and greater/similar yield over the check cultivar were selected. Agronomically superior accession was detected only for the Kanpur location compared to the JG11 check. The accession (ICC7574) had a 25% better 100 SW and a 69% higher yield than the JG11 check (Table 5). None of the accessions was suitable for the remaining four locations compared with the JG11 or KAK2 check.

4. Discussion

Diverse germplasm accessions stored in gene banks (or germplasm repositories) hold the key to most future success in developing improved crop cultivars [22,23]. That said, a major challenge for the gene bank curators or plant breeders is to characterise and determine beneficial genetic variations from the vast germplasm collections, particularly for agronomically important traits that need multi-location evaluation. Developing a composite collection was suggested as a gateway for harnessing the available genetic diversity in applied plant breeding to expand the breeding populations' genetic base [18]. In the present study, the multi-location evaluation of a chickpea composite collection allowed a selection of elite germplasm accessions with superior agronomic performance, different from the check cultivars. This, in turn, provided novel sources of variation for economically important traits, which can be utilised to increase the genetic potential of desi, kabuli, and intermediate type chickpea. When such diverse accessions are deployed in chickpea breeding programs, it is predicted that there will be a high possibility of the appearance of transgressive segregants with useful traits because of the reshuffling of alleles due to recombination. Such beneficial traits can then be selected to identify high-yielding accessions with desired allelic combinations.

A breeder is mostly interested in selecting high-yielding and stable accessions compared to the best check of the location to reap economic benefits. Therefore, the desi, kabuli, and intermediate type accessions that yielded 50% above the check cultivar of a particular location were prioritised in the present study. The desi accessions were compared with either JG11 or Annigeri check cultivars. In contrast, the kabuli accessions were compared with the KAK2 check, representing some of the most widely used checks in India's northern and southern parts. According to a recent survey on the adoption of chickpea varieties, the JG11 cultivar was found to cover almost 82% of the total chickpea growing area in Andhra Pradesh [24]. The desi, kabuli, and intermediate type germplasm accessions producing up to 176%, 270%, and 169% higher yield over the check cultivars were identified in the current study. However, further field evaluation of the selected high-yielding accessions in large trials and optimal sites for the target population of the environment will be required to confirm their yield potential and their deployment in chickpea breeding programs.

Chickpea is usually grown on residual soil moisture in the post-rainy season and is mostly subjected to terminal drought and intermittent heat or is sown after harvest of long/medium duration rainy season crops that face heat stress towards the end of the cropping cycle [6,25]. Developing early maturing chickpea cultivars that can escape terminal drought or heat stresses is highly desirable. Efforts are being made to develop varieties with varying maturity duration (75–120 d) for cultivation under rainfed and irrigated conditions in different parts of the country. For example, early (90–100 d), extra early (85–90 d), and super early (75–80 d) maturing cultivars of desi and kabuli types will have an advantage in southern and central India. A key success story of the adoption of early-maturing chickpea is represented by the chickpea revolution being brought about in the Andhra Pradesh state of India, where over 80% of the chickpea growing areas are now cultivated with short-duration improved cultivars such as JG11 (desi) and KAK2 (kabuli) [26]. In the present study, desi accessions that showed at least three days early flowering and seven days early maturity when compared to JG11 or Annigeri, with higher/similar SY than the respective check, were selected.

On the other hand, kabuli and intermediate type accessions having early/similar flowering and maturity and higher/similar yield over the respective check cultivar were selected. Such short-duration chickpea could be used as a cash crop (after rice harvest and before wheat sowing). It may provide extra income to the farmers and utilisation of available resources. These accessions will also provide an opportunity to expand the chickpea area under late-sown conditions, which is immediately required to diversify the rice-wheat cropping system [27].

Although mechanical harvesting of pulse crops is extensively practised in countries such as the United States of America, Canada, and Australia [28], chickpea is still harvested manually in the Middle East, North Africa, and South and West Asian countries [29]. In most countries, labour cost is continuously rising, and manual harvesting has become an expensive and time-consuming field operation. Mechanical harvesting of chickpea offers a promising alternative to manual harvest. It is expected to reduce production costs and the chances of damage to the crop due to fluctuating environments, which usually occurs when there is a delay in harvesting due to the non-availability of labour. The harvest loss during machine harvest is higher for the semi-erect genotype (~20%) and low in tall and erect genotypes (2.6–5.0%) [16]. Therefore, germplasm accessions showing at least a 10 cm increase in PLHT over the check cultivars were selected in the present study. These selected accessions must be further evaluated under large-scale field trials for yield potential and machine harvesting to identify the percentage of economic gain associated with the harvest.

In chickpea, erectness and height of the first pod from the ground (ground clearance) are the two most crucial traits that primarily decide a cultivars' suitability for mechanical harvesting [29]. Therefore, there is also an emerging need to study the selected accessions' growth habits and the lower pods' height from the base before their recommendation to be included in breeding programs. The resulting taller and erect genotypes with higher yields are predicted to enhance chickpea area and production mostly in the dryland tropics, which is required to achieve self-sufficiency in pulse production.

The large-seeded desi and kabuli types have high consumer preferences because of the premium price to the farmers. The bold seeded chickpea is used as a green vegetable, parched, fried, roasted, and boiled as a snack food and chhole, while sprouted seeds are eaten as vegetables or added to salads. A farmer prefers to have large-seeded cultivars with high yield potential from the market point of view for gaining extra income. This is because the trading of extra-large seeded kabuli types dominates the international market [17,30]. The premium price of >USD 1000 per tonne is paid for kabuli types having extra-large seeds; whereas for kabuli types with medium-size seeds, the price is about USD 600 per tonne, and for desi types with medium-size seeds, the prices range between USD 400 and 500 per tonne. Keeping these things in mind, desi germplasm accessions showing at least a 3 g increase in 100 SW and higher/similar yield over the JG11 or Annigeri were selected. In addition, kabuli and intermediate type accessions with larger/similar 100 SW and SY over the check cultivars were selected. This resulted in identifying desi, kabuli, and intermediate type accessions showing up to 183%, 41%, and 25% increase in 100 SW, respectively, with higher/similar yields over the check cultivar. These germplasm accessions can be deployed in a breeding program to develop large-seeded high-yielding cultivars that combine earliness, high pod clearance, and 100 seed weight or can be used directly for cultivation after evaluating their performance in large-scale field trials.

5. Conclusions

Over two years, the chickpea composite collection was evaluated at five locations in India for five agronomic traits. The desi, kabuli, and intermediate type chickpea showed significant variation for PLHT and 100 SW. The selected germplasm accessions displayed 169–270% higher yield over check cultivars. About 25–183% higher 100 SW was observed in selected germplasm accessions compared to check cultivars. The identified superior accessions hold potential for enhancing the genetic potential of chickpea cultivars.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy12092013/s1, Table S1: Entry number and name of desi type chickpea lines used for ranking biplots; Table S2: Entry number and name of kabuli and intermediate type chickpea lines used for ranking biplots; Table S3: Mean for five agronomic traits among accessions belonging to desi, kabuli, and intermediate types in chickpea composite collection evaluated for two years at five locations in India; Table S4: Differences between means of desi, kabuli, and intermediate type chickpea for five agronomic traits evaluated for two years at five locations in India; Table S5: Pearson correlation analysis for five agronomic traits evaluated for two years at five locations in India.

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