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Exploring the phenotypic performance of chickpea (*Cicer arietinum* L.) lines for improved breeding

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Abstract

PKV Kabuli-4, a widely cultivated chickpea variety in the Vidarbha region of Maharashtra, is valued for its superior grain quality but has recently become highly susceptible to *Fusarium* wilt, leading to significant yield losses. The existence of pathogenic variability in *Fusarium oxysporum* f. sp. *ciceri* across different regions necessitates the incorporation of resistance against multiple races (1–5) through marker-assisted backcrossing. In the present study, a backcross breeding programme was undertaken using PKV Kabuli-4 as the recurrent parent and WR 315 as the donor parent. BC₁F₁ seeds were sown along with the parents during the Rabi 2021–22 season, and the population was evaluated for important agronomic traits. The phenotypic assessment of the BC₁F₁ population revealed substantial variability, enabling the identification of promising lines based on yield-contributing traits such as pod number, branching ability, and maturity duration. Among these, BC₁F₁-28 recorded the highest yield potential with 176 pods per plant. Other superior lines included BC₁F₁-35, which combined a high pod number with increased branching, BC₁F₁-25 with both high branching and pod production, BC₁F₁-40 with high pod number and desirable plant height, and BC₁F₁-41, which exhibited overall balanced performance. Additionally, BC₁F₁-6 and BC₁F₁-48 showed strong pod-bearing capacity, making them suitable candidates for further advancement. The BC₂F₁ population was further evaluated to identify lines with superior combined performance. BC₂F₁-81 exhibited the highest number of pods per plant, indicating strong yield potential, while BC₂F₁-58 and BC₂F₁-101 recorded the highest 100-seed weight. Early flowering was observed in BC₂F₁-18, BC₂F₁-73, and BC₂F₁-113 (46 days), contributing to earliness and adaptability. BC₂F₁-87 showed superior plant height, reflecting good vigour. Several lines also exhibited favourable traits such as early maturity (101 days), a higher number of primary branches, and desirable seed characteristics, including angular shape and white seed colour similar to the recurrent parent. Overall, the study demonstrated wide morphological variation among backcross populations and identified elite BC₁F₁ and BC₂F₁ lines combining yield and adaptive traits. These lines hold significant potential for developing *Fusarium* wilt-resistant chickpea varieties and can be effectively utilized in future breeding programmes.

Keywords: Phenotypic, performance, DUS, variation, breeding

Introduction

Chickpea (*Cicer arietinum* L.) is the world's second most important grain legume after dry beans (*Phaseolus* sp.) (Mir *et al.*, 2021) [6]. It is a self-pollinated diploid species having a chromosome number of $2n = 2x = 16$ (Upadhyaya *et al.*, 2008) [11] with a comparatively small genome size of 738 Mbp (Varshney *et al.*, 2013) [12]. The *Cicer* genus belongs to the family *Leguminosae*, the sub-family *Papilionaceae*, and the tribe *Cicereae*. It is considered to have originated in southeastern Turkey and the adjoining Northern region of Syria (Saxena and Singh, 1987) [9] and evolved from its wild progenitor, *Cicer reticulatum* L., by selection (Maesen and Pundir, 1984) [5]. The geographic distribution differs for the two types of chickpeas; kabuli chickpeas are grown in temperate regions, whereas the desi type is grown in semi-arid regions. The “kabuli” (also known as macrosperma) types are usually taller and have white flowers, a lack of anthocyanin pigmentation on stems, and large white, beige, or cream-colored seeds with a “ram’s head” shape, a thin seed coat, and a smooth seed surface. The “desi” (also known as microsperma) types are generally shorter, possessing small leaflets, pods, seeds, and predominantly pink flowers, anthocyanin pigmentation on stems, and a colored and thick seed

coat (Moreno and Cubero, 1978) ^[7]. Nutritionally, chickpea seed is enriched with protein (20-60%), carbohydrate (62%), fat (4%), essential amino acids, vitamins A, B, and C, minerals, soluble and insoluble fiber (Bodake *et al.*, 2014) ^[2]. Chickpea can fix the atmospheric nitrogen in the root nodules through biological nitrogen fixation by rhizobium bacteria, which increases the soil fertility in the dry lands (Alyemeni *et al.*, 2016) ^[1].

The productivity of chickpea is reduced due to different biotic and abiotic stresses under different agroclimatic conditions. The major constraints affecting chickpea production are *fusarium* wilt, *ascochyta* blight (AB), dry root rot, botrytis gray mould, pod borer, drought, heat, salinity, and chilling are the major stresses which adversely affect the chickpea production. It faces production limitations due to the adverse impacts of various biotic and abiotic stresses (Mannur *et al.*, 2019; Suthar *et al.*, 2021) ^[4, 10]. Among biotic stresses, *Fusarium* wilt (FW), a fungal disease caused by the soilborne pathogen *Fusarium oxysporum* f. sp. *ciceri* (Foc) (Jamil and Ashraf, 2021) ^[4], can lead to complete yield loss in chickpea under favorable conditions (Jendoubi *et al.*, 2017) ^[5]. With a global annual production of approximately 16.53 million tons, chickpea is cultivated in more than 50 countries. India accounts for the largest share, producing 12.27 million tons from 10.47 million hectares, with an average yield of 1,171.6 kg/ha (FAOSTAT, 2023) ^[3]. In India, six major chickpea-producing states are Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh, and Karnataka. Madhya Pradesh leads in chickpea production with a total share of 40.93%, followed by Maharashtra with a total share of 15.84% in chickpea production.

Morphological characterization involves the systematic evaluation of observable traits in crop species and serves as a fundamental approach for the identification and classification of breeding lines. In chickpea, it facilitates the differentiation of varieties or breeding lines based on distinct morphological attributes and enables the detection of genetic variation or mutations within populations. Furthermore, this approach

provides valuable information that enhances breeders' understanding of the genetic basis underlying morphological traits. In addition, morphological characterization contributes to phylogenetic analysis by offering insights into evolutionary relationships, as well as the origin, development, and functional significance of traits across diverse genotypes (Nandedkar *et al.*, 2021) ^[10]. Chickpea plants have several stable morphological characters as well as qualitative characters that can be utilized to assess the variability among the breeding lines. The present study was carried out to assess the phenological and morphological variability among the 133 BC₁F₁ and 196 BC₂F₁ lines and to identify the best-performing lines based on yield and component traits to be utilized in future breeding programs.

Materials and methods

Plant material

The present investigation was carried out at the Experimental field, Biotechnology Centre, Department of Agricultural Botany, Post Graduate Institute, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India, which is situated between 20.70 °N latitude and 77.02 °E longitude and 286 meters above mean sea level. Experimental material comprised of 2 parents, 66 BC₁F₁ lines, and 123 BC₂F₁ lines. The recurrent parent PKV Kabuli-4, donor parent WR 315, and BC₁F₁ seeds were sown in single-row lengths of 3 m with a spacing of 45 cm x 15 cm. The standard agronomic practices were carried out for the better growth and development of the crop.

Morphological observations of the backcross populations along with the two parents were recorded on the 8 morphological and yield-attributing traits as per National guidelines for the conduct of tests for Distinctness, Uniformity, and Stability (DUS) (PPV and FR authority, GOI, New Delhi, 2007). The method of taking observation, the appropriate stage, and the measuring scale of various morphological, yield-attributing traits are presented in Table 1. The details of experimental conditions and crop management practices are presented in Table 2.

Table 1: Guidelines for the morphological characterization of chickpea based on DUS characters by PPV&FRA

Sr. No	Characteristics	States	Stage of observation
1	Days to 50% flowering	Number of days from sowing to 50% plants flowered/Extra early (<40 days)/Early (40-60 days)/Medium (61-80 days)/ Late (>80 days)	At the time of flowering/50% flowering
2	Plant height (cm)	Short (<45 cm)/ Medium (45-65 cm)/ Tall (>65 cm)	Fully developed green pod
3	Number of primary branches	Basal primary branches	At the time of harvesting
4	Days to maturity	Number of days from sowing to almost complete (physiological maturity) maturity i.e., when pods turn yellow	At the time of maturity
5	Number of pods per plant	Count of total pods at maturity	At the time of harvesting
6	Seed shape	1 Angular (ram's head shape - most desi types) 2 Owl's head shape (kabuli types) 3 Pea seed shaped (intermediate types)	At the time of harvesting
7	Seed colour	Beige/ Creamy beige/ Green/ Yellow/ Orange/ Brown/ Dark Brown/ Grey/ Black	30 days after harvest
8	100 seed weight (g)	For desi Desi small <15g/100 seed weight Desi medium >15-20 Desi large >20-30 Desi extra large >30 For kabuli Kabuli small <25g/100 seed weight Kabuli medium >25-35 Kabuli large >35-45 Kabuli extra large >45	At the time of harvesting

The details of morphological observations

Plant height at maturity (cm) was measured from the base of the plant to the tip of the main shoot in five randomly selected

plants, and the mean value was calculated. Days to 50% flowering were recorded as the number of days from sowing to the stage when 50% of the plants in each genotype had started

flowering. The number of branches per plant was counted at maturity, and the average was worked out. Days to maturity were recorded as the number of days from sowing to full physiological maturity of each genotype. The number of pods per plant was counted at maturity/harvest from selected plants. Seed shape was classified based on chickpea descriptor standards into angular, owl's head, and pea-shaped categories, while seed colour was also recorded according to standard chickpea descriptors for each backcross line. The 100-seed weight (g) was determined by weighing 100 randomly selected seeds; where fewer than 100 seeds were available, the weight was recorded and then converted proportionally to 100-seed weight.

Table 2: Experimental conditions and crop management practices

Sr. No.	Particulars	Details
1	Crop Name	Chickpea (<i>Cicer arietinum</i> L.)
2	Spacing	45 X 15 cm
3	Plot	As per the population
4	Fertilizer Dose	25:50:30 N: P: K. Kg/ha
5	Seasons	BC ₁ F ₁ Rabi 2021-22, BC ₂ F ₁ Rabi 2022-23
6	Locations	Experimental field, Biotechnology Centre, Dr. PDKV, Akola, Maharashtra
7	Intercultural Practices	Standard recommended agronomic practices were used

Results and Discussion

Phenotypic performance of chickpea BC₁F₁ population derived from the cross F₁ × PKV Kabuli-4

Phenotypic evaluation for agronomic and yield-attributing traits to identify the plants compared to or superior to the recurrent parent was carried out. BC₁F₁ plants were evaluated for morphological characters like plant height, days to 50% flowering, number of primary branches, days to maturity, and pods per plant. The morphological observations recorded during the Rabi 2021-2022 and screening of the BC₁F₁ population are given in Table 3. The field view of the BC₁F₁ population of chickpea is shown in Figure 1.

Plant height among the backcross lines ranged from 29 cm (BC₁F₁-44) to 75 cm (BC₁F₁-22), with a mean of 54.83 cm, which was higher than the mean plant heights of the parents, PKV Kabuli-4 (48 cm) and WR 315 (42 cm). The maximum plant height was recorded in BC₁F₁-22 (75 cm), and four plants were found to be at par with this genotype. A total of 54 plants exhibited superior plant height compared to the recurrent parent PKV Kabuli-4. The taller plants, namely BC₁F₁-22 (75 cm), BC₁F₁-37 (71 cm), and BC₁F₁-40 (67 cm), may be considered promising for traits associated with vigorous growth and higher biomass production. Days to 50% flowering among the backcross lines ranged from 48 days (BC₁F₁-48) to 68 days (BC₁F₁-16), in comparison to the parental means of 50 days for PKV Kabuli-4 and 58 days for WR-315. The earliest flowering was observed in BC₁F₁-18 (48 days), which was earlier than the recurrent parent, while nine plants were found to be at par, and two plants exhibited fewer days to 50% flowering than PKV Kabuli-4. The early flowering lines identified were BC₁F₁-18 (48 days), BC₁F₁-21 (49 days), and BC₁F₁-1, BC₁F₁-10, BC₁F₁-12, BC₁F₁-17, BC₁F₁-26, and BC₁F₁-29 (approximately 50 days), which may be useful for early maturity breeding programmes. The number of primary branches in BC₁F₁ progenies ranged from 2 (BC₁F₁-5) to 9, with a mean of 5.51, compared to the mean values of 3 and 7 observed in the recurrent and donor parents, respectively. The highest number of

primary branches (9) was recorded in BC₁F₁-25, BC₁F₁-33, BC₁F₁-35, BC₁F₁-45, BC₁F₁-52, and BC₁F₁-61. A total of 12 plants were found to be at par, while 53 plants exhibited a higher number of primary branches than the recurrent parent, PKV Kabuli-4. This trait is of significance as a greater number of branches provides more potential sites for pod development.

Days to physiological maturity among the BC₁F₁ progenies ranged from 101 days after sowing (DAS) in BC₁F₁-12, BC₁F₁-33, and BC₁F₁-52 to 121 DAS in BC₁F₁-14, BC₁F₁-35, and BC₁F₁-54, compared to 115 and 109 days for the parents PKV Kabuli-4 and WR-315, respectively. The mean days to maturity were 111.37. A total of four plants were found to be at par, while 44 plants matured earlier than the recurrent parent, PKV Kabuli-4. The earliest maturing lines were BC₁F₁-12, BC₁F₁-33, and BC₁F₁-52 (101 DAS), whereas BC₁F₁-14, BC₁F₁-35, and BC₁F₁-54 (121 DAS) were identified as late maturing lines. Early maturing genotypes may be advantageous for drought escape, while late maturing ones may offer higher yield potential due to longer growth duration.

The number of pods per plant was recorded and ranged from 4 for (BC₁F₁-44) to 176 for (BC₁F₁-55), and the mean was 50.33 as compared to 60 (PKV Kabuli-4) and 75 (WR-315) parents. The highest number of pods per plant was observed in plant BC₁F₁-28, i.e., 176, and the mean is 50.33; 22 plants had more pods than the PKV Kabuli-4. Top performer lines are BC₁F₁-28 (176 pods) (Outstanding), BC₁F₁-35 (131 pods), BC₁F₁-6 (117 pods), BC₁F₁-48 (117 pods), BC₁F₁-25 (108 pods), BC₁F₁-58 (105 pods), BC₁F₁-40 (103 pods), and BC₁F₁-41 (102 pods). These are elite yield lines. Seed shape was classified based on chickpea descriptor standards into angular, owl's head, and pea-shaped categories. Among the BC₁F₁ progenies, 26 plants exhibited angular seed shape, 22 showed owl's head shape, and 18 displayed pea-shaped seeds. Angular seed shape was the most frequent, followed by pea-shaped (moderately distributed) and owl's head types, which were also significant. The variation in seed shape may be utilized depending on breeding objectives, such as market preference or genetic trait characterization. Seed colour in the BC₁F₁ population was recorded based on chickpea descriptor standards, revealing considerable variation among the progenies. A total of 9 BC₁F₁ plants exhibited white seed colour similar to the recurrent parent, PKV Kabuli-4, while the remaining lines showed a wide range of colours, including brown/dark brown, yellow/yellow-brown, beige, and mosaic types. This broad diversity in seed colour is valuable for genetic variability and can be effectively utilized in selection programmes depending on breeding objectives and market preferences.

Best overall BC₁F₁ backcross lines (Combined traits)

Based on pod number, branching ability, and acceptable maturity duration, several BC₁F₁ lines were identified as promising. Among these, BC₁F₁-28 exhibited the highest yield potential with 176 pods per plant. Other superior lines included BC₁F₁-35 (high pod number coupled with a greater number of branches), BC₁F₁-25 (combining high branching with high pod production), BC₁F₁-40 (high pod number along with good plant height), and BC₁F₁-41 (showing overall balanced performance). Additionally, BC₁F₁-6 and BC₁F₁-48 were also identified as promising due to their strong pod-bearing capacity. These lines may be considered potential candidates for further selection and advancement in breeding programmes. The descriptive statistics of the BC₁F₁ population are presented in Table 4.



Fig 1: The field view of the BC₁F₁ population of chickpea

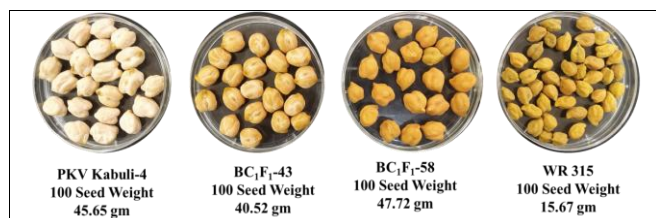


Fig 2: 100 seed weight of recurrent parent PKV Kabuli-4, donor parent WR 315, and promising BC₁F₁ lines

Table 4: Descriptive statistics of the BC₁F₁ population

Trait	Mean	Min	Max	Range
Plant Height (cm)	54.83	29	75	46
Days to 50% Flowering	58.04	48	68	20
Primary Branches	5.51	2	9	7
Days to Maturity	111.37	101	121	20
Pods per Plant	50.33	4	176	172

Phenotypic performance of chickpea BC₂F₁ population derived from cross BC₁F₁ × PKV Kabuli-4 for different morphological traits

The phenotypic performance of BC₂F₁ plants was evaluated with respect to plant height, days to 50% flowering, number of primary branches, days to maturity, number of pods per plant, seed shape, seed colour, 100 seed weight, and the results are presented in Table 5.

Plant height ranged from 21 cm in BC₂F₁-40 to 79 cm in BC₂F₁-87, while the recurrent parent PKV Kabuli-4 and the donor parent exhibited plant heights of 48 cm and 42 cm, respectively. The maximum plant height was recorded in BC₂F₁-87 (79 cm). In total, three plants were found to be comparable to the recurrent parent, whereas 71 plants showed superior plant height compared to PKV Kabuli-4. Days to 50% flowering were recorded across individual plants and showed variation ranging from 46 days (BC₂F₁-18, BC₂F₁-73, and BC₂F₁-113) to 69 days (BC₂F₁-96). The recurrent parent PKV Kabuli-4 and donor parent WR 315 recorded mean values of 50 days and 58 days, respectively. The earliest flowering was observed in BC₂F₁-18, BC₂F₁-73, and BC₂F₁-113, each requiring 46 days, which was earlier than the recurrent parent. In total, 14 plants were found to be comparable with the recurrent parent for this trait, while eight plants exhibited earlier flowering than PKV Kabuli-4. The number of primary branches in BC₂F₁ plants ranged from 2 to 7, compared with 3 in the recurrent parent PKV Kabuli-4 and 7 in the donor parent WR 315. The maximum number of primary branches (7) was recorded in BC₂F₁-6, BC₂F₁-38, BC₂F₁-60, and BC₂F₁-102, while the population mean was 3.57. A total of 48 plants exhibited some primary branches equal to the recurrent parent, whereas 51 plants showed superiority over PKV Kabuli-4 for this trait. The days to physiological maturity of BC₂F₁ plants ranged from 101 days (BC₂F₁-12, BC₂F₁-33, BC₂F₁-52,

BC₂F₁-78, BC₂F₁-99, and BC₂F₁-118) to 121 days (BC₂F₁-14, BC₂F₁-35, BC₂F₁-54, BC₂F₁-80, BC₂F₁-101, and BC₂F₁-120), compared with 115 days and 109 days for the recurrent parent PKV Kabuli-4 and donor parent WR 315, respectively. The population mean for days to maturity was 111.44 days. A total of seven plants were found to be equivalent to the parental values, while 79 plants exhibited earlier maturity than the recurrent parent PKV Kabuli-4.

The number of pods per plant in BC₂F₁ progenies ranged from 60 (BC₂F₁-7, BC₂F₁-11, BC₂F₁-13, BC₂F₁-21, BC₂F₁-24, BC₂F₁-31, BC₂F₁-38, BC₂F₁-43, BC₂F₁-55, and BC₂F₁-108) to 80 (BC₂F₁-81), compared with 60 in the recurrent parent PKV Kabuli-4 and 75 in the donor parent WR 315. The maximum number of pods per plant was recorded in BC₂F₁-81 (80 pods). The population mean for this trait was 26.70. A total of two plants were found to be equivalent to the parental value, while nine plants exhibited a higher number of pods per plant than PKV Kabuli-4. The seed weight (g) of BC₂F₁ progenies ranged from 20 g in BC₂F₁-46 and BC₂F₁-87 to 45 g in BC₂F₁-58 and BC₂F₁-101, compared with 45 g in the recurrent parent PKV Kabuli-4 and 15 g in the donor parent WR 315. The highest 100-seed weight was recorded in BC₂F₁-58 and BC₂F₁-101 (45 g). The field view of the BC₂F₁ chickpea population is presented in Figure 3, while the 100-seed weight of BC₂F₁ progenies along with the donor parent (WR 315) and recurrent parent (PKV Kabuli-4) is shown in Figure 4. Seed shape was assessed as per chickpea descriptors, namely angular, owl's, and pea types. Both parents exhibited an angular seed shape. Among the BC₂F₁ progenies, 52 plants showed an angular seed shape, 39 plants had an owl's seed shape, and 32 plants exhibited a pea seed shape. A greater proportion of BC₂F₁ plants expressed the angular seed shape, similar to that of the parents. Seed colour was evaluated based on chickpea descriptors in the BC₂F₁ population, and 17 BC₂F₁ plants exhibited white seed colour similar to the recurrent parent PKV Kabuli-4.

Statistical conclusion of the phenotypic performance of the BC₂F₁ population

“Analysis of variability revealed considerable differences among BC₂F₁ genotypes for all traits. The highest variability was observed for the number of pods per plant and 100-seed weight, indicating strong scope for selection. Moderate variability was recorded for plant height and number of primary branches, whereas days to 50% flowering and days to maturity showed relatively low variability, suggesting stability of these traits.”

Interpretation of the genetic parameters of the BC₂F₁ population

The analysis of yield and its component traits revealed considerable variability and differing responses to selection. Estimates of genetic variability, heritability, and genetic advance for chickpea traits are presented in Table 6. Pods per plant exhibited very high genotypic and phenotypic coefficients of variation along with high heritability (87%) and very high genetic advance (93%), indicating the predominance of additive gene action and suggesting that this trait is highly amenable to direct selection. Similarly, 100-seed weight showed high GCV and PCV, coupled with high heritability (74%) and substantial genetic advance (43%), reflecting strong genetic control and its suitability for improving seed size, particularly in kabuli-type genotypes. Primary branches per plant displayed moderate to high variability with high genetic advance, emphasizing its importance as a key yield-contributing trait and its effectiveness for selection. Plant height exhibited moderate variability and

good heritability, indicating that it can also be improved through selection, albeit with moderate progress. In contrast, flowering and maturity traits recorded low GCV and PCV, along with moderate heritability and low genetic advance, suggesting greater environmental influence and limited scope for improvement through direct selection. Overall, the results

indicate that traits governed by additive gene action, particularly pods per plant and 100-seed weight, offer significant potential for genetic improvement through selection, whereas traits like flowering and maturity may require alternative breeding strategies.

Table 6: Estimates of genetic variability, heritability, and genetic advance for BC₂F₁ population for different traits

Trait	Mean	GCV (%)	PCV (%)	Heritability (%)	Genetic Advance (% of Mean)
Plant Height	51.54	18.5	21.2	76	33
Days to 50% Flowering	56.45	8.2	10.5	61	13
Primary Branches	3.57	22.8	27.5	69	39
Days to Maturity	111.44	6.5	8.0	66	11
Pods per Plant	26.70	48.5	52.0	87	93
100-Seed Weight	~34.5	24.0	27.8	74	43



Fig 3: The field view of the BC₂F₁ population of chickpea



Fig 4: 100 seed weight of recurrent parent PKV Kabuli-4, donor parent WR 315, and promising BC₂F₁ lines

Table 3: Phenotypic performance of the BC₁F₁ population derived from the cross F₁ × PKV Kabuli-4

Sr. No.	Name of Plants	Plant Height (cm)	Days to 50% Flowering	Number of Primary Branches	Days to Maturity	Number of Pods Per Plant	Seed Shape	Seed Colour
1	BC1F1-1	48	50	6	115	93	Owl's	Yellow brown
2	BC1F1-2	53	58	8	109	65	Pea	Yellow brown
3	BC1F1-3	57	54	5	110	93	Owl's	Brown beige
4	BC1F1-4	53	51	5	110	97	Pea	Yellow brown
5	BC1F1-5	43	66	2	110	37	Owl's	Black brown mosaic
6	BC1F1-6	58	53	8	108	117	Angular	Beige
7	BC1F1-7	65	62	7	118	76	Angular	Beige
8	BC1F1-8	53	66	4	108	9	Angular	Brown beige
9	BC1F1-9	31	59	4	110	7	Angular	Brown beige
10	BC1F1-10	58	50	3	109	14	Angular	Brown beige
11	BC1F1-11	56	58	4	106	12	Owl's	Dark brown
12	BC1F1-12	55	50	3	101	29	Owl's	Brown beige
13	BC1F1-13	59	60	5	109	34	Owl's	Green
14	BC1F1-14	54	61	5	121	44	Pea	Brown beige
15	BC1F1-15	49	60	6	119	22	Angular	Beige
16	BC1F1-16	48	68	3	116	32	Owl's	Black brown mosaic
17	BC1F1-17	50	50	4	117	6	Owl's	Black brown mosaic
18	BC1F1-18	62	48	6	107	14	Pea	Brown
19	BC1F1-19	59	53	4	116	13	Angular	Beige
20	BC1F1-20	43	56	4	109	18	Angular	Yellow

21	BC1F1-21	55	49	4	107	13	Angular	Yellow
22	BC1F1-22	75	60	8	115	83	Owl's	Yellow brown
23	BC1F1-23	63	60	3	109	72	Angular	Yellow brown
24	BC1F1-24	59	60	4	110	31	Owl's	Brown
25	BC1F1-25	65	60	9	110	108	Pea	Dark brown
26	BC1F1-26	42	50	6	116	31	Pea	Reddish brown
27	BC1F1-27	63	66	4	108	36	Pea	Reddish brown
28	BC1F1-28	62	60	6	118	176	Pea	Brown
29	BC1F1-29	54	50	7	108	22	Owl's	Brown
30	BC1F1-30	36	60	3	110	19	Pea	Brown
31	BC1F1-31	42	66	8	109	39	Angular	White
32	BC1F1-32	55	60	5	106	58	Angular	White
33	BC1F1-33	46	56	9	101	27	Angular	Dark brown
34	BC1F1-34	57	58	3	109	10	Angular	White
35	BC1F1-35	51	68	9	121	131	Angular	White
36	BC1F1-36	50	60	6	119	38	Pea	Yellow
37	BC1F1-37	71	60	6	116	52	Angular	Yellow
38	BC1F1-38	62	60	5	117	84	Angular	Brown
39	BC1F1-39	61	66	4	109	49	Angular	White
40	BC1F1-40	67	60	8	107	103	Pea	Greenish yellow
41	BC1F1-41	62	60	7	115	102	Owl's	Yellow
42	BC1F1-42	38	66	8	109	16	Pea	Brown
43	BC1F1-43	59	54	6	110	18	Angular	White
44	BC1F1-44	29	51	3	110	4	Owl's	Brown
45	BC1F1-45	58	50	9	110	62	Owl's	Light brown
46	BC1F1-46	61	53	8	116	28	Angular	Light yellow
47	BC1F1-47	60	54	7	118	60	Pea	Light yellow
48	BC1F1-48	60	66	4	108	117	Owl's	White brown
49	BC1F1-49	60	53	7	110	88	Angular	White
50	BC1F1-50	52	56	6	109	81	Angular	White
51	BC1F1-51	65	66	8	106	69	Pea	Brown
52	BC1F1-52	57	51	9	101	71	Pea	Yellow brown
53	BC1F1-53	52	54	7	109	81	Owl's	Brown
54	BC1F1-54	57	50	5	121	40	Angular	White brown
55	BC1F1-55	55	66	3	119	4	Owl's	Brown
56	BC1F1-56	49	66	5	116	48	Owl's	White brown
57	BC1F1-57	54	63	4	117	41	Pea	Yellow brown
58	BC1F1-58	64	66	7	109	105	Owl's	White
59	BC1F1-59	63	59	3	107	33	Pea	Greenish yellow
60	BC1F1-60	48	54	4	115	27	Angular	Brown
61	BC1F1-61	51	51	9	109	43	Owl's	Light yellow
62	BC1F1-62	48	66	3	110	9	Owl's	Greenish brown
63	BC1F1-63	63	50	6	110	54	Angular	White brown
64	BC1F1-64	58	66	3	110	28	Owl's	White brown
65	BC1F1-65	55	66	3	116	58	Pea	Dark Brown
66	BC1F1-66	51	52	7	108	21	Angular	White
	WR 315	42	58	7	109	75	Angular	Brown
	PKV Kabuli-4	48	50	3	115	60	Angular	White
	Mean	54.83	58.04	5.51	111.37	50.33		

Table 5: Phenotypic performance of the BC₂F₁ population derived from cross BC₁F₁ × PKV Kabuli-4

Sr. No.	Name of Plants	Plant Height (cm)	Days to 50% Flowering	Number of Primary Branches	Days to Maturity	Number of Pods per plant	100-Seed Weight (g)	Seed Shape	Seed Colour
1	BC2F1-1	54	56	4	115	21	25	Pea	Brown
2	BC2F1-2	57	54	3	109	6	27	Owl's	Brown
3	BC2F1-3	41	52	2	110	10	38	Pea	Brown
4	BC2F1-4	40	50	3	110	6	40	Angular	White
5	BC2F1-5	71	52	4	110	25	44	Angular	White
6	BC2F1-6	67	56	7	108	30	42	Angular	Dark brown
7	BC2F1-7	34	59	4	118	3	41	Angular	White
8	BC2F1-8	33	54	2	108	15	36	Angular	White
9	BC2F1-9	66	53	6	110	32	35	Pea	Yellow
10	BC2F1-10	48	57	6	109	14	32	Angular	Yellow
11	BC2F1-11	54	60	4	106	3	23	Angular	Brown
12	BC2F1-12	46	50	2	101	42	36	Angular	White
13	BC2F1-13	29	53	3	109	3	39	Pea	Greenish yellow
14	BC2F1-14	37	52	2	121	12	38	Owl's	Yellow

15	BC2F1-15	35	58	2	119	15	25	Pea	Brown
16	BC2F1-16	37	49	3	116	42	26	Angular	White
17	BC2F1-17	33	50	5	117	45	41	Owl's	Brown
18	BC2F1-18	50	46	2	107	5	40	Owl's	Light brown
19	BC2F1-19	26	48	3	116	4	28	Angular	Light yellow
20	BC2F1-20	46	50	2	109	4	23	Pea	Light yellow
21	BC2F1-21	40	52	4	107	3	41	Owl's	White brown
22	BC2F1-22	42	53	3	115	7	40	Angular	White
23	BC2F1-23	43	54	2	109	23	32	Angular	White
24	BC2F1-24	35	59	2	110	3	38	Pea	Brown
25	BC2F1-25	53	58	4	110	9	26	Pea	Yellow brown
26	BC2F1-26	42	53	6	116	58	41	Owl's	Brown
27	BC2F1-27	48	56	3	108	42	43	Angular	White brown
28	BC2F1-28	23	57	3	118	32	40	Owl's	Yellow brown
29	BC2F1-29	33	50	3	108	21	26	Owl's	White
30	BC2F1-30	31	54	3	110	52	35	Pea	Greenish yellow
31	BC2F1-31	39	56	2	109	3	38	Angular	Brown
32	BC2F1-32	56	58	5	106	23	29	Pea	Light yellow
33	BC2F1-33	52	54	3	101	48	25	Pea	Greenish brown
34	BC2F1-34	40	53	3	109	7	26	Owl's	White brown
35	BC2F1-35	40	54	4	121	8	34	Pea	Dark brown
36	BC2F1-36	60	56	2	119	6	26	Angular	White
37	BC2F1-37	31	58	4	116	12	25	Owl's	Brown
38	BC2F1-38	35	59	7	117	3	43	Pea	Light brown
39	BC2F1-39	31	53	4	109	58	40	Angular	Greenish brown
40	BC2F1-40	21	52	2	107	6	26	Angular	Greenish brown
41	BC2F1-41	29	57	3	115	4	23	Angular	Yellow white
42	BC2F1-42	38	56	3	109	6	28	Owl's	Greenish brown
43	BC2F1-43	41	50	2	110	3	44	Angular	Light yellow
44	BC2F1-44	34	54	2	110	4	37	Owl's	Brown beige
45	BC2F1-45	29	57	2	110	45	44	Owl's	Yellow brown
46	BC2F1-46	69	62	5	116	25	20	Owl's	Yellow brown
47	BC2F1-47	44	66	5	118	36	28	Pea	Light brown
48	BC2F1-48	43	61	4	108	28	37	Angular	Light brown
49	BC2F1-49	40	66	3	110	9	29	Angular	White
50	BC2F1-50	74	58	3	109	20	37	Pea	Light yellow
51	BC2F1-51	62	50	5	106	19	39	Angular	Light brown
52	BC2F1-52	67	60	3	101	18	28	Owl's	Yellow brown
53	BC2F1-53	66	59	3	109	35	24	Owl's	Light green
54	BC2F1-54	50	60	3	121	14	36	Angular	Brown
55	BC2F1-55	61	53	5	119	3	35	Angular	Yellow white
56	BC2F1-56	44	50	3	116	20	38	Pea	White brown
57	BC2F1-57	59	61	3	117	47	39	Angular	Reddish brown
58	BC2F1-58	45	58	3	109	12	45	Owl's	Yellow brown
59	BC2F1-59	35	52	3	107	6	23	Pea	Yellow brown
60	BC2F1-60	66	53	7	115	48	26	Owl's	Brown beige
61	BC2F1-61	62	60	3	109	7	34	Pea	Yellow brown
62	BC2F1-62	69	60	5	110	22	28	Owl's	Black brown mosaic
63	BC2F1-63	63	60	4	110	20	23	Angular	Beige
64	BC2F1-64	60	60	5	110	27	40	Angular	Beige
65	BC2F1-65	57	50	3	116	40	23	Angular	Brown beige
66	BC2F1-66	72	66	5	108	34	23	Angular	Brown beige
67	BC2F1-67	70	60	3	115	25	25	Angular	Brown beige
68	BC2F1-68	70	50	6	109	45	34	Owl's	Dark brown
69	BC2F1-69	65	60	3	110	29	40	Pea	Yellow brown
70	BC2F1-70	56	66	6	110	36	42	Owl's	Brown beige
71	BC2F1-71	68	60	4	110	45	41	Owl's	Green
72	BC2F1-72	64	49	6	108	21	43	Angular	Beige
73	BC2F1-73	58	46	5	118	16	39	Pea	Brown beige
74	BC2F1-74	60	48	3	108	14	28	Angular	Beige
75	BC2F1-75	64	60	2	110	61	37	Angular	Brown beige
76	BC2F1-76	63	60	3	109	25	40	Angular	Brown beige
77	BC2F1-77	73	60	4	106	66	41	Owl's	Black brown mosaic
78	BC2F1-78	71	66	3	101	42	25	Owl's	Black brown mosaic
79	BC2F1-79	56	60	3	109	60	38	Pea	Brown
80	BC2F1-80	65	60	2	121	65	44	Angular	Beige
81	BC2F1-81	65	66	5	119	80	41	Angular	Yellow
82	BC2F1-82	72	56	4	116	38	35	Angular	Yellow

83	BC2F1-83	70	58	2	117	29	39	Owl's	Yellow brown
84	BC2F1-84	59	56	3	107	26	28	Angular	Yellow brown
85	BC2F1-85	58	52	3	116	62	37	Owl's	Brown
86	BC2F1-86	69	53	3	109	29	31	Owl's	Brown beige
87	BC2F1-87	79	66	4	107	69	20	Pea	Dark brown
88	BC2F1-88	59	57	4	115	74	26	Pea	Reddish brown
89	BC2F1-89	57	52	6	109	51	24	Owl's	Green
90	BC2F1-90	55	62	5	110	73	35	Pea	Reddish brown
91	BC2F1-91	70	50	4	110	23	43	Owl's	Dark brown
92	BC2F1-92	67	66	5	116	28	39	Angular	Beige
93	BC2F1-93	62	66	5	108	63	28	Owl's	Brown beige
94	BC2F1-94	54	66	3	118	17	40	Owl's	Green
95	BC2F1-95	50	66	3	108	35	42	Angular	Yellow
96	BC2F1-96	60	69	3	110	18	35	Pea	Brown beige
97	BC2F1-97	58	66	5	109	31	38	Angular	Beige
98	BC2F1-98	71	50	4	106	26	26	Owl's	Yellow brown
99	BC2F1-99	55	52	4	101	8	27	Angular	Yellow brown
100	BC2F1-100	63	56	5	109	53	41	Owl's	Black brown mosaic
101	BC2F1-101	65	66	3	121	29	45	Owl's	Black brown mosaic
102	BC2F1-102	68	54	7	119	53	36	Pea	Brown
103	BC2F1-103	69	66	5	116	27	24	Angular	White
104	BC2F1-104	60	66	5	117	55	25	Angular	White
105	BC2F1-105	45	53	3	109	24	39	Pea	Yellow
106	BC2F1-106	45	58	2	107	42	40	Angular	Yellow
107	BC2F1-107	34	59	3	115	57	42	Angular	Brown
108	BC2F1-108	50	51	2	109	3	38	Angular	White
109	BC2F1-109	39	56	1	110	42	37	Pea	Greenish yellow
110	BC2F1-110	46	50	5	110	56	29	Owl's	Yellow
111	BC2F1-111	31	52	2	110	5	28	Pea	Brown
112	BC2F1-112	33	58	3	116	5	41	Angular	White
113	BC2F1-113	45	46	4	118	12	40	Owl's	Brown
114	BC2F1-114	43	48	3	108	7	35	Owl's	Light brown
115	BC2F1-115	50	56	3	110	9	38	Angular	Light yellow
116	BC2F1-116	55	59	3	109	6	29	Pea	Light yellow
117	BC2F1-117	38	53	3	106	9	37	Owl's	White brown
118	BC2F1-118	50	52	3	101	14	26	Angular	White
119	BC2F1-119	48	66	6	109	9	20	Angular	White
120	BC2F1-120	42	56	1	121	53	25	Pea	Brown
121	BC2F1-121	43	66	1	119	4	28	Pea	Yellow brown
122	BC2F1-122	56	50	3	116	60	39	Owl's	Brown
123	BC2F1-123	51	56	3	117	8	35	Angular	White brown
	WR 315	42	58	7	109	75	15	Angular	Brown
	PKV Kabuli-4	48	50	3	115	60	45	Angular	White
	Mean	51.54	56.45	3.57	111.44	26.70			

Conclusion

Chickpea is a rich source of nutrition and is ranked second amongst food legumes after the common bean. It is considered one of the important sources of proteins, carbohydrates, and minerals, hence called "Poor man's meat". Chickpea has high nitrogen content, due to its ability to fix atmospheric nitrogen (N) through biological nitrogen fixation, and improves soil fertility, particularly in drylands. Chickpea is grown on a large scale, but its productivity and production are reduced due to a variety of biotic and abiotic factors, including *Fusarium* wilt, *Ascochyta* blight, insects, nematodes, parasitic weeds, drought, salinity, waterlogging, high temperatures, and chilling. Two fungal diseases, *Ascochyta* blight and *Fusarium* wilt, are economically significant diseases of chickpea. Among the biotic stresses, *Fusarium* wilt caused by *Fusarium oxysporum* f. sp. *ciceris* is the major disease limiting chickpea productivity in India.

The phenotypic performance of the BC₁F₁ population was checked for different agronomic traits. The plant height ranged from 29cm to 75cm, and 54 plants were superior to the recurrent

parent PKV Kabuli-4. The lowest days to 50% flowering were observed, i.e., 48 days, which is less than the recurrent parent. The highest number of primary branches was observed, i.e., 9, which is more than the mean value of recurrent and donor parents. The total of 12 plants has an equal number of primary branches, and 53 plants are superior to the recurrent parent PKV Kabuli-4. The lowest days to maturity were recorded, i.e., 101 days, which is less than both parents. The 4 plants were equivalent, and 44 plants had fewer days to maturity than the recurrent parent PKV Kabuli-4. Up to 176 pods per plant were recorded, and 22 plants had more pods than the PKV Kabuli-4. The 26 plants showed the angular seed shape, 22 plants showed the owl's seed shape, and 18 plants showed the pea seed shape. The 9 BC₁F₁ plants indicated the white seed colour, as the recurrent parent of PKV Kabuli-4.

The phenotypic performance of the BC₂F₁ population was evaluated for different agronomic traits. The maximum plant height (cm) was seen in plant BC₂F₁-87, which measured 79cm, and a total of three plants were found comparable, and 71 plants were superior to the recurrent parent PKV Kabuli-4. The plants

BC₂F₁-18, BC₂F₁-73, and BC₂F₁-113 took a minimum days to 50% flowering, i.e., 46 days, which was less than the recurrent parent (50 days), and a total of 14 plants were comparable for the trait, with eight plants having fewer days to 50% flowering than PKV Kabuli-4. The total of 48 plants had an equal number of primary branches, and 51 plants were superior to the recurrent parent PKV Kabuli-4 for this trait. The lowest days to maturity were recorded, i.e., 101 days, which is less than both parents. The 7 plants were equivalent, and 79 plants had fewer days to maturity than the recurrent parent PKV Kabuli-4. The highest number of pods per plant was observed in plant BC₂F₁-81, i.e., 86, and the mean of the population was 26.70. The 2 plants were equivalent, and 9 plants had more pods than the PKV Kabuli-4. The highest 100 seed weight was found in BC₂F₁-58 and BC₂F₁-101. The higher number of BC₂F₁ plants had an angular seed shape like the parents. The 17 BC₂F₁ plants indicated the white seed colour, like the recurrent parent PKV Kabuli-4.

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References

1. Alyemeni MN, Hayat Q, Hayat S, Faizan M, Faraz A. Exogenous proline application enhances the efficiency of nitrogen fixation and assimilation in chickpea plants exposed to cadmium. *Legume Research*. 2016;39:221-227. doi:10.18805/lr.v0iOF.9291
2. Bodake KK, Wagh RS, Deshmukh DV. Morpho physiological characterization of chickpea (*Cicer arietinum* L.) genotypes. *International Journal of Agricultural Sciences*. 2014;10:512-518.
3. Food and Agriculture Organization of the United Nations. FAOSTAT. 2023. <https://www.fao.org/faostat/en/#data/QC/visualize>
4. Jamil A, Ashraf S. Sustainable management of chickpea wilt incited by *Fusarium oxysporum* f. sp. *ciceri* using plant extracts. *Journal of Plant Pathology*. 2021;103:519-529. doi:10.1007/s42161-021-00776-7
5. Jendoubi W, Bouhadida M, Boukteb A, Beji M, Kharrat M. *Fusarium* wilt affecting chickpea crop. *Agriculture*. 2017;7:1-16. doi:10.3390/agriculture7030023
6. Mannur D, Babbar A, Thudi M, Sabbavarapu MM, Roorkiwal M, Yeri SB, *et al.* Super Annigeri1 and improved JG74: Two *Fusarium* wilt-resistant introgression lines developed using marker-assisted backcrossing approach in chickpea (*Cicer arietinum* L.). *Molecular Breeding*. 2019;39:1-2. doi:10.1007/s11032-018-0908-9
7. Maesen LVD, Pundir RPS. Availability and use of wild *Cicer* germplasm. 1984;19-24.
8. Mir AH, Bhat MA, Dar SA, Sofi PA, Bhat NA, Mir RR. Assessment of cold tolerance in chickpea (*Cicer* spp.) grown under cold/freezing weather conditions of North-Western Himalayas of Jammu and Kashmir, India. *Physiology and Molecular Biology of Plants*. 2021;27:1105-1118. doi:10.1007/s12298-021-00997-1
9. Moreno MT, Cubero JJ. Variation in *Cicer arietinum* L. *Euphytica*. 1978;27:465-485.
10. Nandedkar K, Saxena RR, Dixit GP, Rawte S, Saxena RR. DUS based agro-morphological characterization and classification of desi chickpea (*Cicer arietinum* L.). *Pharma Innovation Journal*. 2021;10:716-722.
11. Saxena MC, Singh KB. Chickpea breeding. In: Saxena MC, Singh KB, editors. *The chickpea*. Wallingford: CAB International; 1987. p. 127-162. doi:10.1016/S0378-4290(97)00029-4
12. Suthar K, Rajkumar B, Parmar PR, Singh D. Molecular mechanism underlying chickpea-*Fusarium oxysporum* f. sp. *ciceri* interaction. In: Guleria P, Kumar V, Lichtfouse E, editors. *Sustainable agriculture reviews 51: Legume agriculture and biotechnology*. 2021;2:213-245. doi:10.1007/978-3-030-68828-8_8
13. Upadhyaya HD, Dwivedi SL, Baum M, Varshney RK, Udupa SM, Gowda CL, *et al.* Genetic structure, diversity, and allelic richness in composite collection and reference set in chickpea (*Cicer arietinum* L.). *BMC Plant Biology*. 2008;8:106-117.
14. Varshney RK, Song C, Saxena RK, Azam S, Yu S, Sharpe A, *et al.* Draft genome sequence of chickpea (*Cicer arietinum*) provides a resource for trait improvement. *Nature Biotechnology*. 2013;31:240-246.