Correlation, path analysis and genetic divergence of various agro-morphological traits and traits suitable for mechanical harvesting of chickpea (*Cicer arietinum* L.) germplasm

Comment [VK1]: Correlation, path, genetic divergence and plant architecture traits study suitable for mechanical harvesting of chickpea (*Cicer arietinum* L.) germplasm

Abstract: At Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India, during rabi, 2021–2022, five checks were used to evaluate the agro-morphological features and traits appropriate for mechanical harvesting of 540 chickpea germplasm (RLBGK-1, BG 3062, RVG 204, Phule Vikram, NBeG 47). Investigative methods included augmented plot design. Correlation and path coefficient analysis and estimation of genetic divergence have been carried out among chickpea germplasm based on mechanical harvesting and other agro-morphological traits. Plant height, growth habit, the height of the initial podding node, and the angle of the primary branch are characteristics that have been researched to help identify lines that are suited for mechanical harvesting. Peduncle length, no. of primary branches, no. of secondary branches, no. of pods per plant, chlorophyll content, leaf area index, chlorophyll fluorescence has shown positive correlation with seed yield per plant. Plant height and height of first podding node were showing positive high indirect effects through no. of secondary branches on seed yield per plant. Cluster 1 was the largest with 399 germplasm and smallest in Cluster 24 to Cluster 37 (1 each). Plant height and height of first podding node were showing maximum mean in cluster 32, whereas seed yield per plant maximum mean was in cluster 14. According to percent contribution of different characters to total divergence obtained, the most significant contributors to the divergence were no. of pods per plant and plant height. Correlation indicated that traits suitable for mechanical harvesting are not directly correlated with seed yield, while path coefficient analysis indicated that they have indirect effects on seed yield through number of primary and secondary branches per plant.

Introduction

The most prominent and historically significant legume is the chickpea (Cicer arietinum L.). It is a diploid (2n=16) pulse crop that self-pollinates. It has a 738 million base pair genome (Varshney et al.2013). The Latin term cicer, which refers to the Fabaceae plant family of legumes, is where the name "chickpea" originates. A relatively nutrient-dense pulse crop, chickpeas have modest levels of digestible carbohydrates (40–60%), protein (15–22%), and essential fats (4–8%). Chickpea is the most versatile legume consumed in India, being used for main meals, savoury snacks, and sweets. This is primarily due to its taste. It can be eaten whole, sprouted, immature pods, mature green seed, or ground into dhal and flour. The grain and flour are both further processed into a variety of products. Its flour is fine and quick to prepare. Technology for making ready-to-eat foods such as biscuits, cookies, and fermented foods. Alternative uses for chickpeas include soup mixes made with chickpea flour (Geervani *et al.*1989). They are divided into desi and kabuli categories. The kabuli kinds have higher sugar levels and lower fibre levels than the desi types. The kabuli varieties have larger seeds and have a greater market price than the desi varieties. The price premium in kabuli varieties rises in tandem with the seed size (Gaur *et al.*2010). Mechanical harvestable

varieties released in India are NBeG 47 (ICCV 05106), Phule Vikram (ICCV 08108), BG 3062 (1CCV 08112), RVG 204 (ICCV 08102). Traditional varieties are short, semi spreading, height of lower pods 15-20cm from ground, whereas mechanical harvestable varieties are upright and tall, fruiting zone start about 30cm from ground. Total mechanization of harvesting is cost effective and quicker, reducing the risk of ripened crops exposure to untimely rain or other extreme weather conditions. The canopy structure of mechanical harvestable varieties leads to high photosynthetic efficiency, low humidity which helps in reducing foliar diseases. Mechanical harvesting is labour friendly, save time, save money. Mechanical harvesting is better for the health of labourers especially women, as handling the crop causes painful dermatitis due to its high acid content (Singh *et al*.2018). These varieties are developed to address the issue of labour shortage on farms and reduce drudgery. The yield of these varieties is on par and in some conditions better than existing varieties, other disease resistance traits are also on par. Improves resource use efficiency and also developing mechanical harvestable varieties is needed to enhance area and production for reaching country's goal of self-sufficiency in pulse production. The present investigation helps to find out inter-relationships among various quantitative traits especially traits suitable for mechanical harvesting towards seed yield in chickpea and estimation of genetic divergence helps in selection of parents for utilizing in hybridization programme aimed at combining characters related to mechanical harvesting and yield attributes.

Materials and methods

At Block-D3, University Seed and Research Farm, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India, during rabi, 2021–2022, the current field experiment was conducted with 540 germplasm, including 5 checks. In order to perform the research, augmented block design was used. Each germplasm was cultivated in a single row that was 2 metres long, with a 30 cm between-row distance and a 10 cm plant-to-plant distance. In order to grow the crop germplasm, the advised set of procedures were followed. Five plants from each germplasm were randomly chosen and the observations were then recorded. Data were recorded on quantitative characteristics such days to 50% flowering, the length of the peduncle, the number of primary branches, the number of secondary branches, days to maturity, the number of pods per plant, and the number of seeds per pod, 100 seed weight, seed yield per plot, plant height, height of first podding node, chlorophyll content, leaf area index, chlorophyll fluorescence. Coorelation coefficients were calculated as followed by Fisher, (1954) and Al- Jibouri *et al.,* (1958), path coefficients were calculated as followed by Wright (1921), Li, (1955) and Dewey and Lu, (1959) and genetic divergence analysis by using D^2 Statistics Mahalanobis, (1936).

Results and discussion

Information on the type of character associations with economic yield is crucial for the selection procedure. The correlation coefficient, denoted by the symbol r, has a value that can be between -1 and +1. When these numbers (r) diverge significantly from zero, only then does the correlation coefficient's range apply. In any case, the values point to a lack

of association. Table 1 shows the estimations of the simple correlation calculated between the fourteen chickpea traits under investigation. Correlation studies were done to know correlation between different traits and seed yield per plant. Peduncle length, no. of primary branches, no. of secondary branches, no. of pods per plant, chlorophyll content, leaf area index and chlorophyll fluorescence have shown positive correlation with seed yield per plant. Whereas days to 50% flowering, days to maturity, no. seeds per pod, plant height, height of first podding node have shown negative correlation with seed yield per plant.

In path coefficient analysis the residual effect (R = 0.3823) indicated that 38.23 per cent variability of seed yield per plant was explained by other traits. The direct effect was maximum for days to 50% flowering (6.4209) and days to maturity (-6.4209) followed by height of first podding node (2.3450), plant height (-2.3429), no of secondary branches (1.3229), no of primary branches (-1.3180), leaf area index (-1.0758), chlorophyll content (0.2623), number of pods per plant (0.2497), 100 seed weight (-0.2114), number of seeds per pod (0.0556). The indirect effect was also in the same order through these characters. Genotypic path analysis in table 2 and phenotypic path analysis in table 3.

Equilibrium distance was carried out using 14 characters *viz*., days to 50% flowering, peduncle length, no of primary branches, no of secondary branches, days to maturity, number of pods per plant, number of seeds per pod, 100 seed weight, plant height, height of first podding node, chlorophyll content, leaf area index, chlorophyll fluorescence, seed yield per plant having significant difference between genotypes. The 540 genotypes were grouped in 37 clusters. The number of germplasms in different clusters ranged from 1 to 399. Cluster- 1 was the largest with 399 germplasm followed by cluster- 2 (20), Cluster- 5 (17), Cluster- 6 (14), Cluster- 4 (12), Cluster- 6 (10), Cluster- 9 (8), Cluster- 10 (7), Cluster- 3, 8 (6 each), Cluster-14 (4), Cluster- 13,15,16,18 (3 each), Cluster- 11,12,17,19,20,21,22,23 (2 each) and Cluster- 24 to Cluster 37 (1 each).

The most significant contributors to the divergence were the parameters no. of pods per plant and plant height (Table 4). The analysis of variance revealed significant difference between cluster means for days to 50% flowering, peduncle length, no of primary branches, no of secondary branches, days to maturity, number of pods per plant, number of seeds per pod, 100 seed weight, plant height, height of first podding node, chlorophyll content, leaf area index, chlorophyll fluorescence, seed yield per plant. The accessions having traits suitable for mechanical harvesting were grouped in cluster 32 and high seed yielding accessions were grouped in cluster 14. Vishnu *et al.* (2020) viewed most divergence in clusters IV & V in both rainfed and irrigated conditions. Mastamaradi *et al.* (2020) grouped genotypes into different clusters and observed that genotypes from cluster II & I have suitable traits for machine harvesting, whereas genotypes of cluster IV & III shown good yield.

Conclusion

From the results of present investigation, it is clear that, traits responsible for mechanical harvesting has indirect effects through number of primary branches and secondary branches per plant towards seed yield, so seed yield might be improved by selecting for more number of primary branches and secondary branches per plant. For selection of parents having mechanical harvestable ability and parents for high seed yield for

utilization in hybridization, germplasm in cluster 32 and cluster 14 are selected as plant height and height of first podding node were showing maximum mean in cluster 32, whereas seed yield per plant maximum mean was in cluster 14.

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Table 1: Estimation of the phenotypic (below diagonal) and genotypic (above diagonal) correlation coefficient between fourteen characters in chickpea 2021-2022

Comment [VK4]: Yield and related traits

	Character	DF	PL	NPB	NSB	DM	NPPP	NSPP	SW100	PH	HFPN	CC	LAI	CF	SYPP
1	**DF**		-0.02	-0.03	-0.03	1.00	**-0.15****	**-0.10***	**-0.18****	0.03	0.03	0.04	**-0.51****	**0.16****	**-0.50****
2	**PL**	-0.01		**0.70****	**0.70****	-0.02	**-0.89****	**0.87****	0.61	**-0.10***	**-0.11***	**-0.62****	**-0.14****	**-0.44****	**0.51****
3	**NPB**	-0.02	0.08		1.00	-0.03	**0.18****	-0.08	**-0.57****	0.04	0.04	**-0.18****	**0.30****	**-0.15****	**0.39****
4	**NSB**	-0.02	0.08	1.00		-0.03	**0.18****	-0.08	**-0.58****	0.04	0.04	**-0.18****	**0.30****	**-0.15****	**0.39****
5	**DM**	1.00	-0.01	-0.02	-0.02		**-0.15****	**-0.10***	**-0.18****	0.03	0.03	0.04	**-0.51****	**0.16****	**-0.50****
6	**NPPP**	**-0.09***	-0.04	**0.14****	**0.14****	**-0.09***		-0.00	**0.09***	**0.09***	**0.09***	**0.10***	**0.23****	**-0.24****	**0.35****
7	**NSPP**	-0.06	-0.01	-0.01	-0.01	-0.06	0.01		0.99	**-0.17****	**-0.17****	**0.12****	-0.03	**-0.16****	**-0.09***
8	**SW100**	-0.07	0.00	-0.02	-0.02	-0.07	-0.00	-0.00		**0.88****	**0.88****	-0.19	**0.60****	-0.10	0.10
9	**PH**	0.05	-0.00	0.05	0.05	0.05	0.08	0.00	0.03		1.00	**0.15****	**0.22****	-0.03	**-0.13****
10	**HFPN**	0.05	-0.00	0.05	0.05	0.05	0.08	0.00	0.03	1.00		**0.15****	**0.22****	-0.03	**-0.13****
11	**CC**	-0.03	-0.06	-0.02	-0.02	-0.03	-0.02	0.01	0.02	-0.04	-0.04		0.00	**0.24****	**0.34****
12	**LAI**	**-0.32****	0.01	**0.24****	**0.24****	**-0.32****	**0.21****	0.01	0.08	**0.16****	**0.16****	0.04		**-0.34****	**0.13****
13	**CF**	0.02	0.03	**-0.09***	**-0.09***	0.02	**-0.13****	-0.03	**-0.14****	0.07	0.07	**0.15****	**-0.21****		**0.22****
14	**SYPP**	**-0.18****	-0.04	**0.25****	**0.25****	**-0.18****	**0.28****	0.02	0.07	-0.01	-0.01	0.01	**0.09***	0.03	

* and ** correlation is significant at the 0.05 and 0.01 level.

Table 2: Genotypic path analysis direct effects(diagonal) and indirect effects (off-diagonal) of different traits on Seed yield per plant

S. N	Character	DF	NPB	NSB	DM	NPPP	NSPP	SW100	PH	HFPN	CC	LAI	r
1	**DF**	**6.4209**	4.0422	-4.0198	-6.4209	-0.0362	-0.0058	0.4617	-7.6817	7.7140	0.0098	0.5520	-0.4995**
2	**NPB**	-1.9692	**-1.3180**	1.3229	1.9692	0.0448	-0.0043	0.1208	-9.6424	9.7074	-0.0481	-0.3233	0.3872**
3	**NSB**	-1.9511	-1.3180	**1.3229**	1.9511	0.0448	-0.0042	0.1220	-9.7356	9.8006	-0.0483	-0.3232	0.3881**
4	**DM**	6.4209	4.0422	-4.0198	**-6.4209**	-0.0362	-0.0058	0.4617	-7.6817	7.7140	0.0098	0.5520	-0.4995**
5	**NPPP**	-9.3122	-2.3654	2.3739	9.3122	**0.2497**	0.0000	-0.0182	-2.1149	2.1184	0.0263	-0.2450	0.3545**
6	**NSPP**	-6.7128	1.0089	-1.0010	6.7128	-0.0001	**0.0556**	-0.4207	4.0946	-4.0981	0.0311	0.0361	-0.0922*
7	**SW100**	-1.4024	7.5331	-7.6351	1.4024	0.0215	0.1107	**-0.2114**	-2.0628	2.0607	-0.3132	-0.6436	1.0963
8	**PH**	2.1052	-5.4244	5.4970	-2.1052	0.0225	-0.0097	-0.1861	**-2.3429**	2.3450	0.0398	-0.2321	-0.1347**
9	**HFPN**	2.1122	-5.4561	5.5288	-2.1122	0.0226	-0.0097	-0.1857	-2.3429	**2.3450**	0.0398	-0.2323	-0.1347**
10	**CC**	2.3917	2.4151	-2.4342	-2.3917	0.0250	0.0066	0.2524	-3.5534	3.5581	**0.2623**	-0.0023	0.3418**
11	**LAI**	-3.2943	-3.9612	3.9737	3.2943	0.0569	-0.0019	-0.1264	-5.0541	5.0639	0.0006	**-1.0758**	0.1327**

* and ** correlation are significant at the 0.05 and 0.01 level.

Residual = 0.3823

Table 3: Phenotypic path analysis direct effects(diagonal) and indirect effects (off-diagonal) of different traits on Seed yield per plant

S. N	Character	DF	NPB	NSB	DM	NPPP	NSPP	SW100	PH	HFPN	CC	LAI	r
1	**DF**	**7.46896**	-2.16180	2.14680	-7.46896	-0.02680	-0.00170	6.04485	-6.03859	0.00190	-0.00530	0.00090	-0.1797**
2	**NPB**	-1.25389	**1.28767**	-1.28519	1.25389	0.04200	-0.00040	6.17353	-6.17762	0.00140	0.00410	-0.00560	0.2512**
3	**NSB**	-1.24760	1.28767	**-1.28519**	1.24760	0.04210	-0.00040	6.16441	-6.16851	0.00150	0.00410	-0.00560	0.2512**
4	**DM**	7.46896	-2.16180	2.14680	**-7.46896**	-0.02680	-0.00170	6.04485	-6.03859	0.00190	-0.00530	0.00090	-0.1797**
5	**NPPP**	-6.77177	1.83376	-1.83120	6.77177	**0.29520**	0.00040	9.08912	-9.09421	0.00150	0.00350	-0.00790	0.2845**
6	**NSPP**	-4.43500	-1.61480	1.60000	4.43500	0.00430	**0.02810**	4.98600	-4.99330	-0.00060	0.00010	-0.00180	0.02120
7	**SW100**	4.01451	7.06850	-7.04440	-4.01451	0.02390	0.00010	**1.12464**	-1.12469	0.00310	0.00270	0.00430	-0.00570
8	**PH**	4.01015	7.07280	-7.04880	-4.01015	0.02390	0.00010	1.12464	**-1.12469**	0.00310	0.00270	0.00430	-0.00570
9	**HFPN**	-1.94760	-2.53900	2.55110	1.94760	-0.00620	0.00020	-4.80158	4.80839	**-0.07350**	0.00070	0.00910	0.01500
10	**CC**	-2.36227	3.13730	-3.13080	2.36227	0.06230	0.00020	1.84752	-1.84847	-0.00320	**0.01660**	-0.01270	0.0938*
11	**LAI**	1.17674	-1.21481	1.21287	-1.17674	-0.03930	-0.00090	8.21707	-8.21171	-0.01120	-0.00360	**0.05920**	0.03200

* and ** correlation are significant at the 0.05 and 0.01 level.

Residual = **0.8795**

Table 4: Percent contribution of different characters to total divergence

Method	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Ch13	Ch14
Eigen %	3.63	1.51	0.30	0.00	0.00	75.12	0.02	0.56	10.49	0.00	0.09	0.06	0.00	8.21