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Character Association and Path Analysis for Yield, Yield attributing, Root and Nutritional Traits in Chickpea (*Cicer arietinum* L.) Genotypes

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ABSTRACT: With an aim of establishing selection criteria for breeding high yielding varieties offering high nutritional content and good root architecture, association analysis was performed among 106 chickpea genotypes including 8 checks for eighteen yield, yield attributing, root and nutritional traits during Rabi 2020-21 and Rabi 2021-22. Simple correlation and path analysis based on pooled data of two seasons suggested that while exercising selection index due weightage given to the traits *viz.,* biological yield, harvest index for improving seed yield per plant and 100 seed weight will be rewarding for simultaneous improvement in these traits. Selection of genotypes with high protein content, larger root length and moderate seed size will be helpful in developing high yielding high protein content varieties with good root architecture. Whereas, direct selection of plant height will be rewarding for developing machine harvestable varieties by improving height of 1st pod.

Keywords: Chickpea, Correlation, Direct effects, Yield, Root, Nutrition.

INTRODUCTION

After common bean and field pea, chickpea (*Cicer arietinum* L.) is the third-ranked major Rabi season food legume crop (Aggarwal *et al*., 2015). The chickpea is the first grain legume domesticated by humans and one of the most significant crops for human consumption among pulses (Kerem *et al.,* 2007; Nagaroje *et al*., 2016). It is a self-pollinated diploid crop (2n=2x=16), which can be distinguished into the Desi and Kabuli types based on the type of seed. Almost all crops have a significant economic trait called seed yield that is complex in nature, polygenic in control, and shows multiplicative interactions with its component traits and surroundings (Singh *et al*., 2014). Seed yield in chickpea is determined by the balanced or total net effects that are brought about by different yield-contributing traits and interactions among them (Janghel *et al*., 2020). The complex trait of seed yield is regulated by the interactions of several component traits, each of which is influenced by the genetic makeup of the component traits and the environment in which the crop is cultivated. Due to the impact of the environmental component, the direct assessment and improvement of seed yield itself may be confusing. As a result, it is essential to conduct a data analysis to determine the proportional contributions of different components to yield performance. Since knowledge of correlation is essential while selecting multiple characters at once by using a simultaneous selection model, simple correlation serves as a crucial tool for this purpose (Singh, 1972). Even if the goal is selection based on a single trait, understanding correlation is crucial to avoid unfavourable correlation changes in other traits. The relationship studies between yield and different other traits in chickpea were earlier attempted by several researchers. Saxena *et al.* (2021); reported significant positive association of seed yield with plant height, number of pods and 100 seed weight and negative significant association with days to flowering and days to maturity. Studies conducted by Dawane *et al*. (2020); Jain *et al.* (2019); Kumar *et al.* (2019) revealed high significant positive correlation of seed yield with plant height, seed per pod, pods per plant, harvest index and 100 seed weight. Janghel *et al.* (2020) reported positive and highly significant genotypic and phenotypic correlation of seed yield with no. of secondary branches, no. of pods/plant, no. of seeds per plant, and 100 seed weight. Negative association of protein, Fe and Zn content with seed yield was reported by Srungarapu *et al.* (2022); Saxena *et al.* (2021); Diapari *et al.* (2014). For potential yield increase, it is important to understand the level and extent of trait variability, relationship among traits, and genetic diversity in promising chickpea genotypes (Upadhyaya *et al.,* 2007). The current investigation was designed to measure the genetic relationships among yield and its component traits in order to make effective selection for improvement in yield and nutritional content of the chickpea genotypes.

MATERIAL AND METHODS

The experiment material comprised of a set of 98 chickpea genotypes obtained from Genomic Selection trial, AICRP on chickpea, IIPR, Kanpur (Table 1) and 8 different checks for yield and its attributing traits, protein, iron and zinc content obtained from different sources (Table 2). The experiment was conducted at Research cum Instructional farm, Department of Genetics and Plant Breeding, College of agriculture, Indira Gandhi Agricultural University, Raipur, Chhattisgarh, during the *Rabi* 2020-21 and *Rabi* 2021-22. All the entries were grown and evaluated in augmented design with checks replicated twice. Each entry was sown in a single row of 4.0 m length; inter and intra-row space was 30 × 10cm. The seeds were pre-treated with Bavistin, Trichoderma, Azatobacter, Rhizobium and PSB culture. Fertilizer dose @ of 20:40:20 kg per hectare (NPK) was applied and two irrigations were given to the crop. Agronomical practices adopted for successful raising of crop were similar for both the seasons. For studying various traits, observations were taken on 5 randomly selected and tagged plants from each genotype and the average of these samples constituted the mean data for 1stseason. Similarly the data for 2nd season was recorded and pooled data of both seasons was obtained. Protein content was estimated using Kjeldahl method which yields total nitrogen content in samples which was multiplied by a conversion factor of 6.25 to obtain protein content (%). Iron and Zinc content was estimated by digesting the grounded chickpea samples with di acid (Nitric acid and per chloric acid in 5:1 ratio) and then the aliquots from digests were subjected to AAS to obtain the iron and zinc content expressed in ppm. The root traits were evaluated by sowing 2-3 seeds of each genotype in plastic bottles filled with mixture of sand and soil (1:1). The plants were provided with 3 irrigations on alternate days after sowing and at 35 DAS the roots were harvested, washed properly to remove all the soil and then subjected to WHIN RHIZO root scanner to record three root parameters i.e. root length (cm), root diameter (mm) and root volume (cm^3). Simple correlation and path analysis was performed for these yield & yield related, root and nutritional traits.

Table 1: List of 98 GS entries used as experimental material.

Sr. No.	Accessions	Sr. No.	Accessions
1.	NBeG 776	50.	Narsinghpur Bold
2.	JSC 35	51.	CSN 8962
3.	RVSSG 75	52.	GLW 64
4.	ICC 4958	53.	GL 13042
5.	RVG 204	54.	GL 1202
6.	RVG 205	55.	PG 211
7.	JG 16	56.	PG 222
8.	JSC 37	57.	PG 172
9.	RVSSG 74	58.	PG 170
10.	CSJ 303	59.	PG 221
11.	CSJ 313	60.	PG 158
12.	AKG 70	61.	GJK 0921
13.	PDKV Kanchan	62.	GJG 0814
14.	JAKI 9218	63.	GG 4
15.	AKG 46	64.	GJG 0922
16.	H 15-25	65.	GJG 6
17.	H 15-04	66.	GAG 1107
18.	GNG 2285	67.	GAG 111
19.	H 15-13	68.	GJG 3
20.	H 12-29	69.	GJG 0904
21.	H 08-18	70.	ICC 4658
22.	H 12-63	71.	ICC 1710
23.	H 14-01	72.	ICC 5912
24.	H 13-01	73.	IPC 2005-24
25.	H 14-22	74.	ICC 2277
26.	H 13-09	75.	ICC 11764
27.	HC-1	76.	Phule G 06102
28.	H 12-22	77.	IPC 2005-64
29.	H 13-36	78.	JG 37
30.	H 15-03	79.	GL 13001
31.	H 12-26	80.	Rajendra Chana-1
32.	H 16-17	81.	IPC 2005-28
33.	H 16-12	82.	JG 3-14-16
34.	H 16-08	83.	CSJ 556
35.	H 15-27	84.	IPC 2012-98
36.	ILC 166	85.	IPC 2008-103
37.	Phule G-96006	86.	IPC 2008-11
38.	Mahabaleswar-1	87.	IPC 2012-49
39.	ICCV 92944	88.	KGD 99-4
40.	JG 24	89.	IPC 2013-33
41.	ICCV 96854	90.	IPC 2007-28
42.	JG 2018-53	91.	IPC 2010-134
43.	JG2017-48	92.	GNG 2226
44.	JG2018-50	93.	JG 35
45.	JG47315-2	94.	GNG 2264
46.	JG2018-54	95.	MABC 66-266
47.	JG 2016-141611	96.	DKG 964
48.	JG74315-14	97.	IPC 2006-88 X ILWC 179
49.	JG 2018-51	98.	IPC 2008-69

Source- Genomic Selection trial, AICRP on chickpea, IIPR, Kanpur.

Table 2: List of 8 chickpea varieties included as checks.

Sr. No.	Check Varieties	Source	Special Trait
1.	RG 2015-08	IGKV, Raipur	High yield, wilt resistance
2.	JG 315	JNKVV, Jabalpur	Wilt resistance, high yield, high iron content
3.	IPC 2005-62	IIPR, Kanpur	Wilt resistance, high yield
4.	IPC 2006-77	IIPR, Kanpur	Wilt resistance, high yield
5.	CG CHANA-2	IGKV, Raipur	Wilt resistance, high yield
6.	IC-1 (Indira Chana-1)	IGKV, Raipur	Wilt resistance, high yield
7.	T-39-1 B (Blue flower)	Germplasm line	High protein content
8.	T-39-1 P (Pink flower)	Germplasm line	High protein content

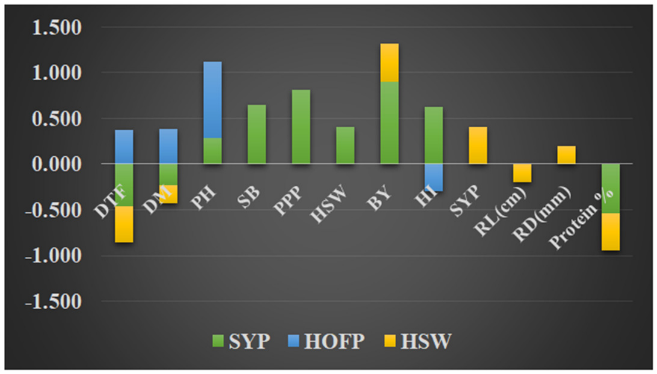
RESULT AND DISCUSSION

Simple Correlation analysis. As a result of simple correlation analysis (Table 3 and Fig. 1), Seed yield per plant was found to have significant positive correlation with plant height, no. of secondary branches, pods per plant, 100 seed weight, biological yield and harvest index indicating strong association of these traits with plant yield and thus, the selection of these traits will be rewarding in improving plant yield. Similar associations of seed yield were recorded by Janghel *et al*. (2020); Kaur and Bhardwaj (2019); Jain *et al*. (2019); Jha *et al*. (2015); Johnson *et al*. (2015) Whereas, it was found to be negatively correlated with the traits days to flowering and days to maturity (Kumar *et al*., 2019) and protein content . Earlier studies of Srungarapu *et al*. (2022); Saxena *et al*. (2021) have also indicated negative relation of yield with protein content. The negative correlation of days to flowering and days to maturity with the seed yield can be utilized for developing early flowering and early maturing varieties keeping the high seed yield in mind. Whereas, in case of negative association of seed yield with protein content, weightage to any one of the two traits can be given compromising with the another one. Therefore, for breeding high yielding varieties with high protein content breaking of this negative association through appropriate crossing program may be suggested.

Height of 1st pod showed highest significant and positive correlation with plant height followed by days to flowering and days to maturity. However, it showed significant negative correlation with harvest index. Positive association of height of 1st pod and plant height suggests the selection and improvement of plant height can result in simultaneous improvement of both the traits which will be useful for breeding varieties for mechanical harvesting. Strong positive association of plant height with 1st pod height was also reported by Jayalakshmi *et al*. (2020).

100 seed weight/seed size was significantly and positively correlated with biological yield, seed yield per plant and root diameter. Whereas, it was found to be negatively correlated with protein content, days to flowering, days to maturity and root length. Since, 100 seed weight is the basis of seed size, the large sized seeds increasing the seed yield is very obvious. Also the positive correlation of seed size or 100 seed weight with Root diameter suggests that large sized seeds exhibits large root diameter. But the negative associations, indicates the association of small sized seed varieties being early flowering and early maturing. Also, it indicates, smaller the seed size higher is the protein content of the genotype i.e. T-39-1 (B). A negative relationship between seed size and protein content implies that as seed increases in size there is an increased amount of starch deposition altering the starch / protein ratio (Bahl *et al.,* 1979). Protein content has been found to be negatively correlated in chickpea by Frimpong *et al*. (2009); Gangola *et al*. (2012); Saxena *et al*. (2021). Selection of genotypes with high protein content and moderate seed size is recommended to balance both the traits and to develop high yielding protein rich varieties (Saxena *et al.,* 2021). Also, smaller the size of seed greater will be the root length in the genotypes, suggesting the suitability of small seeded genotypes for drought/rainfed conditions.

Path coefficient analysis. It is essential to determine the true contribution of a variable to seed yield because correlation analysis alone is insufficient to draw a precise picture of relationship among traits. By measuring the direct and indirect effects of independent traits on dependent traits via other traits at correlation levels, path analysis was performed taking seed yield, height of 1st pod and 100 seed weight as dependent variable (Table 4) result of which revealed that biological yield and harvest index exhibited high direct positive effect on seed yield per plant. Results similar to present findings were reported by Johnson *et al.* (2015); Dehal *et al*. (2016); Kumar *et al.* (2019); Kaur and Bhardwaj (2019). Plant height exhibited high direct positive effect whereas, days to maturity was found to have low direct and positive effect on height of 1st pod. Traits like seed yield per plant, 100 seed weight and protein content were found to have low direct but negative effects and moderate direct negative effects were established by pods per plant. High direct positive effect on 100 seed weight was recorded by plant height and seed yield per plant whereas, direct positive but moderate effects were exhibited by biological yield. High direct but negative effects on 100 seed weight was exhibited by pods per plant and height of 1st pod, moderate negative effects by protein content and low direct negative effects by seeds per pod and root length.



DTF= days to flowering, DM= days to maturity, PH= plant height, SB= number of secondary branches, PPP= pods per plant, HSW= hundred seed weight, BY= biological yield, HI= harvest index, SYP= seed yield per plant, RL= root length, RD= root diameter.

Fig. 1. Upstream and downstream relationship of (a) seed yield per plant; (b) height of 1st pod and (c) 100 seed weight with other yield related, nutritional and root traits.

Table 3: Simple Correlation analysis among yield and yield attributing traits based on pooled mean data of 2 seasons.

	DTF	DM	HOFP	PH	PB	SB	PPP	SPP	HSW	BY	HI	SYP	RL(cm)	RD(mm)	RV(cm3)	Protein %	Zn (ppm)	Fe (ppm)
DTF	**1.000**																	
DM	0.575	**1.000**																
HOFP	0.374	0.381	**1.000**															
PH	0.096	0.139	0.839	**1.000**														
PB	0.108	0.144	-0.038	-0.074	**1.000**													
SB	-0.241	-0.235	-0.106	0.061	0.170	**1.000**												
PPP	-0.417	-0.219	-0.010	0.283	0.252	0.711	**1.000**											
SPP	0.141	0.066	0.073	0.018	0.049	0.108	-0.033	**1.000**										
HSW	-0.392	-0.197	-0.126	0.110	-0.143	0.042	0.048	-0.177	**1.000**									
BY	-0.310	-0.047	0.095	0.390	0.131	0.582	0.708	-0.099	0.412	**1.000**								
HI	-0.537	-0.482	-0.297	-0.078	0.061	0.345	0.559	0.101	0.181	0.278	**1.000**							
SYP	-0.468	-0.231	-0.047	0.276	0.174	0.639	0.804	0.018	0.404	0.898	0.622	**1.000**						
RL(cm)	0.118	0.101	-0.053	-0.164	0.025	0.043	-0.018	0.099	-0.202	-0.091	-0.039	-0.073	**1.000**					
RD(mm)	-0.080	0.014	0.016	0.042	-0.032	-0.139	-0.059	-0.050	0.198	0.030	-0.081	-0.012	-0.313	**1.000**				
RV(cm3)	0.109	0.158	-0.006	-0.103	0.042	0.016	-0.019	0.089	-0.142	-0.047	-0.103	-0.071	0.900	-0.034	**1.000**			
Protein %	0.502	0.224	0.188	0.078	-0.202	-0.308	-0.376	0.069	-0.417	-0.417	-0.349	-0.538	0.007	-0.024	0.013	**1.000**		
Zn (mg/kg)	0.175	0.154	0.141	0.037	0.026	-0.197	-0.177	0.016	-0.076	-0.040	-0.190	-0.155	0.038	-0.073	0.027	0.161	**1.000**	
Fe(mg/kg)	-0.191	0.030	0.018	-0.022	-0.012	0.236	0.104	-0.023	0.148	0.190	0.079	0.153	0.172	0.011	0.193	-0.213	0.138	**1.000**

DTF= days to flowering, DM= days to maturity, HOFP= height of 1st pod, PH= plant height, PB= number of primary branches, SB= number of secondary branches, PPP= pods per plant, SPP= seeds per pod, HSW= hundred seed weight, BY= biological yield, HI= harvest index, SYP= seed yield per plant, RL= root length, RD= root diameter, RV= root volume, Zn= zinc content and Fe= iron content.

Note- The highlighted correlation values represents significance at 1% and 5% level of significance.

Table 4: Study of Direct effects of different traits taking Seed yield per plant, Height of 1st pod and 100 seed weight as dependent variable.

	SYP		HOFP		HSW	
	Direct effect	Correlation	Direct effect	Correlation	Direct effect	Correlation
DM			0.161	0.381		
PH			0.966	0.839		
BY	0.694	0.898			0.26	0.412
HI	0.357	0.622				
SYP					0.371	0.404
RL(cm)					-0.105	-0.202
Protein %					-0.253	-0.417
	Residual effect = 0.026		Residual effect =0.128		Residual effect = 0.414	

Moreover, residual effects which measures the error and unexplained variance by other possible independent variables on dependent variables (Janghel *et al*., 2020) was found to be negligible (0.026) in case of seed yield as dependent variable, low (0.128) for height of 1st pod as dependent variable indicating that the characters included in the present study were sufficient enough to account for the variability in the dependent traits *i.e.* Seed yield per plant and height of 1st pod whereas, high (0.414) residual effect was reported in case of 100 seed weight as dependent variable.

Correlation and path analysis are important tools for getting appropriate information regarding interrelationship among different characters for effective selection programme. The traits biological yield and harvest index possessed positive correlation with seed yield along with direct positive effects, which indicates true relationship of the seed yield with these two traits and thus, direct selection of these two traits will be effective for improvement in seed yield per plant. The result was in accordance with Hailu *et al.* (2021) who also suggested that seed yield in chickpea could be enhanced by inclusion of biological yield along with harvest index as selection criteria. Among all the traits having direct positive or negative effects on height of 1st pod, the correlation estimates reported significant and positive association of plant height and days to maturity along with direct positive effect on height of 1st pod therefore, direct selection and improvement of plant height can achieve improvement in height of 1st pod. For 100 seed weight as dependent variable, biological yield and seed yield per plant exhibited significant positive correlation along with direct positive effect on 100 seed weight, thus these two traits can be considered for direct selection for improvement in 100 seed weight in chickpea genotypes. However, the traits like protein content and root length exhibited negative significant correlations along with direct negative effects on 100 seed weight indicating smaller the seed size higher the protein content and larger the root length will be and vice versa.

CONCLUSIONS

Correlation and path analysis suggested selection of traits *viz*., biological yield and harvest index for seed yield per plant, selection of plant height for height of 1st pod and biological yield and seed yield per plant for 100 seed weight will be rewarding for simultaneous improvement in these traits in breeding programmes. Also selection of genotypes with high protein content, larger root length, root volume and moderate seed size will be helpful in developing high yielding high protein content varieties with good root architecture. Hence, it is suggested that while exercising selection index due weightage should be given to these traits.

FUTURE SCOPE

Understanding of the interrelated traits involved in the genetic variation of seed yield has been aided by the current work. This would undoubtedly offer guidance for developing selection criteria to enhance yield traits. Given the significance of the chickpea crop in the diets of the majority of people and the significant global health issues associated with micronutrient malnutrition, an understanding of the current correlation pattern between yield, protein, seed-Fe, and Zn concentrations will be beneficial for their biofortification as well as yield enhancement.

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Conflict of Interest. None

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