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COMBINING HIGH SEED NUMBER AND WEIGHT TO IMPROVE SEED YIELD POTENTIAL OF CHICKPEA IN INDIA

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ABSTRACT

Increasing seed size and seed weight is an important trait for trade, yield component and adaptation of chickpea (*Cicer arietinum)*. Information on genetic control of such component traits has been generated in chickpea mostly based on germplasm/breeding lines. We studied three chickpea segregating populations to determine seed number and weight, as potential characters for yield improvement through correlation and path coefficients analysis. Three F_2 populations, along with their four parents, were studied under irrigated conditions. Estimates of heritability varied from 19.84 to 98.51%, depending on traits and crosses. However, its magnitude was high (> 65%) in all the crosses for seed yield per plant, 100-seed weight, plant height and primary branches per plant. Seed yield per plant was correlated strongly with seeds per plant (r=0.84-0.91), pods per plant (r=0.64-0.79), 100-seed weight (r=0.50-0.66) and biological yield (r=0.50-0.68). Seeds per plant exhibited a significant positive association with pods per plat (r=0.73-0.83) and biological yield (r=0.41-0.64), Path analysis confirmed that the number of seeds per plant (0.672 to 0.821) and 100-seed weight (0.441 to 0.501) had the highest positive direct influence on grain yield per plant. Both traits also displayed a positive indirect effect considerably to biological yield per plant and harvest index. Thus, combined selection for seed number and weight would be fruitful to improve yield potential of chickpea.

Key Words: *Cicer arietinum*, heritability, path coefficient

RÉSUMÉ

L'augmentation de la taille et du poids du grain constitue une caractéristique importante pour le commerce, la composante du rendement et l'adaptation du pois chiche (*Cicer arietinum)*. L' information sur le contrôle génétique de tels composants de traits a été généré dans le pois chiche principalement sur base du germoplasme des lignées améliorées. Trois populations de ségrégation du pois chiche étaient étudiées pour déterminer le nombre de grains et le poids, comme caractères potentiels pour l'amélioration du rendement à travers l'analyse des coefficients de piste et de correlation. Trois populations F_2 avec leurs quatre parents étaient étudiés en conditions irriguées. Les estimations de l'heritabilité a varié de 19.84 à 98.51% en se basant sur les traits et les croisements. Par ailleurs, sa magnitude était élevée (> 65%) dans tous les croisements en rapport avec le rendement de grains par plant, le poids de 100 grains, la hauteur des plants et les banches primaires par plant. Le rendement en grain par plant était fortement corrélé avec les grains par plant (r=0.84-0.91), les gousses par plant (r=0.64-0.79), le poids de 100 grains (r=0.50-0.66) et le rendement biologique (r=0.50-0.68). Les grains par plant ont exhibé une association positive significative avec les gousses par plant (r=0.73-0.83) et le rendement biologique (r=0.41-0.64). L'analyse du coefficient de piste a confirmé que le nombre de grains par plant (0.672 à 0.821) et le poids de 100 grains (0.441 à 0.501) avaient une influence directe la plus élevée sur le rendement en grains par plant. Tous les deux traits ont considéralement montré un effet indirect positif sur le rendement biologique par plant et l'indice de récolte. Ainsi, la selection combine pour le nombre de grains et le poids pourrait avec succès améliorer le rendement potentiel do pois chiche.

Mots Clés: *Cicer arietinum*, heritabilité, coefficient de piste

INTRODUCTION

It is well established that seed yield is the final product and many traits contribute to its performance. Therefore, seed yield directly or indirectly is dependent on the performance of other related traits. Wallance *et al.* (1993) suggested that efficient breeding for higher yield requires simultaneous selection for three major genetically controlled physiological components: a superior rate of biomass accumulation, a superior rate of actual yield accumulation in order to acquire a high harvest index, and a time to harvest maturity that is coinciding the duration of the growing season. That duration is provided by the environment, which is the fourth major determinant of yield.

Appreciable genetic variation has been revealed for many of the physiological components of crop photosynthesis and of the distribution and use of assimilates, including their response to temperature and water stress. Its effective use in a breeding programme depends on the identification of those components that are most important in determining yield or quality, and the development of rapid and reliable screening procedures that correlate well with the performance of the crop in the field.

Grain yield is a function of the number of seeds produced per unit area and the average weight of the individual seeds (Bruening and Egli, 1999). Both traits are major contributors to biological yield and harvest index. Seed size as determined by seed weight, is an important trait for trade and component of yield and adaptation of chickpea, which is controlled by two genes with dominance epistasis (Upadhyaya *et al.*, 2006).

Different selection criteria have been proposed by researchers for yield improvement in chickpea (Singh *et al.,* 1990; Dasgupta *et al.*, 1993; Kumar *et al.*, 1999; Toker and Cagirgan, 2004). Inconsistency in the results could be due to the different screening methods used previously. In fact, Singh *et al.* (1990) and Toker and Cagirgan (2004) reported that breeding materials should previously be screened and selected for important biotic and abiotic stress factors in the target environment prior to selection for grain yield. Traditional selection procedures will be shortened by these applications.

Looking to the importance of seed size and number in chickpea improvement programmes, knowledge of heritable forces driving phenotypic variation for both these traits and their direct and indirect share toward yield is essential. Unfortunately, such studies in chickpea are mostly based on germplasm/breeding lines. In this study, we attempted to determine importance of seed number and weight through correlation and path coefficients analysis in F_2 generation of three chickpea crosses.

MATERIALS AND METHODS

The F_2 populations derived from three chickpea crosses, together with their four parents, were used in this study. Parents were considered homozygous as chickpea is a strictly self-pollinated crop. Genotype GJG 9905 was considered as female and crossed with three male parents *viz.,* Vishal, ICC 4958 and JCP 27. These produced three crosses, namely, GJG 9905 x Vishal (C_1), GJG 9905 x ICC 4958 (C_2) and GJG 9905 x JCP 27(C_3), referred to hereafter as C_1, C_2 and C_3, respectively.

The F_2 seeds were obtained from F_1 plants through advancement of generation. The experiment was conducted during rabi-2009 under irrigation at the Instructional Farm, College of Agriculture, Junagadh Agricultural University, Junagadh in India.

A plot of five rows to each F_2 and of single row to each parent was allotted and replicated thrice. Plant spacing was 10 cm between plants in rows that were 4 meters long, and 45 cm apart. Fertiliser was applied at the rate of 25 kg ha^{-1} N and 50 kg ha^{-1} P in the form of urea and diammonium phosphate (DAP). Weeds were controlled manually throughout the growing season.

Seventy five plants from each F_2 and five from each parent selected randomly per plot, were used for data collection. Quantitative traits, i.e., days to flowering, flowering period days to maturity, plant height, primary branches per plant, pods per plant, seeds per pod, 100-seed weight, biological yield per plant, harvest index and seed yield per plant, were the parameters considered.

Variability from plant to plant within individual parents for each of the eleven characters was used as the environmental variance. Similarly, total variance was estimated from the F_2 plants. Heritability in individual populations was calculated using the procedure described by Mahmud and Kramer (1951). Simple correlation coefficients between the traits were computed as per Panse and Sukhatme (1967). Path coefficients were estimated according to Dewey and Lu (1959), where grain yield per plant was kept as resultant variable and other contributing characters as causal variables.

RESULTS AND DISCUSSION

The F_2 plants of C_3 were remarkably late maturing and showed high performance for seed yield per plant (Table 1). Such combination is not desirable to develop high yielding early cultivars suitable for short growing environment. The F_2 population of C3 also expressed better performance and a higher range for other characters like pods per plant, seeds per plant, 100-seed weight, biological yield per plant and harvest index.

The heritability estimates for the traits varied from 19.84 to 98.51%, depending on traits and crosses. High heritability estimates (>65%) were found for plant height, primary branches per plant, 100-seed weight and seed yield per plant in all crosses studied. Heritability estimates for days to flowering and flowering period were low to moderate, ranging from 36.91 to 63.66% and 19.84 to 64.64%, respectively. The magnitude of heritability was inconsistent for the remaining traits.

Our results are partly in agreement with those reported by Dasgupta *et al.* (1993) and Kumar *et al.* (1999). It may be noted here that the cross C_3 of the present study provides an advantage, since maximum traits expressed high heritability. However, it is worthwhile to mention that in addition to heritability, the mean of base population should be taken into account while selecting for superior types (Johnson *et al.*, 1955).

Correlation coefficients for eleven characters in three F_2 populations of chickpea (Table 2) revealed that seed yield per plant, pods per plant, seeds per plant and biological yield per plant exhibited strong relationships among each other.

TABLE 1. Range and heritability (h^2) in broad sense for eleven characters in three F_2 populations of chickpea in India

Character	C_1			C_2			C_3		
	Mean	Range	h^2 (%)	Mean	Range	h^2 (%)	Mean	Range	h^2 (%)
Days to flowering	39.20	38.2-39.8	36.91	42.81	41.2-43.8	63.66	57.07	56.2-57.6	60.82
Flowering period	36.13	35.4-37.2	19.84	36.07	35.21-36.61	61.34	26.40	25.4-27.2	64.64
Days to maturity	99.20	98.2-99.8	46.94	100.47	100.2-103.8	60.92	107.14	105.2-108.8	77.21
Plant height (cm)	30.33	29.2-30.9	81.98	31.88	31.20-32.60	78.46	31.54	30.6-32.6	77.78
Primary branches/plant	8.24	7.2-9.4	69.74	7.26	6.20-8.31	65.29	9.70	9.43-9.96	76.42
Pods/plant	22.83	21.79-23.64	42.98	23.60	23.31-24.16	50.24	33.44	33.05-33.69	76.57
Seeds/plant	26.70	26.13-27.31	69.78	27.95	27.67-28.41	55.53	41.35	41.0-41.67	90.96
100-seed weight (g)	12.62	12.34-12.84	95.72	10.93	10.87-10.98	67.68	13.77	13.74-13.8	89.96
Biological yield/plant (g)	14.02	13.45-14.93	24.06	13.26	12.90-13.63	69.23	21.42	21.26-21.59	27.62
Harvest index (%)	24.52	24.26-25.5	98.51	23.80	23.66-24.02	58.62	26.94	26.60-27.13	36.29
Seed yield/plant (g)	3.38	3.30-3.47	85.60	3.07	3.03-3.12	85.72	5.69	5.64-5.74	94.26

C1 = GJG 9905 x Vishal, C2 = GJG 9905 x ICC 4958 and C2 = GJG 9905 x JCP 27

TABLE 2. Simple correlation coefficient for ten characters with seed yield per plant in three chickpea crosses in India

Character	Cross	Flowering period	Days to maturity	Plant height (cm)	Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Seed yield/ plant (g)
Days to flowering	C_1	0.53**	0.81**	-0.07	0.02	-0.06	-0.11	0.03	-0.13	0.05	-0.07
	C_2	0.85**	0.95**	-0.03	-0.28**	-0.13	-0.16*	-0.02	-0.09	-0.02	-0.12
	C_3	0.74**	0.85**	0.14	0.08	0.10	0.09	0.05	0.09	0.03	0.09
Flowering period	C_1		0.75**	0.10	0.03	0.13	0.00	0.04	0.06	-0.02	0.03
	C_2		0.85**	-0.02	-0.23**	-0.09	-0.12	0.03	0.03	-0.04	-0.09
	C_3		0.91**	0.06	0.01	0.07	0.00	-0.05	0.02	-0.04	-0.03
Days to maturity	C_1			0.08	0.03	0.07	-0.05	0.06	-0.05	0.06	0.00
	C_2			-0.02	-0.23**	-0.13	-0.15*	-0.02	-0.07	-0.05	-0.11
	C_3			0.09	0.05	0.07	0.06	-0.03	0.05	0.00	0.03
Plant height (cm)	C_1				0.34**	0.40**	0.41**	0.14*	0.36**	0.07	0.40**
	C_2				0.45**	0.34**	0.37**	0.17*	0.50**	-0.17*	0.36**
	C_3				0.39**	0.25**	0.20**	0.09	0.30**	-0.09	0.21**
Primary branches/plant	C_1					0.44**	0.44**	0.05	0.35**	0.04	0.36**
	C_2					0.39**	0.45**	0.22**	0.55**	-0.20**	0.44**
	C_3					0.33**	0.29**	0.09	0.26**	0.04	0.28**
Pods/plant	C_1						0.79**	0.21**	0.62**	0.17*	0.73**
	C_2						0.83**	0.31**	0.58**	0.17*	0.79**
	C_3						0.73**	0.04	0.34**	0.31**	0.64**
Seeds/plant	C_1							0.16*	0.62**	0.31**	0.84**
	C_2							0.27**	0.64**	0.22**	0.91**
	C_3							0.00	0.41**	0.48**	0.86**
100-seed weight (g)	C_1								0.36**	0.42**	0.66**
	C_2								0.32**	0.33**	0.65**
	C_3								0.30**	0.22**	0.50**
Biological yield/plant (g)	C_1									-0.31**	0.68**
	C_2									-0.49**	0.64**
	C_3									-0.45**	0.50**
Harvest index (%)	C_1										0.45**
	C_2										0.32**
	C_3										0.53**

C1 = GJG 9905 x Vishal, C2 = GJG 9905 x ICC 4958 and C2 = GJG 9905 x JCP 27. * and ** represent significant values at <0.05 and <0.01 probability levels, respectively

TABLE 3. Direct (bold) and indirect effect of ten component characters on seed yield per plant in three chickpea crosses in India

Character	Cross	Days to flowering	Flowering period	Days to maturity	Plant height (cm)	Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight (g)	Biological yield/ plant (g)	Harvest index (%)	Correlation with seed yield/plant (g)
Days to flowering	C_1	**-0.007**	-0.005	0.010	-0.001	0.000	-0.002	-0.077	0.016	-0.009	0.003	-0.07
	C_2	**0.000**	-0.002	-0.002	0.000	0.003	-0.003	-0.128	0.011	0.002	0.001	-0.12
	C_3	**-0.014**	0.004	0.004	0.000	-0.001	-0.002	0.070	0.023	0.006	0.002	0.09
Flowering period	C_1	-0.004	**-0.009**	0.009	0.001	0.000	0.004	0.003	0.021	0.004	-0.001	0.03
	C_2	0.000	**-0.002**	-0.002	0.000	0.002	-0.002	-0.095	0.012	0.001	0.001	-0.09
	C_3	0.010	**0.005**	0.004	0.000	0.000	-0.001	0.001	-0.025	0.001	-0.003	-0.03
Days to maturity	C_1	-0.006	-0.006	**0.012**	0.001	0.000	0.002	0.031	0.032	-0.004	0.003	0.00
	C_2	0.000	-0.002	**-0.002**	0.000	0.002	-0.003	-0.117	0.007	0.002	0.001	-0.11
	C_3	-0.012	0.005	**0.004**	0.000	0.000	-0.001	0.047	-0.016	0.003	0.000	0.03
Plant height (cm)	C_1	0.004	-0.001	0.001	**0.013**	0.000	0.012	0.277	0.69	0.025	0.004	0.40**
	C_2	0.000	0.000	0.000	**-0.007**	-0.004	0.009	0.293	0.075	-0.011	0.004	0.36**
	C_3	-0.002	0.000	0.000	**0.000**	-0.004	-0.004	0.166	0.043	0.021	-0.006	0.21**
Primary branches/plant	C_1	0.000	0.000	0.000	0.004	**0.000**	0.014	0.297	0.024	0.024	0.002	0.36**
	C_2	0.000	0.001	0.001	-0.003	**-0.010**	0.010	0.355	0.095	-0.012	0.005	0.44**
	C_3	-0.001	0.000	0.000	0.000	**-0.009**	-0.005	0.239	0.041	0.018	0.003	0.28**
Pods/plant	C_1	0.000	-0.001	0.001	0.005	0.000	**0.031**	0.532	0.107	0.043	0.008	0.73**
	C_2	0.000	0.000	0.000	-0.002	-0.004	**0.025**	0.655	0.136	-0.013	-0.004	0.79**
	C_3	-0.001	0.000	0.000	0.000	-0.003	**-0.015**	0.600	0.017	0.023	0.021	0.64**
Seeds/plant	C_1	0.001	0.000	-0.001	0.005	0.000	0.024	**0.672**	0.080	0.043	0.015	0.84**
	C_2	0.000	0.000	0.000	-0.002	-0.004	0.021	**0.792**	0.120	-0.014	-0.005	0.91**
	C_3	-0.001	0.000	0.000	0.000	-0.003	-0.011	**0.821**	-0.001	0.028	0.032	0.86**
100-seed weight (g)	C_1	0.000	0.000	0.001	0.002	0.000	0.007	0.107	**0.501**	0.025	0.020	0.66**
	C_2	0.000	0.000	0.000	-0.001	-0.002	0.008	0.216	**0.441**	-0.007	-0.008	0.65**
	C_3	-0.001	0.000	0.000	0.000	-0.001	-0.001	-0.002	**0.465**	0.020	0.015	0.50**
Biological yield/plant (g)	C_1	0.001	-0.001	-0.001	0.005	0.000	0.019	0.419	0.179	**0.069**	-0.015	0.68**
	C_2	0.000	0.000	0.000	-0.003	-0.005	0.015	0.508	0.141	**0.022**	0.001	0.64**
	C_3	-0.001	0.000	0.000	0.000	-0.002	-0.005	0.333	0.139	**0.068**	-0.030	0.50**
Harvest index (%)	C_1	0.000	0.000	0.001	0.001	0.000	0.005	0.212	0.210	-0.022	**0.047**	0.45**
	C_2	0.000	0.000	0.000	0.001	0.002	0.004	0.178	0.144	0.011	**-0.023**	0.32**
	C_3	0.000	0.000	0.000	0.000	0.000	-0.005	0.391	0.104	-0.031	**0.066**	0.53**

Residual effect: C1 = 0.094, C2 = 0.072 and C3 = 0.071. C1 = GJG 9905 x Vishal, C2 = GJG 9905 x ICC 4958 and C2 = GJG 9905 x JCP 27. * and ** represent significant values at <0.05 and <0.01 probability levels, respectively

Similarly, seed yield per plant was also correlated strongly with 100-seed weight and harvest index. Our findings are akin to those reported by Kumar *et al*. (1999). Further, it was observed that relationships among days to flowering, flowering period and days to maturity were significant and positive, but none was correlated with seed yield per plant.

Path coefficient analysis revealed that seeds per plant exhibited the highest positive direct effect (0.672 to 0.821), followed by 100-seed weight (0.441 to 0.501) on seed yield per plant (Table 3). Direct effects of other traits were negligible. Significant positive associations of biological yield per plant and harvest to seed yield per plant was responsible due to their major indirect share through seeds per plant and 100-seed weight. Our results are consistent with the earlier reports (Singh *et al*., 1990; Dasgupta *et al.*, 1993; Toker and Cagirgan, 2004).

Significant negative correlation between biological yield per plant and harvest index; and significant positive association of both these characters with seed yield per plant indicated that harvest index might serve as an index for identifying chickpea genotypes with higher seed yield per plant. It also implies that genotypes having potential of high dry matter production have the good potential of converting relatively most of it to economic yield. Thus, higher yield requires a larger proportion biomass and/or higher harvest index. It is also associated with increased number of pods and seeds per plant. Improvement in harvest index has been a consequence of increased seed number, coupled with stable individual seed weight (Ayaz *et al.*, 2001).

In most grain crops, individual seed weight is commonly analysed as the product of the individual seed growth rate by the duration of seed filling. Grain yield is directly dependent on sink size, which is largely determined during the vegetative period and the photosynthetic capacity of the crop during the grain filling period (Bingham, 1967). In the case of legume crops, the active filling period begins when the pod wall has approximately reached its final size (Carlson, 1973). Variations in seed filling duration among genotypes and environments have been reported, but it is rarely correlated with seed size (Pfeiffer and Egli, 1988). For a given genotype, genotypic variation in individual seed weight is mainly due to differences in individual seed growth rates (Egli *et al.,* 1981), even if the duration of seed filling varies among different environmental situations (Munier-Jolain and Ney, 1995).

This study has revealed that seeds per plant and 100-seed weight exert maximum positive indirect effect on biological yield per plant and harvest index. Heitholt *et al.* (1985) pointed out that seed number and weight are related to availability of assimilate to the reproductive organs during flowering and seed set, and prioritised partitioning of dry matter to reproductive parts will increase both of these yield components. A better understanding at physiological level of the interaction between vegetative and reproductive growth is essential as a basis for further improvement in yield. Information generated in present study indicated that selection for seed number and seed weight together would undoubtedly culminate significant improvement in yield potential of chickpea.

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