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Correlation and Path Coefficient Analysis for Various Quantitative Traits in Desi Chickpea Genotypes under Rainfed Conditions in Ethiopia

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Abstract

Chickpea is rich in protein and micronutrients and plays a significant role in human diet especially as accompaniment to staples, but grain yields in Ethiopia are still below the crop potential. Field experiments were conducted during 2007/8-2009/10 to determine relationships among yield and some yield components using correlation and path coefficient analysis in desi chickpea grown under rainfed conditions. Correlation studies revealed that seed yield was significantly and positively correlated with days to flowering, days to maturity, number of pods per plant, number of seeds per pod, stand count at harvest, plant height and biomass. The path coefficient analysis based on seed yield, as a dependent variable, revealed that biomass had the greatest direct effect on seed yield (0.0146) and followed by stand count at harvest and plant height. Both correlation and path analyses indicated that biomass, stand count at harvest and plant height were the major direct contributors to seed yield. Thus, the present study suggests that more biomass production, stand count at harvest and plant height are major yield factors in selecting high yielding desi chickpea cultivars.

Keywords: chickpea, correlation, path analysis, seed yield

1. Introduction

Ethiopia is the leading producer, consumer and exporter of chickpea in Africa and shares some 4.5% of global chickpea market and more than 60% of Africa's global chickpea market (FAOSTAT, 2015). The area under chickpea cultivation has increased by 55% from about 154,281 ha in 2003 to about 239,755 ha in 2014 while yields jumped from about 881 kg/ha to 1,913 kg/ha (117%) during the same period (CSA, 2015). Although this growth is impressive, chickpea productivity in Ethiopia is still below the potential 6 t/ha that was reported in Israel in 2012 (FAOSTAT, 2013). The reasons for this yield gap include limited availability and adoption of high yielding varieties with abiotic and biotic stress resistance, high response to inputs and other management practices and wide adaptability to different ecological zones. As such, it is of prime importance to analyze, evaluate and inform the crop improvement program of the factors contributing to growth and yield of chickpea.

Genetic variation and diversity among the plant traits is a pre-requisite in breeding and selecting desirable types with yield as an end product. Independent variables influence yield directly or indirectly and they are inter-related in a complex way (Singh et al., 1995). In biological systems most of the traits are associated with each other by simple or complex path and to investigate the actual path for yield potential is the task of breeders. Therefore, approaches to make significant genetic improvement in chickpea productivity need information on nature and magnitude of genetic variation in quantitative characters and their inter-relationship in population comprising diverse genotypes. Several researchers (Malik et al., 1983; Malik et al., 1988; Ghafoor et al., 1990; Ghafoor et al., 2000) have emphasized the utility of the estimates of heritability (h^2) and genetic advance in the prediction of response of quantitative characters to selection in chickpea.

Yield is a complex character and is determined by many component characters. The identification of important characters and their interrelationship would be useful for developing improved genotypes. Thus, effective improvement in yield may be brought about through selection based on yield component characters.

Information on correlation and path coefficient analysis is of much use to plant breeders for selection and breeding genotypes with increased yield potential. Correlation analysis for seed yield provides opportunity for selection and leads to a directional model based on yield and its components in field experiments (Khan & Qureshi, 2001). Path coefficient analysis is a technique of statistical analysis specially designed to quantify direct and indirect trait association with yield (Gull, 1995; Bakhsh et al., 1998; Saleem et al., 2002). When more characters are involved in correlation study it becomes difficult to ascertain the characters which significantly contribute to yield. The path coefficient analysis under such situations helps to determine the direct contribution of these characters and their indirect contributions *via* other characters (Singh et al., 1990).

Many of the studies on correlation and path analyses have been conducted in field crops. Correlation coefficients between yield and yield components and direct and indirect effects of various plant characters on yield and yield components have been reported by Saleem et al. (2002); Noor et al. (2003); Arshad et al. (2004); Atta et al. (2008); Yucel and Anlarsal (2010); Naveed et al. (2012); Padmavathi et al. (2013).

Singh et al. (1990) reported that seed yield had close association with harvest index and plant height and harvest index had high direct and positive effect on seed yield and selection for high harvest index would lead to high seed yield. Positive and significant correlations were found among seed yield and plant height, number of branch, number of pods per plant, harvest index and number of seeds per plant (Ciftci et al., 2004). There was strong direct effect of harvest index on the seed yield. Talebi et al. (2007) examined 36 genotypes and reported positive and significant relationships between 100 seed weight and plant height, seed yield and number of pod/ plant, number of seed/pod, and harvest index. Ghafoor at al. (1990) reported a positive and direct effect of harvest index on grain yield while pods per plant and seeds per pod contributed to grain yield indirectly through harvest index.

The objective of the present study was to investigate the association among various quantitative traits and their direct or indirect contribution to grain yield through the use of path coefficient analysis in desi chickpea. This information will be helpful to devise efficient selection criteria for the most desirable, high yielding varieties and lines of chickpea for production under rainfed conditions.

2. Materials and Methods

Twenty genotypes of *Desi* chickpea (Table 1) were grown in randomized complete block design with four replications during main cropping season 2007/08- 2009/10 at three Debre Zeit Agricultural Research Stations (Debre Zeit, Akaki and Chefe Donsa) of Ethiopia. Each plot consisted of single rows of 4 meter length with a spacing of 30 × 10 cm. Pesticides and fungicides were sprayed to save the crop from infestation of pests and Ascochyta blight. Data were recorded on days to flowering and maturity (50%), number of pods per plant, number of seeds per pods, stand count at harvest, plant height (cm), 100 seed weight (gm), biomass (Kg/ha), grain yield (Kg/ha) and harvest index. Days to 50% flowering, days to maturity, 100-seed weight, and harvest index were recorded on plot basis. Harvest index was determined as economic yield over total biomass. Genetic parameters, genetic correlation coefficients and path coefficients analysis were computed according to the methods followed by Singh and Chaudhry (1979).

2.1 Correlation Coefficient (r)

Genotypic correlation, the inherent association between two variables were estimated using the standard procedure followed by Singh and Chaudhry (1979). Covariance analysis between all pairs of the variables followed the same form as the variance. Thus, estimates of genetic covariance component between two traits (σg_{xy}) was derived in the same way as for the corresponding variance components:

$$r_{gxy} = \left[\frac{\sigma g_{xy}}{\sqrt{\sigma^2 g_x \times \sigma^2 g_y}} \right] \quad (1)$$

Where, σg_{xy} = genotypic covariance of two variables x and y, $\sigma^2 g_x$ = genotypic variance for variable x and $\sigma^2 g_y$ = genotypic variance for variable y.

2.2 Path Coefficient Analysis

Path coefficient analysis was carried out using the genotypic correlation coefficients to determine the direct and indirect effects of the yield components and other morphological characters on seed yield. Path coefficient analysis was also conducted to determine the direct and indirect effect of various traits on seed yield using the general formula of Dewey and Lu (1959). Path coefficient is determined as:

$$r_{ij} = P_{ij} + \Sigma r_{ik} p_{kj} \quad (2)$$

Where, r_{ij} = mutual association between the indpendent character (i) and dependent character (j) as measured by the correlation coefficients; P_{ij} = components of direct effects of the independent character (i) on the dependent variable (j) as measured by the path coefficients and $\Sigma r_{ik} p_{kj}$ = summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k). The recorded data were analyzed using R 2.15.2 statistical software.

Table 1. List of genotypes used

1.	ICCV-00202	8.	ICCV-97030	15.	ICCX-940002-F5-335P-1-1-1
2.	ICCV-00104	9.	ICCV-03103	16.	ICCX-940002-F5-242P-1-1-1
3.	ICCX-940002-F5-88P-1-1-1	10.	ICCV-03107	17.	ICCX-940002-F5-294P-1-1-1
4.	ICCX-940002-F5-6P-1-1-1	11.	ICCV-03203	18.	ICC-3195
5.	ICCV-95138	12.	ICCX-910144-4	19.	Akaki
6.	ICCV-00110	13.	ICCX-910121-5	20.	Natoli
7.	ICCV-04111	14.	ICCV-92219	21.	Local Check

3. Results and Discussions

3.1 Correlation Coefficient Analysis

The estimates of genotypic correlation coefficients between yield and yield attributes are given in Table 2. The table revealed that biomass, plant height, stand count at harvest, number of pods per plant, number of seeds per pod, days to maturity and days to flowering exhibited significant and positive correlation with seed yield at genotypic level. The degree of association was highest between biomass and seed yield (0.83), followed by plant height and seed yield. Hamdi et al. (2003) also reported that seed yield was positively and significantly correlated with pod numbers, harvest index and negatively with flowering duration. High positive correlation of number of pods per plant with seed yield may be attributed to the increased sink strength (Nakaseko, 1984). Diaz Carrasco et al. (1985) also suggested that yield could be raised by selecting for earliness, tallness and more pods per plant, which is evident in the present study. Amongst the yield-contributing characters, plant height showed positive and significant correlation with biomass, indicating that increased plant height is associated with more production of biomass. Number of pods per plant exhibited significant positive association with plant height. Days to 50% flowering revealed significant correlation with all the traits except harvest index at genotypic levels.

Table 2. Genotypic correlation coefficient among different characters

Characters	DF	DM	NPP	NSP	SCAH	PH	100 SW	Biomass	YLD	HI
DF	1.00									
DM	0.38**	1.00								
NPP	0.49**	0.31**	1.00							
NSP	0.15**	0.03 ^{NS}	0.20**	1.00						
SCAH	-0.21*	0.05**	-0.10*	0.03 ^{NS}	1.00					
PH	0.09**	0.21**	0.25**	0.07**	0.32**	1.00				
100 SW	-0.21*	-0.09*	-0.30*	-0.22*	-0.06*	-0.01^{NS}	1.00			
Biomass	0.23**	0.24**	0.33**	0.12**	0.44**	0.67**	0.00^{NS}	1.00		
YLD	0.07**	0.15**	0.28**	0.12**	0.51**	0.67**	-0.01^{NS}	0.83**	1.00	
HI	-0.03^{NS}	-0.08*	-0.06^{NS}	0.02^{NS}	-0.07^{NS}	-0.01^{NS}	-0.01^{NS}	-0.25**	0.04^{NS}	1.00

Note. ** = Significant at 5 % level; DF = Days to 50% flowering; DM = Days to maturity; NPP = Number of pods per plant; NSP = Number of seeds per pod; SCAH = Stand count at harvest; PH = Plant height; 100 SW = 100-seed weight; YLD = Seed yield and HI = Harvest index.

Similarly, number of seeds per pod showed significant correlation with all characters but positive and non-significant with stand count at harvest and harvest index. Hundred seed weight showed significant negative correlation with all traits except biomass, seed yield and harvest index. Likewise, days to 50% flowering revealed significant correlation with number of pods per plant. A positive significant association was noted between days taken to flowering and 100-seed weight. Significant and positive association has been reported between days to flowering and grain yield per plant (Yadav et al., 2001; Saleem et al., 2002; Noor et al., 2003).

Days to maturity showed positive significant correlation with days to 50% flowering and pods per plant as also reported by Arshad et al. (2004). A positive and significant association occurred between the days to maturity with most of the traits except number of seed per pod and 100-seed weight with which there was significant negative correlation. Grains per plant have been reported to be positively and significantly correlated with days to maturity (Raval & Dobariya 2003; Obaidullah et al., 2006; Atta et al., 2008). Plant height showed a positive correlation with seed yield, number of pods per plant and seeds per pod. Positive correlation of plant height with seed yield has also been reported by Kumar et al. (2004). Biomass had significant correlation with plant height at genotypic levels as similarly reported by Luthra and Sharma (1990). High significance of days to flowering, days to maturity, number of pods per plant, number of seeds per pod, stand count at harvest, plant height and biomass showed that any improvement of these traits may result in an increment of seed yield. The current findings agree with earlier studies on chickpea from which positive correlations of grain yield with pods per plant were reported (Saleem et al., 2002; Falak et al., 2003; Arshad et al., 2004; Atta et al., 2008; Diriba et al., 2014). The positive association between grain yield and yield attribute is also in accord with an earlier study on character association in chickpea by (Atta et al., 2008; Padmavathi et al., 2013; Arshad et al., 2004).

The potential for yield improvement through manipulation of yield attributes requires a proper understanding of the magnitude of correlations among various yield traits. Indirect selection is important when desirable characters have low heritability measure in one sex only. The efficiency of indirect selection is measured as a correlated response (Falconer, 1960). Knowledge of correlation is required when selection is to be made on several characters at a time through some simultaneous selection model (Singh, 1972). Even if, the objective is to make selection on a single trait, the knowledge of correlation is essential to avoid the undesirable correlated changes in other characters. In this study, magnitude of genotypic correlation was higher than their corresponding phenotypic correlation coefficients in most of the characters suggesting that a strong inherent association exists for the traits studied and phenotypic selection may be rewarding. Similar results were also reported by (Pathak et al., 1986). Higher magnitude of genotypic correlation helps in selection for genetically controlled characters and gives a better response for seed yield improvement than that would be expected on the basis of phenotypic association alone (Robinson et al., 1951).

3.2 Path Coefficient Analysis

The path coefficient analysis was carried out in this study to analyze the relative contribution of grain yield related factors. The genotypic correlation coefficients were partitioned into direct and indirect effects by various yield contributing characters are presented in Table 3. The direct effects exhibited by days taken to flowering, days to maturity and number of seeds per pod were negative, whereas all other characters gave positive direct effects. The highest direct effect of 0.0146 was exhibited by biomass and it was followed by number of pods per plant, stand count at harvest, plant height and 100-seed weight but the direct effect of these traits was low. Biomass, plant height, stand count at harvest and number of pods per plant showed significant positive association with grain yield, suggesting that these traits could be exploited for crop improvement. Naveed et al. (2012) reported a positive direct effect of biomass on seed yield. The positive direct effect of number of pods per plant on seed yield is also in agreement with previous reports (Jatasra et al., 1978; Padmavathi et al., 2013; Shanko et al., 2014).

Correlation and path coefficient analysis indicated that biomass, plant height, stand count at harvest and number of pods per plant were potent contributors to grain yield through direct effects. Although days to flowering, days to maturity and number of seeds per pod had significant association, these exhibited negative direct effects. In contrast, Singh et al. (1995) reported high direct effects of biological yield, pods per plant and 100-seed weight with supplemental irrigation as opposed to this study conducted under rainfed conditions that are subject to terminal drought challenges. Saleem et al. (1999) reported negative direct effect of days to maturity in agreement with the present study.

Table 3. Estimates of direct (bold diagonal) and indirect effect (off diagonal) of various characters to seed yield in chickpea genotypes

Characters	DF	DM	NPP	NSP	SCAH	PH	100 SW	Biomass	YLD	HI
DF	**-0.0036**	-0.0027	0.0048	-0.0001	-0.0007	0.0002	-0.0003	0.0033	0.0641	-0.0001
DM	-0.0013	**-0.0070**	0.0031	0.0000	0.0002	0.0005	-0.0001	0.0035	0.1515	-0.0003
NPP	-0.0017	-0.0022	**0.0099**	-0.0001	-0.0003	0.0006	-0.0004	0.0048	0.2798	-0.0003
NSP	-0.0005	-0.0002	0.0020	**-0.0005**	0.0001	0.0002	-0.0003	0.0018	0.1174	0.0001
SCAH	0.0007	-0.0004	-0.0009	0.0000	**0.0035**	0.0007	-0.0001	0.0064	0.5004	-0.0003
PH	-0.0003	-0.0015	0.0025	0.0000	0.0011	**0.0023**	0.0000	0.0097	0.6563	0.0000
100 SW	0.0008	0.0006	-0.0029	0.0001	-0.0002	0.0000	**0.0014**	0.0000	-0.0077	0.0000
Biomass	-0.0008	-0.0017	0.0032	0.0001	0.0015	0.0015	0.0000	**0.0146**	0.8127	-0.0010
YLD	-0.0002	-0.0011	0.0028	-0.0001	0.0018	0.0015	0.0000	0.0120	**0.9831**	0.0002
HI	0.0001	0.0006	-0.0006	0.0000	-0.0002	0.0000	0.0120	-0.0037	0.0378	0.0041

Note. Residual Effect = -0.00014; DF = Days to 50% flowering; DM = Days to maturity; NPP = Number of pods per plant; NSP = Number of seeds per pod; SCAH = Stand count at harvest; PH = Plant height; 100 SW = 100-seed weight; YLD = Seed yield and HI = Harvest index.

Days taken to flowering had negative direct effect and indirect effects via days to maturity, number of seed per pod, stand count at harvest and 100 seed weight whereas all other traits had positive indirect effects. These positive indirect effects via number of pod per plant, plant height and biomass cancelled the negative effects resulting from positive association between days to flowering and seed yield. Days to maturity had a negative direct effect but maximum positive indirect effects through number of pods per plant and biomass nullified the negative effect and produced a positive association between seed yield and days taken to maturity. Plant height was reported to have a positive direct effect with seed yield (Roshan et al., 1993; Saleem et al., 1999) in agreement with the results of the present study. The negative effect of plant height through days to flowering and maturity cannot be ignored while selecting for desirable genotypes. Number of seeds per pod had negative direct effect but number of pods per plant and biomass produced positive indirect effects through this trait. Shanko et al. (2014) reported a negative direct effect of number of seeds per pod which is in accordance with the present findings. Therefore, indirect selection through these traits might be helpful in yield improvement. Stand count at harvest had positive direct effect and indirect effects via biomass. The positive direct effects of biomass and indirect effects via plant height and stand count at harvest. Maximum indirect positive effect of biomass was observed through number of pods per plant and therefore biomass in turn had a positive and strong association with seed yield. Therefore, a good compromise between biomass and number of pods per plant is an important consideration for selection. The results are in line with the findings of Naveed et al. (2012) and Saleem et al. (2002). Hundred seed weight had positive direct effects but had negative indirect effects through number of pods per plant in agreement with the work of Naveed et al. (2013). Traits like number of pods per plant, stand count at harvest, plant height, 100 seed weight, biomass and harvest index which ultimately affects seed yield were the components that exerted a substantial direct effect on seed yield. Biomass, plant height and stand count at harvest contributed to seed yield mainly via their high and positive indirect effect with days to maturity.

4. Conclusion

Under rainfed conditions biomass, plant height, stand count at harvest and number of pods per plant had the highest contribution in determining seed yield. Besides, there was a high indirect contribution to seed yield via 100 seed weight by harvest index, hence these traits along with biomass, plant height, stand count at harvest and number of pods per plant are worth considering while selecting chickpea genotypes for high yield. Maximum positive effect of biomass on seed yield coupled with relatively strong and positive value of genotypic correlation suggested that direct selection for this trait would be effective for selecting for high yielding chickpea. Likewise, correlation and path coefficient studies also showed that plant height, stand count at harvest and number of pods per plant are also useful selection criteria for higher yielding chickpea genotypes.

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