International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 1102-1105

Received: 15-07-2018
Accepted: 16-08-2018

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Estimates of direct and indirect effects among yield, yield contributing and quality traits in *Kabuli* chickpea

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Abstract
Present study was conducted to investigate direct and indirect effects and selection criteria among the thirty genotypes of *kabuli* chickpea. The experiment was carried out in the Regional Agricultural Research Station, Nandyal, Andhra Pradesh during *rabi* at 2016-17. The genotypes were evaluated in a Randomized Block Design having three replications under rainfed and irrigated conditions. The most important characters accounting for cause and effect relationships on seed yield of *kabuli* chickpea were shoot biomass and harvest index under rainfed as well as irrigated conditions through their high direct effects as well as high indirect contributions *via* other traits *viz.*, days to 50 percent flowering, number of primary branches, number of pods per plant and number of seeds per plant under rainfed condition. While, days to 50 percent flowering, days to maturity, number of pods per plant and number of seeds per plant under irrigated condition. Therefore, selection for high shoot biomass and harvest index would leads to the high seed yield.

Keywords: Direct indirect effects, *Kabuli* chickpea, path analysis, seed yield

Introduction

Chana or chickpea is an ancient crop that marked its origination even before 10000 B.C and the regions of Turkey and the ancient city of Jericho domesticated this crop around 7500 B.C and since then, it started getting popular. It is highly nutritious grain legume and an abundant source of energy, protein, minerals, vitamins, fiber and phytochemicals (Geervani, 1991) [10]. Chickpea has many medicinal properties such as increasing the sperm count, curing menstrual and urinary problems and kidney stones in human beings. Further, it makes up the deficiency of cereal diets (Jeena and Arora, 2001) [12] and also plays an important role in sustaining soil fertility by fixing atmospheric nitrogen through symbiosis (Singh and Shiv, 2013) [21].

Seed yield is a polygenic and complex trait which is affected by a large number of other components. So, direct selection based on association pattern alone between two variables may sometimes mislead the breeder. Hence, it should split into direct and indirect effects for effective selection. Path coefficient analysis examine each and every component and provides information on cause of association between two traits. If the association between yield and other character is due to direct effect, it indicates true and perfect correlation between those two traits and selection would be effective for that character to improve seed yield.

Materials and Methods

A set of thirty *kabuli* chickpea genotypes were evaluated in a Randomized Block Design (RBD) with three replications under rainfed and irrigated conditions during *rabi*, 2016-17 at Regional Agricultural Research Station, Nandyal, Andhra Pradesh. Data collected for yield, yield attributing and quality traits *viz.*, plant height, days to 50 percent flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, SPAD chlorophyll meter reading (SCMR), number of pods per plant, number of seeds per plant, shoot biomass, harvest index, 100 seed weight, seed diameter, 100 grain volume, protein content and seed yield. Phenotypic and genotypic correlation coefficients were utilized for path coefficient analysis. The direct and indirect contribution of various traits were calculated through path coefficient analysis as suggested by Wright (1921) [27] and later elaborated by Dewey and Lu (1959) [8].

Results and Discussion

Path coefficient analysis for 15 yield and yield contributing traits in *kabuli* chickpea under rainfed and irrigated conditions were furnished in Table 1 and Table 2, respectively.

In present study, under rainfed condition, the results of path coefficient analysis among yield and its contributing traits revealed that seed yield had significant positive association with number of pods per plant, number of seeds per plant, shoot biomass, harvest index, number of primary branches per plant and days to 50 percent flowering. Path coefficient values of these traits revealed that only shoot biomass (0.6687, 0.8702), harvest index (0.6085, 0.6623) had positive direct effect on seed yield. However, number of pods per plant, number of seeds per plant, number of primary branches per plant and days to 50 percent flowering exhibited low and negligible positive direct effect on seed yield. But these traits exhibited their positive correlation through its high indirect effects *via* shoot biomass and harvest index. Number of seeds per plant (0.0870, 0.1494), number of primary branches per plant (0.0329, 0.0795) even though exhibited very low and positive direct effects, on seed yield, but they established highly significant and positive correlation with seed yield through their indirect effects *via* shoot biomass (0.2760, 0.4887) (0.0876, 0.1698) and harvest index (0.3822, 0.5083) (0.1614, 0.2148), respectively. Similar results reported by Singh *et al.* (2001) [22], Annapurna (2008) [4] and Vaghela *et al.* (2009) [26] for indirect effects of number of pods per plant *via* shoot biomass and harvest index and Kayan and Sait Adak (2012) [14] through harvest index, Naveed (2012) [15], Jeena and Arora (2002) [12] through shoot biomass.

Under irrigated condition, seed yield exhibited significant and positive phenotypic and genotypic correlation with shoot biomass, number of pods per plant, number of seeds per plant, harvest index, days to 50 percent flowering and days to maturity. But the direct effects of shoot biomass (0.8104, 0.7753) and harvest index (0.6720, 0.4821) on seed yield were higher in magnitude. While, other traits *viz*., number of pods per plant, number of seeds per plant and days to 50 percent flowering exhibited negligible and positive direct correlation towards yield. But these traits showed high positive indirect effects *via* shoot biomass and harvest index. Number of pods per plant exhibited its positive correlation through high indirect effects *via* shoot biomass (0.3517, 0.4141) and harvest index (0.2272, 0.3044). Similarly, number of seeds per plant exhibited its positive correlation through high indirect effects *via* shoot biomass (0.3792, 0.5815) and harvest index (0.0907, 0.2239), days to 50 percent flowering exhibited its positive correlation through its high indirect effects *via* shoot biomass (0.1868, 0.1965) and harvest index (0.0899, 0.1191).

The current investigation reports are in accordance to the earlier reports of Ciftci *et al*. (2004) [7], Arshad *et al*. (2004) [5], Renukadevi and Subbalakshmi (2006) [19], Thakur and Sirohi (2009) [25], Johnson *et al.* (2015) [13], Bala *et al.* (2015) [6] [who also reported high direct positive effects of biological yield and harvest index on seed yield. While, Ali *et al.* (2011) [3], Alene *et al.* (2016) [2], Tadesse *et al.* (2016) [24] reported high direct effects of biological yield on seed yield and Yucel *et al*. (2010) [28], Padmavathi *et al*. (2013) [17], reported high positive direct effect of harvest index with seed yield. Under both the conditions, days to 50 percent flowering, though exhibited significant and positive correlation with seed yield, its direct effect was negligible (rainfed: 0.0756, -0.3378, irrigated: 0.0081, 0.2314) and its indirect effects were higher in magnitude *via* shoot biomass (rainfed: 0.1033, 0.1635, irrigated: 0.1868, 0.1965) and harvest index (rainfed: 0.1472, 0.1648, irrigted:0.0899, 0.1191). Positive indirect effects of days to 50 percent flowering through these traits were reported by Renukadevi and Subbalakshmi (2006) [19] and Annapurna (2008) [4].

Under irrigated condition, direct effect of days to maturity was negligible and its indirect positive effect *via* harvest index (0.2063, 0.1670) was higher in magnitude. Positive indirect effect of days to maturity through harvest index was also reported by Raval and Dobariya (2003) [18], Dubey *et al.* (2007) [9] and Singh *et al*. (2014) [13]. Under rainfed condition, positive direct effect of primary branches per plant was negligible (0.0329, 0.0795) and its indirect positive effects *via* harvest index (0.1614, 0.2148) were higher in magnitude. Positive indirect effect of primary branches per plant through harvest index also reported by Ozdemir (1996) [16], Singh *et al.* (2001) [22], Raval and Dobariya (2003) [18] and Singh *et al*. (2014) [13].

Under both the conditions, number of pods per plant, though exhibited significant and positive correlation with seed yield, its direct effect was negligible (rainfed: 0.1373, -0.1911, irrigated: -0.0191, 0.0824) and its indirect effects were higher in magnitude *via* shoot biomass (rainfed: 0.3064, 0.4966, irrigated: 0.3517, 0.4141) and harvest index (rainfed: 0.4372, 0.5998, irrigated: 0.2272, 0.3044). Similarly, positive indirect effects of number of pods per plant through these traits were reported by Renukadevi and Subbalakshmi (2006) [19], Annapurna (2008) [4] and Vaghela *et al*. (2009) [26].

Under rainfed situation, negative direct effect of 100 seed weight was negligible but its indirect negative effect *via* harvest index (-0.4031, -0.4592) was higher in magnitude. The direct effects of seed diameter and 100 grain volume were negligible but their indirect effects *via* harvest index (-0.4002, -0.4986) (-0.4054, -0.4631) were negative and higher in magnitude. The results are in line with the earlier reports of Sandhu *et al.* (1991) [20], Singh *et al.* (2001) [22], Renukadevi and Subbalakshmi (2006) [19]. Under irrigated condition, direct effects of SCMR were negligible but its indirect effects *via* shoot biomass (-0.2096, -0.3354), harvest index (-0.2704, -0.4047) were negative and higher in magnitude. While, direct effect of seed diameter was negligible but its indirect effects *via* harvest index (-0.1659, -0.1865) and 100 seed weight (-0.3470, -0.8755) were higher in magnitude. Similar results of negative indirect effects of SCMR through shoot biomass were reported by Jagadish and Jayalakshmi (2015) [11].

In the present investigation, residual effects were lower in magnitude under both the conditions (irrigated-phenotypic: 0.0712, genotypic: 0.0946 and rainfed-phenotypic: 0.0804, genotypic: 0.1565). It indicated that characters included in this study were effective for improving the yield of *kabuli* chickpeas. It is very clear through path analysis that most important characters accounting for cause and effect relationships on seed yield of *kabuli* chickpea were shoot biomass and harvest index under rainfed as well as irrigated conditions. It is witnessed from their high direct effects as well as high indirect contributions *via* other traits *viz.*, days to 50 percent flowering, number of primary branches, number of pods per plant and number of seeds per plant under rainfed condition. While, days to 50 percent flowering, days to maturity, number of pods per plant and number of seeds per plant under irrigated condition. Therefore, selection for high shoot biomass and harvest index would leads to the high seed yield and selection for days to 50 percent flowering, number of primary branches, number of pods per plant and number of seeds per plant under rainfed and days to 50 percent flowering, days to maturity, number of pods per plant and number of seeds per plant under irrigated condition would also facilitate for high shoot biomass.

Table 1: Phenotypic and genotypic path coefficients, among 15 characters in 30 chickpea genotypes under rainfed condition

Character		DF	DM	PH	NPB	NSB	SCMR	NPP	NSP	SBP	HI	100 SW	SD	100 GV	PC	SY
DF	P_p	0.0756	0.0350	-0.0410	0.0254	0.0084	-0.0174	0.0335	0.0303	0.0117	0.0183	-0.0363	-0.0425	-0.0333	-0.0125	0.2999**
	P_g	-0.3378	-0.1652	0.2089	-0.1459	-0.0931	0.1219	-0.2018	-0.1816	-0.0635	-0.0841	0.1725	0.2120	0.1578	0.0682	0.3226
DM	P_p	0.0064	0.0138	-0.0040	0.0037	0.0037	-0.0049	0.0002	-0.0007	-0.0008	-0.0007	0.0002	-0.0022	0.0004	-0.0043	-0.0857
	P_g	-0.0068	-0.0138	0.0048	-0.0047	-0.0066	0.007	0.0006	0.0011	0.0009	0.0008	-0.0001	0.0028	-0.0004	0.0048	-0.0950
PH	P_p	-0.0173	-0.0092	0.0318	-0.0043	0.0017	0.0013	-0.0058	-0.0052	-0.0007	-0.0049	0.0110	0.0061	0.0119	0.0010	-0.1220
	P_g	0.1934	0.1075	-0.3129	0.0572	-0.0385	-0.0238	0.0736	0.0667	0.0057	0.0553	-0.1135	-0.0585	-0.1230	-0.0123	-0.1273
NPB	P_p	0.0111	0.0088	-0.0045	0.0329	0.0068	-0.009	0.0119	0.0122	0.0043	0.0087	-0.0046	-0.0089	-0.0045	-0.0086	0.3173**
	P_g	0.0343	0.0271	-0.0145	0.0795	0.0418	-0.0324	0.0488	0.0483	0.0155	0.0258	-0.0153	-0.0301	-0.0136	-0.0263	0.4080
NSB	P_p	-0.0056	-0.0134	-0.0027	-0.0103	-0.0500	-0.0152	-0.0060	-0.0073	-0.0149	0.0051	-0.0061	-0.0058	-0.0075	-0.0099	0.1781
	P_g	-0.0193	-0.0333	-0.0086	-0.0368	-0.0700	-0.0378	-0.0089	-0.0244	-0.0394	0.0110	-0.0151	-0.0203	-0.0175	-0.0228	0.3513
SCMR	P_p	-0.0118	-0.0181	0.0020	-0.014	0.0156	0.0511	-0.0090	-0.0045	-0.0022	-0.0095	0.0037	0.0108	0.0034	0.0204	-0.1242
	P_g	-0.0201	-0.0282	0.0042	-0.0227	0.0300	0.0556	-0.0136	-0.0056	-0.0031	-0.0136	0.0047	0.0136	0.0043	0.0272	-0.1632
NPP	P_p	0.0610	0.0018	-0.0252	0.0496	0.0166	-0.0242	0.1373	0.1190	0.0629	0.0987	-0.0996	-0.1010	-0.0996	-0.0289	0.8455**
	P_g	-0.1141	0.0078	0.0450	-0.1172	-0.0244	0.0466	-0.1911	-0.1855	-0.1091	-0.1731	0.1683	0.1876	0.1669	0.0385	1.0296
NSP	P_p	0.0350	-0.0047	-0.0141	0.0322	0.0127	-0.0077	0.0754	0.0870	0.0359	0.0547	-0.0614	-0.0531	-0.0609	-0.0150	0.7643**
	P_g	0.0803	-0.0116	-0.0318	0.0908	0.0521	-0.0151	0.1451	0.1494	0.0839	0.1147	-0.1328	-0.1202	-0.1295	-0.0259	0.9602
SBP	P_p	0.1033	-0.0389	-0.0143	0.0876	0.1994	-0.0287	0.3064	0.2760	0.6687	-0.0318	0.0090	-0.0020	0.0101	0.1362	0.7477**
	P_g	0.1635	-0.0568	-0.0158	0.1698	0.4891	-0.0484	0.4966	0.4887	0.8702	0.0036	0.0131	-0.0164	0.0132	0.1946	0.7589
HI	P_p	0.1472	-0.0323	-0.0942	0.1614	-0.0619	-0.1131	0.4372	0.3822	-0.0289	0.6085	-0.4031	-0.4002	-0.4054	-0.2613	0.6122**
	P_g	0.1648	-0.0402	-0.1170	0.2148	-0.1039	-0.1623	0.5998	0.5083	0.0028	0.6623	-0.4592	-0.4986	-0.4631	-0.3032	0.6404
100 SW	P_p	-0.1572	0.0048	0.1127	-0.0454	0.0402	0.0234	-0.2370	-0.2308	0.0044	-0.2166	0.3270	0.2748	0.3241	0.0752	-0.4128**
	P_g	1.5388	-0.0276	-1.0939	0.5805	-0.6485	-0.2554	2.6541	2.6793	-0.0455	2.0900	-3.0143	-2.7660	-3.0044	-0.7228	-0.4205
SD	P_p	-0.0367	-0.0106	0.0125	-0.0176	0.0076	0.0138	-0.048	-0.0398	-0.0002	-0.0429	0.0548	0.0652	0.0534	0.0294	-0.4163**
	P_g	0.1069	0.035	-0.0318	0.0645	-0.0493	-0.0415	0.1672	0.1370	0.0032	0.1282	-0.1563	-0.1703	-0.1523	-0.0912	-0.4741
100 GV	P_p	0.0977	-0.0062	-0.0826	0.0301	-0.0335	-0.0148	0.1606	0.1550	-0.0033	0.1476	-0.2195	-0.1815	-0.2215	-0.0567	-0.4158**
	P_g	-1.4709	0.088	1.2381	-0.5375	0.7879	0.2455	-2.7503	-2.7294	0.0477	-2.2021	3.1389	2.8156	3.1491	0.8395	-0.4251
PC	P_p	-0.0088	-0.0165	0.0016	-0.0139	0.0106	0.0212	-0.0112	-0.0091	0.0108	-0.0228	0.0122	0.0240	0.0136	0.0531	-0.0820
	P_g	0.0095	0.0164	-0.0019	0.0156	-0.0154	-0.0230	0.0095	0.0082	-0.0105	0.0216	-0.0113	-0.0252	-0.0126	-0.0471	-0.0788

*, ** Significant at $P\leq0.05$ and $P\leq0.01$, respectively; P_p: Phenotypic path coefficient, P_g: Genotypic path coefficient **;** Phenotypic residual effect=0.0804; Genotypic residual effect= 0.1565.

DF= Days to 50% flowering, DM=Days to maturity, PH=Plant height, NPB=Number of primary branches, NSB=Number of secondary branches, SCMR=SPAD Chlorophyll meter readings, NPP=Number of pods per plant, NSP= Number of seeds per plant SBP=Shoot biomass per plant, HI=Harvest Index, 100SW=100 seed weight, SD=Seed diameter, 100 GV=100 Grain volume, PC=Protein content, SY=Seed yield per plant

Table 2: Phenotypic and genotypic path coefficients, among 15 characters in 30 chickpea genotypes under irrigated condition

Character		DF	DM	PH	NPB	NSB	SCMR	NPP	NSP	SBP	HI	100 SW	SD	100 GV	PC	SY
DF	P_p	0.0081	0.0043	-0.0048	0.0023	0.0048	-0.0024	0.0056	0.0047	0.0019	0.0011	-0.0050	-0.0046	-0.0046	-0.0001	0.3229**
	P_g	0.2314	0.1379	-0.1662	0.0941	0.2589	0.1169	0.2012	0.2165	0.0586	0.0571	-0.1528	-0.1634	-0.1398	0.0019	0.3721
DM	P_p	-0.0084	-0.0159	0.0052	-0.0034	-0.0048	0.0039	-0.0043	-0.0041	0.0000	-0.0049	0.0033	0.0044	0.0030	-0.0025	0.2072*
	P_g	-0.0097	-0.0163	0.0064	-0.0040	-0.0094	-0.0064	-0.0061	-0.0073	-0.0001	-0.0056	0.0035	0.0047	0.0033	-0.0028	0.1976
PH	P_p	0.0174	0.0096	-0.0292	0.0033	0.0096	0.0007	0.0184	0.0193	0.0030	-0.0004	-0.0183	-0.0147	-0.0185	-0.0055	-0.1216
	P_g	-0.1248	-0.0682	0.1737	-0.0299	-0.1082	0.0281	-0.1424	-0.2082	-0.0224	0.0130	0.1228	0.1218	0.1234	0.0357	-0.1271
NPB	P_p	0.0007	0.0005	-0.0003	0.0023	0.0007	0.0000	0.0004	0.0002	-0.0001	0.0007	-0.0008	-0.0003	-0.0008	0.0002	0.1684
	P_g	-0.0127	-0.0077	0.0054	-0.0313	-0.0332	0.0120	-0.0115	-0.0075	0.0037	-0.0142	0.0149	0.0056	0.0143	-0.0029	0.1851
NSB	P_p	0.0017	0.0009	-0.0010	0.0009	0.0029	-0.0008	0.0008	0.0009	0.0001	0.0006	-0.0008	-0.0002	-0.0008	0.0000	0.1822
	P_g	0.0152	0.0079	-0.0085	0.0144	0.0136	0.0111	0.0075	0.0105	0.0000	0.0103	-0.0071	-0.0004	-0.0067	0.0010	0.3846
SCMR	P_p	-0.0035	-0.0028	-0.0003	-0.0001	-0.0031	0.0116	-0.0028	-0.0016	-0.0030	-0.0047	-0.0006	0.0027	-0.0010	-0.0025	-0.4616**
	P_g	-0.0464	-0.0363	-0.0148	0.0351	-0.0751	-0.0919	-0.0396	-0.0212	-0.0398	-0.0771	-0.0044	0.0254	-0.0103	-0.0323	0.7929
NPP	P_p	-0.0133	-0.0052	0.0120	-0.0036	-0.0049	0.0047	-0.0191	-0.0168	-0.0083	-0.0065	0.0130	0.0135	0.0127	0.0015	0.6114**
	P_g	0.0716	0.0308	-0.0675	0.0304	0.0456	0.0355	0.0824	0.0867	0.0440	0.0520	-0.0652	-0.0832	-0.0642	-0.0062	0.7965
NSP	P_p	0.0094	0.0042	-0.0107	0.0011	0.0048	-0.0022	0.0142	0.0162	0.0076	0.0022	-0.0091	-0.0095	-0.0092	-0.0026	0.5014**
	P_g	-0.0056	-0.0027	0.0072	-0.0015	-0.0046	-0.0014	-0.0063	-0.0060	-0.0045	-0.0028	0.0050	0.0066	0.0050	0.0014	0.8744
SBP	P_p	0.1868	0.0018	-0.0834	-0.0511	0.0224	-0.2096	0.3517	0.3792	0.8104	-0.0859	0.1014	-0.0296	0.1221	-0.1394	0.7534**
	P_g	0.1965	0.0035	-0.0998	-0.0921	0.0023	0.3354	0.4141	0.5815	0.7753	0.0612	0.1013	-0.0302	0.1232	-0.1456	0.8425
HI	P_p	0.0899	0.2063	0.0101	0.2045	0.1348	-0.2704	0.2272	0.0907	-0.0712	0.6720	-0.0832	-0.1659	-0.0882	0.0620	0.5654**
	P_g	0.1191	0.1670	0.0361	0.2181	0.3649	0.4047	0.3044	0.2239	0.0380	0.4821	-0.0769	-0.1865	-0.0849	0.0592	0.6024
100 SW	P_p	0.2977	0.1014	-0.3025	0.1741	0.1295	0.0234	0.3283	0.2710	-0.0605	0.0598	-0.4831	-0.3470	-0.4805	-0.0220	-0.0279
	P_g	-0.7142	-0.2331	0.7647	-0.5144	-0.5648	0.0522	-0.8568	-0.8987	0.1413	-0.1724	1.0817	0.8755	1.0801	0.0553	-0.0328
SD	P_p	-0.0147	-0.0071	0.0130	-0.0038	-0.0014	0.0060	-0.0183	-0.0152	-0.0009	-0.0064	0.0186	0.0259	0.0180	0.0070	-0.2314*
	P_g	0.0467	0.0189	-0.0463	0.0117	0.0020	0.0182	0.0667	0.0721	0.0026	0.0256	-0.0535	-0.0661	-0.0521	-0.0208	-0.2885
100 GV	P_p	-0.2495	-0.0833	0.2789	-0.1543	-0.1131	-0.0362	-0.2942	-0.2505	0.0665	-0.0579	0.4387	0.3066	0.4411	0.0228	-0.0090
	P_g	0.6053	0.2004	-0.7120	0.4567	0.4946	-0.1122	0.7809	0.8262	-0.1592	0.1766	-1.0007	-0.7898	-1.0022	-0.0555	-0.0124
PC	P_p	0.0005	-0.0074	-0.0087	-0.0037	0.0001	0.0099	0.0036	0.0075	0.0081	-0.0043	-0.0021	-0.0127	-0.0024	-0.0468	-0.1278
	P_g	-0.0002	-0.0045	-0.0054	-0.0025	-0.0020	-0.0093	0.0020	0.0062	0.0049	-0.0032	-0.0013	-0.0083	-0.0015	-0.0263	-0.1379

*, ** Significant at $P\leq0.05$ and $P\leq0.01$, respectively; P_p: Phenotypic path coefficient, P_g: Genotypic path coefficient; Phenotypic residual effect=0.0712; Genotypic residual effect= 0.0946.

DF= Days to 50% flowering, DM=Days to maturity, PH=Plant height, NPB=Number of primary branches, NSB=Number of secondary branches, SCMR=SPAD Chlorophyll meter readings, NPP=Number of pods per plant, NSP= Number of seeds per plant SBP=Shoot biomass per plant, HI=Harvest Index, 100SW=100 seed weight, SD=Seed diameter, 100 GV=100 Grain volume, PC=Protein content, SY=Seed yield per plant

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