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Full Length Research Article

Dissection of association of yield and related components into direct and indirect effects in chickpea (*Cicer arietinum* L.) genotypes

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Abstract

Chickpea is very important legume crop and rich source of proteins. This crop must be explored for variability and correlation to facilitate the breeders define the selection criteria for planning breeding program. Fifty diverse chickpea genotypes were evaluated for different yield components. Analysis of variance showed significant differences in genotypes for all the traits under study. Seed yield per plant had positive and significant correlation with plant height, days to flowering, number of primary and secondary branches, number of pods per plant, total biomass per plant and number of seeds per plant. The path-coefficient investigations showed that pods per plant had maximum direct contribution to seed yield followed by number of primary branches, number of seeds per pod and total biomass per plant. From present studies, therefore, it may be concluded that number of pods per plant exerted great influence directly and indirectly on seed yield. The characters like germination percentage, days to flowering, plant height, number of branches per plant, number of seeds per plant, total biomass per plant were most important for selecting high yielding genotypes.

Key words: chickpea, yield, yield contributing traits, association, path analysis.
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Introduction

Pakistan is an agriculture based country, hence agriculture is an important component in the economy of Pakistan because it provides food for human beings and feed for animals. It also provides raw material for industries. Among agricultural crops, pulses play an integral part due to their immense value, and most important among them is chickpea. As a member of family Leguminoseae, sub-family Papillinoidae and tribe Cicereae, chickpea has annual growth habit. It is the only cultivated species of the genus Cicer and ranked third among leading world pulses after dry bean *(Pharsalus vulgaris)* and pea (*Pisum sativum*). It is cultivated in about 33 countries of Europe, Central and West Asia, Australia, North and South America, North Africa and Ethiopia (Mushtaq *et al*., 2013). In Pakistan, chickpea is the most essential Rabi grain legume that is mainly cultivated in rain-fed areas of the country. About 88% of the total area under chickpea cultivation is covered by rain-fed region. It was cultivated on an area of 960 thousand hectares with the production of 484 thousand tones (GOP, 2014-15).

Chickpea is also called as poor man's meat because it is less expensive and rich source of protein. It contains protein 19.5%, carbohydrates 57-60%, fats 1.4%, moisture 4.9-15.59% and ash 4.8% (Ali and Ahsan, 2012). It is rich source of essential amino acids like lysine and tryptophan while cereals lack these amino acids. Its grains are used in salad, ground into flour and 'basen', cooked, roasted, spiced and eaten as a snack (Al- Rifaee *et al*., 2007). Generally, chickpea is divided into two main types i.e., Desi (small, dark seeded with rough coat and an average seed weight of 170-250 mg); and Kabuli (larger, light colored with smooth coat and average seed weight of 270-550 mg) (Siddique *et al*., 2002). Its ability to grow on marginal lands and low input demand especially in case of irrigation water makes it a good choice for the farming community of arid zones of the country (Vural and Karasu, 2007). It is also a very common member of crop rotations in cropping patterns of dry areas (Al-Rifaee *et al*., 2007). Being a leguminous crop, it has the ability to fix atmospheric nitrogen and improve soil fertility with low cost of production (Ali *et al*., 2008).

Regardless of its economic significance and dietary values, the production of chickpea in Pakistan is quite low as compared to other countries. Poor genetic constitution, excessive vegetative growth, less disease tolerance and lack of improved varieties are considered as the main reasons of low average yield (Saleem *et al*., 2005). It requires instant attention of breeders for development of high yielding varieties which should meet the demand of tremendously increasing population. Grain yield is of primary importance and the most complex trait because it is the product of interaction of environment and genetic makeup of the plant (Singh *et al*., 2014). It is governed by many other traits directly or indirectly as well. The purpose of yield improvement is more efficiently fulfilled on the basis of performance of yield and its components, and their direct and indirect effects on yield (Salgotra, 2016). Phenotypic and genotypic correlations are important to indicate the extent of association of different quantitative characters with economic yield (Atta *et al*., 2008). The purpose of the study was to assess the diversity on morphological basis, to explore the interrelationship of various yield attributes, and to identify the direct and indirect effects of different yield components on the yield.

Materials and Methods

The study was carried out in the research area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, during Rabi season 2013-14. The experimental material was comprised of 50 chickpea genotypes (Table 1).

Randomized complete block design was used for the experiment with three replications. Standard agronomic and cultural practices were applied to the experiment throughout the growing season. Row-to-row and plant-to-plant distances were kept 30 cm and 15 cm respectively. Except for days to 50% flowering and days to maturity, 10 guarded plants from each entry were tagged to record data on individual plant basis for the following parameters; germination percentage (%), plant height (cm), number of primary branches per plant, number of secondary branches per plant, total biomass per plant (g), number of pods per plant, number of seeds per pod, number of seeds per plant, harvest index, 100 seed weight (g) and seed yield per plant (g).

The data recorded for various economic traits were analyzed by standard analysis of variance and covariance as given by Steel *et al*. (1997). The individual comparisons of genotypic means were accomplished by using Duncan's new Multiple Range Test (DMR). The mean for each character was calculated. Variance was partitioned into phenotypic and genotypic components which were tested for significance. Phenotypic and genotypic correlation coefficients were calculated according to the formula given by Kwon and Torrie (1946). Path coefficient analysis was performed (Dewey and Lu, 1959) to assess the direct and indirect effects on yield using genotypic correlations where association of all the above traits were calculated by keeping one at a time as response variable and other contributing traits as causal variables. Path analysis was obtained by the simultaneous solution of the following equations.

1. $r_{ay} = P_{ay} + r_{ab}P_{by} + r_{ac}P_{cy} + r_{ad}P_{dy} + r_{ae}P_{ey} + r_{af}P_{fy} + r_{ag}P_{gy} + r_{ah}P_{hy} + r_{ai}P_{iy} + r_{aj}P_{jy} + r_{ak}P_{ky} + r_{al}P_{ly}$
2. $r_{by} = r_{ab}P_{ay} + P_{by} + r_{bc}P_{cy} + r_{bd}P_{dy} + r_{be}P_{ey} + r_{bf}P_{fy} + r_{bg}P_{gy} + r_{bh}P_{hy} + r_{bi}P_{iy} + r_{bj}P_{jy} + r_{bk}P_{ky} + r_{bl}P_{ly}$
3. $r_{cy} = r_{ac}P_{ay} + r_{bc}P_{by} + P_{cy} + r_{cd}P_{dy} + r_{ce}P_{ey} + r_{cf}P_{fy} + r_{cg}P_{gy} + r_{ch}P_{hy} + r_{ci}P_{iy} + r_{cj}P_{jy} + r_{ck}P_{ky} + r_{cl}P_{ly}$
4. $r_{dy} = r_{ad}P_{ay} + r_{bd}P_{by} + r_{cd}P_{cy} + P_{dy} + r_{de}P_{ey} + r_{df}P_{fy} + r_{dg}P_{gy} + r_{dh}P_{hy} + r_{di}P_{iy} + r_{dj}P_{jy} + r_{dk}P_{ky} + r_{dl}P_{ly}$
5. $r_{ey} = r_{ae}P_{ay} + r_{be}P_{by} + r_{ce}P_{cy} + r_{de}P_{dy} + P_{ey} + r_{ef}P_{fy} + r_{eg}P_{gy} + r_{eh}P_{hy} + r_{ei}P_{iy} + r_{ej}P_{jy} + r_{ek}P_{ky} + r_{el}P_{ly}$
6. $r_{fy} = r_{af}P_{ay} + r_{bf}P_{by} + r_{cf}P_{cy} + r_{df}P_{dy} + r_{ef}P_{ey} + P_{fy} + r_{fg}P_{gy} + r_{fh}P_{hy} + r_{fi}P_{iy} + r_{fj}P_{jy} + r_{fk}P_{ky} + r_{fl}P_{ly}$
7. $r_{gy} = r_{ag}P_{ay} + r_{bg}P_{by} + r_{cg}P_{cy} + r_{dg}P_{ey} + r_{eg}P_{ey} + r_{fg}P_{fy} + P_{gy} + r_{gh}P_{hy} + r_{gi}P_{iy} + r_{gj}P_{jy} + r_{gk}P_{ky} + r_{gl}P_{ly}$
8. $r_{hy} = r_{ah}P_{ay} + r_{bh}P_{by} + r_{ch}P_{cy} + r_{dh}P_{dy} + r_{eh}P_{ey} + r_{fh}P_{fy} + r_{gh}P_{gy} + P_{hy} + r_{hi}P_{iy} + r_{hj}P_{jy} + r_{hk}P_{ky} + r_{hl}P_{ly}$
9. $r_{iy} = r_{ai}P_{ay} + r_{bi}P_{by} + r_{ci}P_{cy} + r_{di}P_{dy} + r_{ei}P_{ey} + r_{fi}P_{ey} + r_{hi}P_{hy} + r_{gi}P_{gy} + P_{iy} + r_{ij}P_{jy} + r_{ik}P_{ky} + r_{il}P_{ly}$
10. $r_{jy} = r_{aj}P_{ay} + r_{bj}P_{by} + r_{cj}P_{cy} + r_{dj}P_{dy} + r_{ej}P_{ey} + r_{fj}P_{fy} + r_{gj}P_{gy} + r_{hj}P_{hy} + r_{ij}P_{jy} + P_{jy} + r_{jk}P_{ky} + r_{jl}P_{ly}$
11. $r_{ky} = r_{ak}P_{ay} + r_{bk}P_{by} + r_{ck}P_{cy} + r_{dk}P_{dy} + r_{ek}P_{ey} + r_{fk}P_{fy} + r_{gk}P_{gy} + r_{hk}P_{hy} + r_{ik}P_{iy} + r_{jk}P_{jy} + P_{ky} + r_{kl}P_{ly}$
12. $r_{ly} = r_{al}P_{ay} + r_{bl}P_{by} + r_{cl}P_{cy} + r_{dl}P_{dy} + r_{el}P_{ey} + r_{fl}P_{fy} + r_{gl}P_{gy} + r_{hl}P_{hy} + r_{il}P_{iy} + r_{jl}P_{jy} + r_{kl}P_{ky} + P_{ly}$

Whereas, ‘r’ was genetic correlation coefficient and ‘P_{ay}, P_{by}, P_{cy}, P_{dy}, Pe_{y}, P_{fy}, P_{gy}, P_{hy}, P_{iy} and P_{jy}’ were standardized partial regression coefficients.

Results and Discussion

Analysis of variance suggested highly significant differences among genotypes under study for all the studied traits (germination percentage, plant height, number of primary branches per plant, number of secondary branches per plant, total biomass per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, harvest index, 100 seed weight and seed yield per plant). Previously numerous researchers observed the significant genetic variability for yield and yield components of chickpea (Aslam *et al.*, 2013 & 2014; Maqbool *et al.*, 2015 *a & b*). Maximum seed yield per plant was shown by genotype 2090 (121.0 g); while minimum was observed by genotype 7008 (108.0 g). Mean squares and coefficients of variability for all the traits were estimated (Table 2 and 3). Low values of coefficient of variability indicate high reliability of the data collected. Results of current research were in accordance with Ali *et al.* (2010), Gul *et al*. (2013) and Ramanappa *et al*. (2013). Greater phenotypic coefficient of variability as compared to genotypic coefficient of variability in all the studied traits indicated the influence of environment and a favorable genotypic and environmental interaction as reported by Arshad *et al*. (2003), Sial *et al.* (2003) and Ramanappa *et al.* (2013).

Estimation of genotypic and phenotypic correlations provides a measure of extent of relationship, pleiotropy and linkage among different traits. The estimates of genotypic and phenotypic correlation refer to the association between two traits due to the genetic constitution, and association between the phenotypic appearances respectively. Significant genotypic correlation of grain yield was observed with days taken to 50% flowering, plant height, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per plant, total biomass per plant, harvest index and 100-seed weight. While phenotypic correlation was not significant with any of the traits. Genotypic and phenotypic correlations among yield and its components has been shown in Table-5. It can be seen that in most of the cases, genotypic correlation is higher than phenotypic correlation which indicates that there must be some environmental masking effects on the expression of such traits. This finding was supported by Padmavathi *et al*. (2013) and Ali *et al*. (2011). Highly significant value of correlation of seed yield with number of pods per plant indicate that this could be the prime selection criteria for selection of high yielding genotypes. Moreover, high value of genotypic correlation of seed yield with number of primary branches per plant show that there is some linkage of these traits in the genome. These results were in line with the findings of Shafique *et al*. (2016). Number of primary branches had further significant genotypic correlation with total biomass per plant and harvest index, while significant phenotypic correlation with number of seeds per plant. This indicates that a strong linkage may exist between number of primary branches per plant and seed yield per plant, and increase in number of primary branches may increase the yield. Results of current research were in accordance with Ali *et al.* (2009).

The direct effects of germination percentage, days to 50% flowering, plant height, days to maturity, number of primary branches, number of secondary branches, number of seeds per pod, number pods per plant, total biomass per plant, harvest index, number of seeds per plant and 100 seed weight was observed on seed yield per plant. These results were in support of the findings of Jadhav *et al*. (2014), and Yucel and Anlarsal (2010). Description regarding direct and indirect effects of components on seed yield is shown in Table 6. The direct effect of number of pods per plant on seed yield was maximum positive, showing that this must be the direct selection criteria for selection of high yielding genotypes from the gene pool. Indirect effect of number of pods per plant was highest through days to maturity followed by indirect effect of days to maturity through number of primary branches per plant. This indicates that these could be the indirect selection criteria for increasing the seed yield per plant. Results were similar to the findings of Ali *et al.* (2009) while in contradiction with the findings of Talebi and Rokhzadi (2013).

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Table-1: List of chickpea genotypes used in current research experiment

Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes	Sr. No.	Genotypes
1	Pb-2008	**11**	AUG-812	**21**	6001	**31**	1159	**41**	950131
2	7056	**12**	4064	**22**	5006	**32**	1028	**42**	6027
3	Bital-98	**13**	3008	**23**	3013	**33**	66101	**43**	6003
4	7021	**14**	6054	**24**	2000	**34**	7041	**44**	CH7
5	1013	**15**	3009	**25**	7046	**35**	4004	**45**	Noor2009
6	928	**16**	2090	**26**	2050	**36**	AUG-810	**46**	6002
7	7050	**17**	5028	**27**	1219	**37**	3020	**47**	2052
8	7001	**18**	7012	**28**	6013	**38**	5038	**48**	PCH-15
9	6011	**19**	PB-91	**29**	6002	**39**	3022	**49**	7008
10	5002	**20**	11099	**30**	7002	**40**	1605	**50**	PB2008

Table-2: Mean sum squares for yield and its different components

SOV	G%	D50%F	DM	PH	PBPP	SBPP	TBPP
Replication	44.673	0.0673	128.166	7.13	0.02205	4.7315	0.2932
Genotype	157.138**	29.2546**	171.874**	19.767**	7.09917**	15.8917**	26.8434**
Error	28.409	0.0363	161.271	7.7348	0.01130	4.5967	0.0825
SOV	**PPP**	**SPP**	**S per P**	**HI**	**100SW**	**SYPP**	
Replication	7.2649	0.30378	5.902	0.946	0.2925	1.3758	
Genotype	72.5017**	5.73681**	65.9363**	225.674**	10.9785**	5.967**	
Error	22.5271	2.34323	23.0310	0.265	0.1366	2.026	

Abbreviations: G% = Germination percentage, D50%F = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PBPP = Primary branches per plant, SBPP = Secondary branches per plant, TBPP = Total biomass per plant, PPP = Pods per plant, SPP = Seeds per pod, S per P = Seeds per plant, HI = Harvest index, 100SW = 100 Seed weight, SYPP = Seed yield per plant.

Table- 3: Coefficients of variability for yield and its components

	G%	D50%F	DM	PH	PBPP	SBPP	PPP
CV %	6.34	0.16	7.68	5.48	2.17	1.73	4.12
$\delta^2 g$	70.93	9.739	3.534	10.61	2.36	7.99	41.31
$\delta^2 p$	70.97	9.77	14.633	10.71	2.373	8.009	41.97
GCV	3.09	10.18	9.35	5.75	13.31	7.83	3.53
PCV	3.99	10.48	9.98	9.98	20.65	11.67	5.41
	SPP	**S per P**	**TBPP**	**HI**	**100SW**	**SYPP**	
CV %	1.25	3.76	1.81	1.37	3.93	4.82	
$\delta^2 g$	7.749	40.88	8.92	28.52	3.502	4.77	
$\delta^2 p$	7.74	40.95	9.00	88.26	3.54	4.8	
GCV	10.39	3.43	6.18	2.04	11.22	11.60	
PCV	18.22	5.55	11.16	3.60	11.57	18.50	

Abbreviations: G% = Germination percentage, D50%F = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PBPP = Primary branches per plant, SBPP = Secondary branches per plant, TBPP = Total biomass per plant, PPP = Pods per plant, SPP = Seeds per pod, S per P = Seeds per plant, HI = Harvest index, 100SW = 100 Seed weight, SYPP = Seed yield per plant

Table No. 5: Genotypic and phenotypic correlation of yield and its components of chickpea genotypes

	R	G%	D50%F	DOM	PH	PBPP	SBPP	PPP	SPP	S per p	TBPP	HI	100SW
G%	**G**												
	P												
D50%F	**G**	0.987**											
	P	0.481**											
DM	**G**	0.299	0.288										
	P	0.135	0.583**										
PH	**G**	0.384**	0.394**	0.496*									
	P	0.197	0.135	0.191									
PBPP	**G**	0.886**	0.383*	0.282*	0.195								
	P	0.091	0.135	0.0915	0.292*								
SBPP	**G**	0.448**	0.185	0.277*	0.251*	0.193							
	P	0.720**	0.135	0.747**	0.720**	0.575**							
PP	**G**	0.916**	0.925**	0.920**	0.900**	0.328*	0.351*						
	P	0.183	0.135	0.045	0.0137	0.0216	0.152						
SPP	**G**	0.552**	0.584**	0.586**	0.587**	0.446*	0.365*	0.333*					
	P	0.071	0.135	-0.182	0.405**	0.162	-0.207	0.151					
S per P	**G**	0.143	0.0241	0.0251	0.123	0.109	0.147	0.022	0.056				
	P	-0.144	0.135	0.329*	0.814**	0.773**	0.703**	0.0089	0.104				
TBPP	**G**	0.968**	0.964**	0.967**	0.971**	0.895**	0.834*	0.091	0.0121	0.954**			
	P	0.0018	0.135	0.190	0.127	0.372*	0.470**	0.803**	0.360*	0.0095			
HI	**G**	0.172	0.266*	0.366*	0.066	0.924**	0.891**	0.911**	0.477*	0.062	0.0601		
	P	0.085	0.135	-0.103	0.201	0.127	-0.117	-0.015	0.104	0.359*	0.324*		
100SW	**G**	0.231	0.0821	0.125	0.227	0.115	0.0826	0.047	0.092	0.298	0.300*	0.401*	
	P	0.180	0.135	0.0133	0.111	0.103	0.138	0.111	0.314*	0.801**	0.850**	0.819**	
SYPP	**G**	-0.233	0.323*	0.2073	0.432*	0.790**	0.290*	0.896**	-0.131	0.292*	0.565**	0.346**	0.267*
	P	0.135	0.135	0.2271	0.0298	0.103	0.124	0.0112	0.0311	0.137	0.115	0.106	0.0096

Abbreviations: G% = Germination percentage, D50%F = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PBPP = Primary branches per plant, SBPP = Secondary branches per plant, TBPP = Total biomass per plant, PPP = Pods per plant, SPP = Seeds per pod, S per P = Seeds per plant, HI = Harvest index, 100SW = 100 Seed weight, SYPP = Seed yield per plant

Table-6: Direct and indirect effects of yield and its components of chickpea genotypes

	G%	D50%F	DM	PH	PBPP	SBPP	PPP	SPP	S per P	TBPP	HI	100SW
	0.102	0.092	-0.119	0.129	0.194	0.101	0.493	0.179	0.102	0.133	0.094	0.016
G%		0.0003	0.081	0.0006	0.101	0.103	0.103	0.100	0.103	0.021	0.012	0.109
D50%F	0.001		0.133	0.103	0.007	-0.128	0.009	0.113	0.002	0.101	0.103	0.006
DM	0.039	0.102		0.013	0.013	0.002	0.543	-0.497	0.116	0.101	-0.193	0.013
PH	-0.324	0.001	-0.463		0.0009	0.025	0.107	-0.102	-0.202	0.024	0.100	0.101
PBPP	-0.482	0.007	0.533	0.027		0.100	0.101	0.014	0.019	0.100	0.007	-0.202
SBPP	0.094	0.098	-0.359	0.032	0.102		0.164	0.010	0.001	0.029	0.101	0.100
PPP	0.010	0.0001	0.002	-0.437	0.100	0.001		0.037	0.013	0.001	0.102	0.001
SPP	0.101	0.098	0.043	0.234	0.194	-0.104	0.083		0.101	0.141	0.007	0.003
S per p	0.102	-0.209	0.067	0.127	0.100	0.099	0.005	0.007		0.001	0.029	0.019
TBPP	0.110	0.324	0.237	0.109	-0.102	0.030	-0.778	0.001	0.007		0.002	0.098
HI	0.008	0.008	0.028	0.036	0.009	0.009	0.003	0.003	0.001	0.007		0.003
100SW	0.004	-0.209	0.026	0.057	0.070	0.052	0.033	0.004	0.031	-0.001	-0.017	
Total	-0.336	0.222	0.327	0.301	0.596	0.189	0.404	-0.311	0.190	0.525	0.132	0.252
Correlation	-0.234	0.324	0.207	0.432	0.790	0.290	0.897	-0.132	0.292	0.565	0.346	0.268

Abbreviations: G% = Germination percentage, D50%F = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PBPP = Primary branches per plant, SBPP = Secondary branches per plant, TBPP = Total biomass per plant, PPP = Pods per plant, SPP = Seeds per pod, S per P = Seeds per plant, HI = Harvest index, 100SW = 100 Seed weight, SYPP = Seed yield per plant

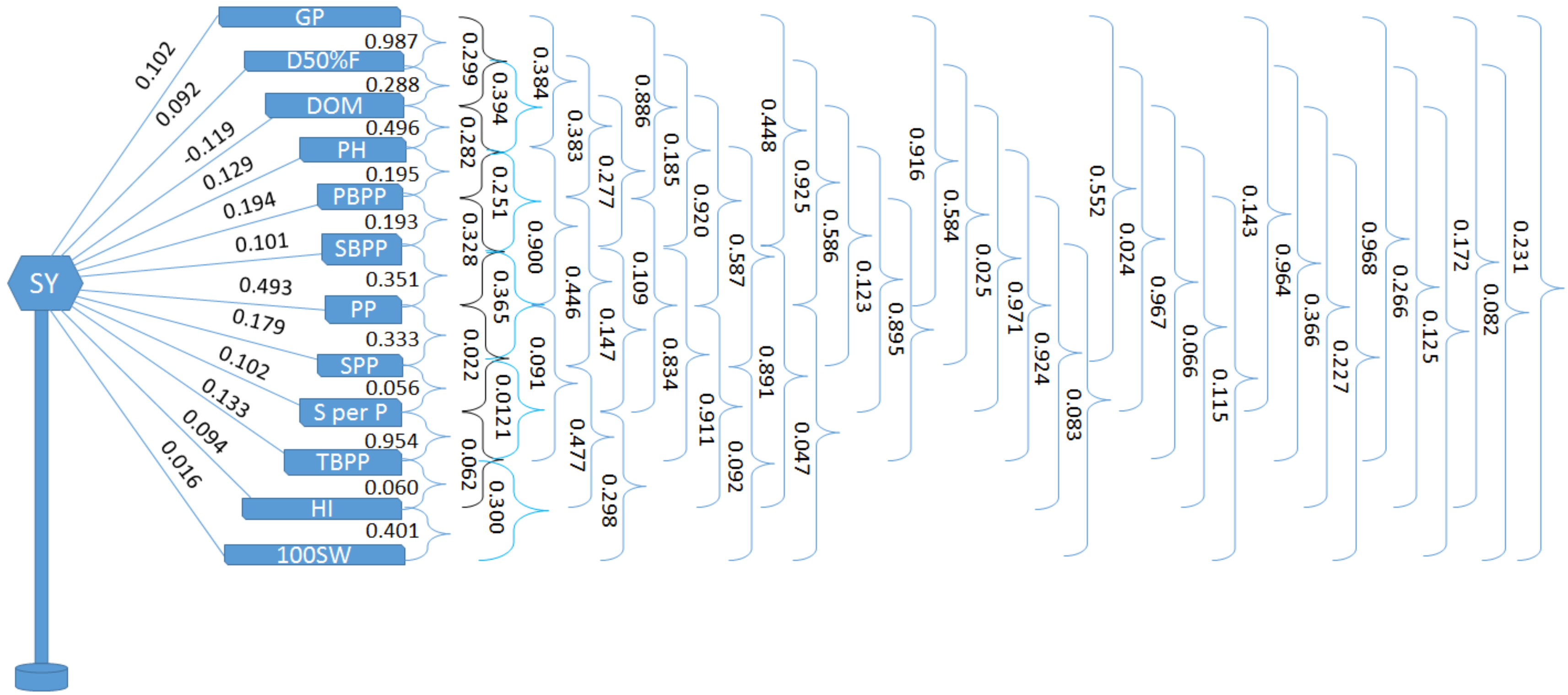

Figure-1: Path diagram of yield and its components showing direct and indirect effects
Abbreviations: G% = Germination percentage, D50%F = Days to 50% flowering, DM = Days to maturity, PH = Plant height, PBPP = Primary branches per plant, SBPP = Secondary branches per plant, TBPP = Total biomass per plant, PPP = Pods per plant, SPP = Seeds per pod, S per P = Seeds per plant, HI = Harvest index, 100SW = 100 Seed weight, SYPP = Seed yield per plant