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Genetic Variability for Pod Yield and Component Traits in Sugar Snaps (*Pisum sativum* var. *saccharatum*)

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ABSTRACT

Background: Edible podded pea is an oriental vegetable crop which shares the cultivation pattern with the garden pea. Fresh tender pods lacking parchment layer are consumed whole like beans. It is a newly introduced crop in India and therefore, it would be imperative to identify the most promising genotypes vis-à-vis traits of interest, those contributing towards maximization of yield. The present investigation was, therefore, planned to assess the genetic parameters of variability for pod yield and related horticultural traits in order to identify the most promising edible pod pea genotypes

Methods: Thirty six genotypes comprising of 29 F_7 advanced breeding lines and nine lines from different institutes including three checks namely, 'Arka Apoorva', 'Arka Sampoorna' and 'Mithi Phali' were evaluated in randomized complete block design over three replications during winters 2016-2017 at C.S.K. Himachal Pradesh Krishi Vishvavidyalaya, Palampur for pod yield and related horticultural traits.

Result: Sufficient genetic variability was observed for all morphological and yield contributing attributes. The magnitude of phenotypic (PCV) and genotypic (GCV) coefficients of variation were high for pod yield while branches per plant, internodal length, harvest duration and pods per plant showed high PCV and moderate GCV. High heritability along with high genetic advance was observed for internodal length, plant height, average pod weight and pod yield per plant indicating the importance of additive gene action. Pod yield per plant revealed positive correlation at both phenotypic and genotypic levels with pods per plant, average pod weight, pod length and pod breadth. Pods per plant and average pod weight at both phenotypic and genotypic levels had maximum positive direct and indirect effects to the total association of component traits suggesting the importance of these traits towards pod yield.

Key words: Correlation, Edible podded pea, Path, Pod yield, Variability.

INTRODUCTION

Edible podded pea comprises of sugar snaps or snap pea (*Pisum sativum* var. *saccharatum*) and snow pea (*Pisum sativum* var. *macrocarpon*), is an oriental vegetable crop that is grown during winter season. It shares the cultivation pattern with the garden pea. It is cultivated for its tender fresh pods lacking parchment layer (Sneddon, 1970) and relatively sweet, crispy and mildly flavoured. Therefore, these are eaten whole as plump pods and peas (seeds) without shelling although the tough strings along the edges are usually removed before eating. Snow pea has thinner walls of the two edible pod variants. Pods of sugar snaps are like a green bean with thick walls and very small peas while pods of snow pea are flat. The combinations of two or three recessive genes contribute to make the whole pod suitable for consumption in the fresh stage. For example, recessive gene 'p' mostly eliminates the schlerenchymatous membrane of inner pod wall while the gene 'v' reduces pod wall thickness and gene 'n' is responsible for thick and fleshy pod walls (McGee and Baggett, 1992; Myers *et al*. 2001). Sugar snaps can be grown in varied agro-climatic conditions but produce best yields and quality in cool and moist growing conditions.

High yield is the basic objective of all crop breeding programmes and it is essential to develop genotypes with potential to surpass commercially adopted/adapted cultivar(s) otherwise the genotype will be of no significance even if it has excellent performance for other traits (Sharma *et al*., 2020). In increasing the production of any crop, the initial and cheapest input is the continuous availability of high yielding and well adapted varieties through a strong breeding programme. Since, it is newly introduced crop and therefore, the most important task in edible pod pea breeding involves the identification of traits of interest, those contributing towards maximization of yield. Utilization of available genetic variability is the primary tool to initiate genetic improvement in a crop (Saravanan *et al*., 2019). It is, therefore, essential to study genetic diversity among genotypes. Knowledge about levels and patterns of genetic diversity can be an invaluable aid in crop breeding for diverse

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applications such as genetic variability in cultivars (Mohammadi and Prasanna, 2003), identification of diverse parental combinations to generate segregating progenies with diverse back ground (Barrett and Kidwell, 1998) and introgression of desirable genes from variable germplasm into the existing genetic base (Thompson and Nelson, 1998), indicating thereby that the success in crop improvement through selection ultimately depend upon the genetic variability (Sharma *et al*., 2020). The response of selection depends upon the relative proportion of the heritable component in the continuous variation with the help of genetic parameters namely, coefficient of variation, heritability and genetic advance.

Since yield is a complex trait, indirect selection through correlated, less complex and easier measurable traits would be an advisable strategy to increase the yield. Efficiency of indirect selection depends upon the magnitude of association between yield and target yield components (Esposito *et al*. 2009). Correlation coefficients, in general, show association among characters which is not sufficient to describe their relationship when the causal association among characters is needed (Toker and Cagirgan, 2004). The correlation *per se* does not give the complete picture of their interrelationships when more than two variables are involved (Fakorede and Opeke, 1985). Path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects which provides actual information on contribution of each character (Nguyen *et al*., 2020) and thus forms the real basis of selection for the yield improvement. Keeping these aspects in view, the present investigation was planned to assess the genetic parameters of variability for pod yield and related horticultural traits in order to identify the most promising traits of interest.

MATERIALS AND METHODS

The present investigation was carried out during winter season of 2016-17 at the Research Farm of the Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (1,290.8 m above mean sea level with 32°6′ N latitude and 76°3′ E longitude). The experimental material comprised of 36 genotypes of snap pea of which 29 are advanced breeding lines (F_7) along with nine varieties from different institutes (Table 1). The advance breeding lines were isolated from four interspecific crosses namely, 'Pb-89 × DPEPP-1', 'Pb-89 × DPEPP-2', 'Palam Priya × DPEPP-1', 'Palam Priya × DPEPP-2'. The lines 'DPEPP-1' and 'DPEPP-2' belong to edible pod pea while varieties 'Pb-89' and 'Palam Priya' belong to garden pea. The experiment was laid out in randomized complete block design with three replications. Each genotype was sown in two rows of 1.8 m length over the replications on November 07, 2016 with inter and intra-row spacing of 45 cm and 10 cm, respectively. The recommended rate of NPK fertilizers @ 50:60:60 kg of N, P_2O_5 and K_2O were applied in rows at the time of sowing through urea, single super phosphate and muriate of potash, respectively. Seed treatment with 'Bavistin' at the rate of 3 g kg^{-1} of seed was done. Irrigation was provided prior to sowing and later as per requirement. The weedicide 'Pendimethalin' @ 1.5 kg a.i. per hectare was applied immediately after sowing followed by two hand weeds to keep the field weed free.

Observations were recorded on randomly selected 10 plants of each genotype in each replication followed by computing their means for first flower node, days to flowering, days to first picking, number of branches/plant, internodal length (cm), nodes/plant, plant height (cm), pod length (cm), pod breadth (cm), seeds/pod, pods/plant, average pod weight (g), harvest duration (days), pod yield/plant (g), seed moisture content (%), total soluble solids (°Brix), ascorbic acid (mg/100 g of fresh weight basis), protein content (%)and total sugars (%).

The plot means were subjected to analysis of variance as per Gomez and Gomez (1983) for randomized block design. Different parameters of variability (Burton and De Vane, 1953; Johnson *et al*., 1955), coefficients of correlation (Al-Jibouri *et al*., 1958) and path coefficients (Dewey and Lu, 1959) were estimated by following standard procedures.

RESULTS AND DISCUSSION

The analysis of variance indicated significant differences among the genotypes for all the traits studied. The estimates of PCV were higher than corresponding GCV (Table 2) though differences were relatively low for all the traits studied. This indicated highly heritable and comparatively stable nature of the characters and thus, the selection based on phenotypic performance would be quite effective in the improvement of these traits (Sekhon *et al*., 2019). The magnitude of PCV and GCV was high for pod yield/plant (Table 2) ensuring ample scope for improvement through selection. Besides, number of primary branches/plant, internodal length, harvest duration and pods/plant also showed high PCV but moderate estimates of GCV. The differences in the magnitude of PCV and GCV indicated that environment had definitely played a role in their manifestations. Sharma *et al*. (2003); Sharma *et al*. (2009); Katoch *et al*. (2016) and Sekhon *et al*. (2019) have also reported high PCV and GCV for pod yield/plant in different studies involving different sets of genotypes in garden pea. In contrary, Sharma *et al*. (2007) and Saxesena *et al*. (2014) also noticed moderate PCV and GCV for pod yield/ plant which could be due to variation in genetic material and environmental conditions. The moderate estimates of PCV and GCV were recorded for plant height, pod breadth, average pod weight, ascorbic acid and total sugars. In addition, pod length, seeds/pod, total soluble solids (whole pod) and protein content was also revealed moderate estimates of PCV but magnitude of GCV was low suggesting cautious approach while following direct selection for these traits.

Table 1: Details of genotypes and their sources of seed.

Genotypes	Plant character	Source
EPP-10-1	Afilla, medium tall	Department of Vegetable Science and Floriculture, COA, CSK HPKV, Palampur
EPP-10-2	Afilla, medium tall	-do-
EPP-11-1	Afilla, medium tall	-do-
EPP-11-2	Afilla, medium tall	-do-
EPP-12-1	Afilla, medium tall	
EPP-12-2	Afilla, medium tall	-do-
EPP-13-1	Afilla, medium tall	-do-
EPP-13-2	Afilla, medium tall	-do-
EPP-14-1	Afilla, medium tall	-do-
EPP-14-2	Afilla, medium tall	-do-
EPP-15-1	Non-afilla, medium tall	-do-
EPP-15-2	Non-afilla, medium tall	-do-
EPP-15-3	Non-afilla, medium tall	-do-
EPP-P-2	Afilla, medium tall	-do-
EPP-P-2-1	Afilla, medium tall	-do-
EPP-P-2-2	Afilla, medium tall	-do-
EPP-P-3	Afilla, medium tall	-do-
EPP-P-3-1	Afilla, medium tall	-do-
EPP-P-4-1	Afilla, medium tall	-do-
EPP-P-4-2	Afilla, medium tall	-do-
EPP-P-4-3	Afilla, medium tall	-do-
EPP-P-5	Afilla, medium tall	-do-
EPP-P-7-1	Non-afilla, medium tall	-do-
EPP-P-7-2-1	Non-afilla, medium tall	-do-
EPP-P-8-1	Non-afilla, medium tall	-do-
EPP-P-9	Non-afilla, medium tall	-do-
EPP-P-9-1	Non-afilla, medium tall	-do-
DPEPP-1	Non-afilla, medium tall	-do-
DPEPP-2	Afilla, medium tall	-do-
Sugar Snap	Non-afilla, tall	Indian Institute of Vegetable Research, Varanasi
VRPO-1	Non-afilla, tall	-do-
VRPO-2	Non-afilla, medium tall	-do-
VRPO-3	Non-afilla, tall	-do-
Arka Sampoorna	Non-afilla, semi tall	Indian Institute of Horticultural Research, Hesaraghatta (Bengaluru)
Arka Apoorva	Non-afilla, semi tall	-do-
Mithi Phali	Non-afilla, medium tall	Punjab Agricultural University, Ludhiana (Punjab)

The magnitude of heritability indicates the reliability with which a genotype can be recognized by its phenotypic expression. However, high heritability alone is not enough to make sufficient improvement through selection generally in advance generations unless accompanied by substantial amount of genetic advance (Sharma and Kalia, 2002). Hence, high genetic advance coupled with high heritability offers the most effective selection criteria for selection (Karimizadeh *et al*., 2011) and was observed for internodal length, plant height, average pod weight and pod yield per plant. The inheritance of these characters indicated the importance of additive gene action and possibility of selection in the early generations (Katoch *et al*., 2016). High heritability along with moderate genetic advance was observed for days to flowering, pod length, pod breadth, pods per plant and total sugars which indicated the preponderance of additive and non-additive gene effects for their inheritance (Saxesena *et al*., 2014), suggesting that improvement in these traits can be achieved by following hybridization and selections in the later generations.

Yield is a complex polygenic trait that results from multiple interactions between component traits. Selection for yield may not be effective unless other yield components influencing it directly or indirectly are taken into consideration. The correlation studies helps in simultaneous selection of traits of interest influencing yield (Semahegn and Tesfaye, 2016). Therefore, identification of key traits is important which contribute effectively for enhancing yield (Jain *et al*., 2015) and defining an ideal plant type. In general, the genotypic correlation coefficients were higher in

Table 2: Estimates of parameters of variability for different characters in edible podded pea.

Traits	Range	Population Mean (mean ± S.E.)	PCV (%)	GCV (%)	h^2_{bs} (%)	ECV (%)	GA (%)
First flower node	16.20-11.53	13.00±0.85	10.07	6.15	37.35	7.97	7.74
Days to flowering	112.66-90.33	100.25±2.71	6.55	5.65	74.49	3.30	10.05
Days to first picking	139.00-126.00	133.50±2.76	3.19	1.95	37.21	2.53	2.45
Number of branches per plant	2.60-1.13	1.71±0.22	23.09	16.61	51.74	16.04	24.61
Internodal length (cm)	10.06-4.65	6.51±0.39	21.28	19.94	87.81	7.43	38.50
Nodes per plant	22.47-16.53	20.10±1.17	9.09	5.65	38.65	7.12	7.24
Plant height (cm)	135.53-60.27	82.95±3.90	18.45	17.54	90.40	5.71	34.36
Pod length (cm)	11.28-6.27	9.23±0.45	10.67	8.89	69.39	5.90	15.26
Pod breadth (cm)	2.19-1.40	1.87±0.09	11.77	10.05	72.96	6.12	17.69
Seeds per pod	7.37-4.60	6.06±0.39	11.99	9.03	56.76	7.88	14.02
Pods per plant	23.83-8.58	17.02±1.74	20.91	16.77	64.35	12.48	27.72
Average pod weight (g)	6.07-2.72	4.55±0.21	16.88	15.86	88.32	5.76	30.71
Harvest duration (days)	26.67-13.00	18.01±2.16	21.55	15.78	53.66	14.66	23.82
Pod yield per plant (g)	115.83-44.00	77.00±5.08	23.83	22.42	88.51	8.07	43.46
Moisture content (%)	85.36-63.32	77.68±1.77	5.29	4.50	72.27	2.79	7.88
Total soluble solids seed (°Brix)	16.93-13.13	14.95±0.86	8.30	4.35	27.51	7.07	4.70
Total soluble solids whole pod (°Brix)	11.80-9.00	10.38±0.86	11.23	4.91	19.14	10.10	4.42
Ascorbic acid (mg/100 g)	31.62-17.36	24.61±2.93	18.60	11.58	38.74	14.56	14.84
Protein content (%)	28.23-20.13	23.83±1.77	11.12	6.39	33.09	9.09	7.58
Total sugars (%)	4.27-9.87	6.91±0.37	16.15	14.76	83.49	6.56	27.79

PCV, GCV and ECV represent phenotypic, genotypic and environmental coefficients of variations, respectively; h^2_{bs}: Heritability in broad sense; GA (%): Genetic advance (%) of mean.

magnitude than the corresponding phenotypic ones (Table 3) which revealed that though there is a strong inherent association between various characters, the phenotypic expression of the correlation gets reduced under the influence of environment. The effective yield improvement would be achieved through the characters which have significant and positive/desirable correlation with each other. Genotypic correlation provides measures of genetic association between characters and is more reliable than phenotypic correlation and thus, helps to identify the characters to be utilized while doing selection in breeding programmes.

Pod yield per plant had shown a positive and significant correlation at both phenotypic and genotypic levels with pod length, pod breadth, pods per plant, average pod weight and total sugars. Precedent studies of many research workers have also indicated significant and positive association of these traits with yield per plant (Sharma and Kalia, 1998; Sharma *et al*., 2007; Sharma *et al*., 2009; Katoch *et al*., 2016). Inter-relationship among different growth parameters revealed that first flower node, days to flowering, days to first picking, and nodes per plant had significant and positive association among themselves. Among the pod characters positive association of pod length was recorded with pod breadth, seeds per pod and average pod weight along with negative correlation with total soluble solids (whole pod) at both genotypic and phenotypic levels. Srivastava and Singh (1989) have also reported positive association of pod length with seeds per pod while Kalloo *et al*. (2005) observed the same with average pod weight. Seeds per pod also showed positive association with average pod weight at both the levels along with moisture content and total soluble solids (whole pod) at genotypic level only. On the other hand, pods per plant indicated negative association with total soluble solids (seed) at both the levels along with protein content at genotypic level only. Besides, a positive association between pods per plant and total sugars at genotypic level was also observed.

Correlation coefficients alone are insufficient to recognize cause and effect relationships among traits associated with yield. Path coefficient analysis permits a better understanding of associations between different characters by dividing the magnitude of association with the dependent character into direct and indirect effects (Ukaoma *et al*., 2013) thus, helps in formulating an effective selection programme. Pods per plant and average pod weight at both genotypic and phenotypic levels revealed maximum positive direct effects on fresh pod yield per plant suggesting the importance of these traits towards fresh pod yield (Table 4). Besides, days to flowering followed by nodes per plant, pod length, total soluble solids (pod) and total sugars had also substantial positive contribution as direct effects towards pod yield at genotypic level. A critical examine of path coefficients revealed that pods per plant and average pod weight, in general, contributed maximum *via* their indirect effect to the total association of majority of traits with pod yield.

Table 3: Phenotypic (P) and genotypic (G) coefficient of correlation among different horticultural traits in edible podded pea.

Traits		Days To flowering	Days to first picking	Number of branches per plant	Inter-nodal length (cm)	Nodes per plant	Plant height (cm)	Pod length (cm)	Pod breadth (cm)	Seeds per pod	Pods per plant	Average pod weight (g)	Harvest duration (days)	Moisture content (%)	Total soluble solids seed (°Brix)	Total soluble solids whole pod (°Brix)	Ascorbic acid (mg/100g)	Protein content (%)	Total Sugar (%)	Pod yield per plant (g)
First flower node	P	0.297*	0.219*	0.162	-0.030	0.247*	0.090	-0.084	0.080	0.063	0.136	-0.222*	-0.175	0.022	-0.111	-0.044	0.037	-0.111	-0.005	-0.027
	G	0.562*	0.408*	0.078	-0.060	0.711*	0.166	-0.149	0.029	0.271*	0.325*	-0.424*	-0.258*	-0.001	-0.320*	-0.340*	-0.280*	-0.129	0.007	-0.033
Days to flowering	P		0.584*	0.039	-0.153	0.255*	-0.121	0.152	0.343*	0.060	0.145	-0.155	-0.283*	0.310*	-0.109	-0.177	0.080	0.015	0.044	0.028
	G		0.802*	0.092	-0.253*	0.348*	-0.174	0.108	0.410*	-0.018	0.219*	-0.246*	-0.337*	0.407*	-0.060	-0.454*	0.154	0.094	0.081	-0.018
Days to first	P			-0.080	-0.111	0.224*	-0.065	0.368*	0.440*	0.154	0.297*	0.045	-0.549*	0.161	-0.303*	-0.328*	0.042	0.107	0.175	0.252*
Picking	G			-0.175	-0.273*	0.249*	-0.215*	0.421*	0.460*	0.132	0.146	0.018	-0.573*	0.289*	-0.332*	-0.727*	0.230*	-0.013	0.396*	0.146
Number of branches	P				-0.125	-0.010	-0.180	-0.057	0.270*	-0.220*	-0.041	0.028	0.212*	-0.164	0.042	0.015	0.079	-0.150	0.015	0.012
per plant	G				-0.234*	0.178	-0.234*	0.011	0.395*	-0.107	0.063	0.038	0.422*	-0.218*	-0.034	-0.424*	0.113	-0.261*	0.069	0.076
Internodal length	P					0.177	0.795*	-0.246*	-0.219*	-0.098	0.197*	-0.045	-0.028	0.164	-0.265*	0.073	-0.059	0.146	0.219*	0.144
(cm)	G					0.344*	0.898*	-0.340*	-0.329*	-0.134	0.278*	-0.093	0.026	0.188	-0.456*	0.145	-0.117	0.277*	0.293*	0.158
Nodes per plant	P						0.504*	-0.131	0.119	0.000	0.486*	-0.301*	-0.221*	0.208*	-0.130	-0.048	0.047	-0.027	0.088	0.178
	G						0.601*	-0.466*	0.316*	-0.195*	0.571*	-0.487*	-0.353*	0.297*	-0.319*	0.172	0.400*	-0.234*	0.242*	0.088
Plant height (cm)	P							-0.252*	-0.212*	-0.017	0.339*	-0.192*	-0.093	0.228*	-0.197*	0.086	-0.042	0.140	0.122	0.134
	G							-0.376*	-0.265*	-0.064	0.353*	-0.235*	-0.080	0.247*	-0.335*	0.234*	-0.100	0.201*	0.162	0.094
Pod length (cm)	P								0.338*	0.515*	0.017	0.636*	-0.038	0.090	0.023	-0.191*	-0.021	0.068	0.042	0.478*
	G								0.288*	0.557*	-0.104	0.748*	0.004	0.122	-0.075	-0.697*	-0.004	0.085	0.103	0.484*
Pod breadth (cm)	P									-0.008	0.044	0.359*	-0.155	0.226*	-0.121	-0.157	0.240*	0.064	0.066	0.310*
	G									-0.098	0.028	0.387*	-0.025	0.326*	-0.367*	-0.591*	0.306*	0.097	0.127	0.320*
Seeds per pod	P										-0.046	0.239*	-0.211*	0.117	0.075	0.062	-0.132	0.114	-0.035	0.136
	G										-0.221*	0.313*	-0.195*	0.218*	0.132	0.273*	-0.115	-0.016	-0.123	0.104
Pods per plant	P											-0.182	-0.135	0.073	-0.192*	-0.078	0.088	-0.010	0.176	0.632*
	G											-0.176	-0.060	0.058	-0.267*	-0.018	0.127	-0.279*	0.295*	0.655*
Average pod	P												0.103	0.072	0.024	-0.081	0.027	0.091	0.096	0.589*
weight (g)	G												0.189	0.081	-0.027	-0.345*	-0.042	0.192*	0.132	0.641*
Harvest duration	P													-0.226*	0.294*	0.079	-0.068	-0.095	-0.121	0.013
(days)	G													-0.316*	0.288*	0.255*	-0.141	-0.020	-0.149	0.118
Moisture content	P														0.025	0.134	0.137	0.089	0.070	0.106
(%)	G														0.073	0.207*	0.139	0.270*	0.122	0.123
Total soluble	P															0.567*	-0.021	-0.184	-0.118	-0.152
solids seed (°Brix)	G															0.456*	-0.090	-0.158	-0.358*	-0.218*
Total soluble solids	P																0.053	-0.188	-0.127	-0.137
whole pod (°Brix)	G																-0.264*	-0.229*	-0.379*	-0.241*
Ascorbic acid	P																	-0.043	-0.089	0.053
(mg/100g)	G																	0.092	-0.086	0.077
Protein content (%)	P																		0.117	0.009
	G																		0.213*	-0.06
Total sugar (%)	P																			0.249*
	G																			0.317*

*Significant at P≤0.05.

Table 4: Estimates of direct and indirect effects of different traits on pod yield per plant at phenotypic (P) and genotypic (G) levels in edible podded pea.

Traits		First flowering node	Days to flowering	Days to first picking	Number of branches per plant	Inter-nodal length (cm)	Nodes per Plant	Plant height (cm)	Pod length (cm)	Pod Breadth (cm)	Seeds per pod	Pods per plant	Average pod weight (g)	Harvest duration (days)	Moisture content (%)	Total soluble solids seed (°Brix)	Total soluble solids whole pod (°Brix)	Ascorbic acid (mg/100g)	Protein content (%)	Total sugars (%)	r
First flower node	P	**0.021**	0.014	-0.008	-0.001	-0.001	0.007	-0.001	-0.001	0.003	0.001	0.101	-0.159	-0.011	0.000	0.004	0.000	-0.001	0.007	0.000	-0.027
	G	**0.047**	0.179	-0.118	-0.008	0.006	0.124	-0.005	-0.018	-0.005	-0.021	0.205	-0.408	-0.013	0.000	0.054	-0.039	-0.024	0.008	0.001	-0.033
Days to flowering	P	0.006	**0.046**	-0.020	0.000	-0.006	0.007	0.002	0.001	0.011	0.001	0.107	-0.111	-0.017	-0.002	0.004	0.001	-0.003	-0.001	0.002	0.028
	G	0.027	**0.319**	-0.231	-0.009	0.026	0.061	0.006	0.013	-0.077	0.001	0.138	-0.237	0.017	-0.010	0.010	-0.052	0.013	-0.006	0.009	-0.018
Days to first	P	0.005	0.027	**-0.035**	0.001	-0.005	0.006	0.001	0.003	0.014	0.003	0.220	0.033	-0.033	-0.001	0.011	0.001	-0.001	-0.007	0.009	0.252*
Picking	G	0.019	0.256	**-0.288**	0.017	0.028	0.043	0.007	0.050	-0.087	-0.010	0.092	0.017	0.029	-0.007	0.056	-0.083	0.019	0.001	0.043	0.146
Number of branches	P	0.003	0.002	0.003	**-0.007**	-0.005	0.000	0.002	-0.001	0.009	-0.004	-0.030	0.020	0.013	0.001	-0.002	0.000	-0.003	0.009	0.001	0.012
per plant	G	0.004	0.029	0.051	**-0.099**	0.024	0.031	0.008	0.001	-0.074	0.008	0.040	0.037	-0.022	0.005	0.006	-0.048	0.010	0.017	0.007	0.076
Internodal length	P	-0.001	-0.007	0.004	0.001	**0.041**	0.005	-0.011	-0.002	-0.007	-0.002	0.146	-0.033	-0.002	-0.001	0.010	0.000	0.002	-0.009	0.011	0.144
(cm)	G	-0.003	-0.081	0.079	0.023	**-0.102**	0.060	-0.030	-0.041	0.062	0.010	0.175	-0.090	0.001	-0.004	0.077	0.017	-0.010	-0.018	0.032	0.158
Nodes per plant	P	0.005	0.012	-0.008	0.000	0.007	**0.028**	-0.007	-0.001	0.004	0.000	0.360	-0.216	-0.013	-0.002	0.005	0.000	-0.002	0.002	0.004	0.178
	G	0.034	0.111	-0.072	-0.018	-0.035	**0.174**	-0.020	-0.056	-0.060	0.015	0.360	-0.469	-0.018	-0.007	0.054	0.020	0.034	0.015	0.026	0.088
Plant height (cm)	P	0.002	-0.006	0.002	0.001	0.032	0.014	**-0.014**	-0.002	-0.007	0.000	0.251	-0.138	-0.006	-0.002	0.007	0.000	0.001	-0.009	0.006	0.134
	G	0.008	-0.055	0.062	0.023	-0.092	0.105	**-0.033**	-0.045	0.050	0.005	0.222	-0.226	-0.004	-0.006	0.057	0.027	-0.008	-0.013	0.017	0.094
Pod length (cm)	P	-0.002	0.007	-0.013	0.000	-0.010	-0.004	0.003	**0.009**	0.011	0.010	0.013	0.458	-0.002	-0.001	-0.001	0.001	0.001	-0.004	0.002	0.478*
	G	-0.007	0.034	-0.122	-0.001	0.035	-0.081	0.012	**0.120**	-0.054	-0.042	-0.065	0.720	0.000	-0.003	0.013	-0.080	0.000	-0.005	0.011	0.484*
Pod breadth (cm)	P	0.002	0.016	-0.015	-0.002	-0.009	0.003	0.003	0.003	**0.033**	0.000	0.033	0.258	-0.009	-0.002	0.005	0.001	-0.008	-0.004	0.003	0.310*
	G	0.001	0.131	-0.133	-0.039	0.034	0.055	0.009	0.035	**-0.188**	0.007	0.017	0.372	-0.001	-0.008	0.062	-0.067	0.026	-0.006	0.014	0.320*
Seeds per pod	P	0.001	0.003	-0.005	0.002	-0.004	0.000	0.000	0.005	0.000	**0.019**	-0.034	0.172	-0.013	-0.001	-0.003	0.000	0.004	-0.007	-0.002	0.136
	G	0.013	-0.006	-0.038	0.011	0.014	-0.034	0.002	0.067	0.018	**-0.076**	-0.139	0.301	-0.010	-0.005	-0.022	0.031	-0.010	0.001	-0.013	0.104
Pods per plant	P	0.003	0.007	-0.010	0.000	0.008	0.014	-0.005	0.000	0.001	-0.001	**0.740**	-0.131	-0.008	-0.001	0.007	0.000	-0.003	0.001	0.009	0.632*
	G	0.015	0.070	-0.042	-0.006	-0.028	0.100	-0.012	-0.012	-0.005	0.017	**0.630**	-0.170	-0.003	-0.001	0.045	-0.002	0.011	0.018	0.032	0.655*
Average pod	P	-0.005	-0.007	-0.002	0.000	-0.002	-0.008	0.003	0.006	0.012	0.005	-0.135	**0.719**	0.006	-0.001	-0.001	0.000	-0.001	-0.006	0.005	0.589*
weight (g)	G	-0.020	-0.078	-0.005	-0.004	0.010	-0.085	0.008	0.090	-0.073	-0.024	-0.111	**0.962**	0.010	-0.002	0.005	-0.039	-0.004	-0.012	0.014	0.641*
Harvest duration	P	-0.004	-0.013	0.019	-0.001	-0.001	-0.006	0.001	0.000	-0.005	-0.004	-0.100	0.074	**0.060**	0.002	-0.011	0.000	0.002	0.006	-0.006	0.013
(days)	G	-0.012	-0.107	0.165	-0.042	-0.003	-0.062	0.003	0.001	0.005	0.015	-0.038	0.182	**0.051**	0.007	-0.049	0.029	-0.012	0.001	-0.016	0.118
Moisture content	P	0.000	0.014	-0.006	0.001	0.007	0.006	-0.003	0.001	0.007	0.002	0.054	0.052	-0.014	**-0.008**	-0.001	0.000	-0.004	-0.006	0.003	0.106
(%)	G	0.000	0.130	-0.083	0.022	-0.019	0.052	-0.008	0.015	-0.062	-0.017	0.037	0.078	-0.016	**-0.023**	-0.012	0.024	0.012	-0.017	0.013	0.123
Total soluble	P	-0.002	-0.005	0.011	0.000	-0.011	-0.004	0.003	0.000	-0.004	0.001	-0.142	0.017	0.018	0.000	**-0.038**	-0.002	0.001	0.011	-0.006	-0.152
solids seed (°Brix)	G	-0.015	-0.019	0.096	0.003	0.047	-0.056	0.011	-0.009	0.069	-0.010	-0.168	-0.026	0.015	-0.002	**-1.169**	0.052	-0.008	0.010	-0.039	-0.218*
Total soluble solids	P	-0.001	-0.008	0.012	0.000	0.003	-0.001	-0.001	-0.002	-0.005	0.001	-0.058	-0.058	0.005	-0.001	-0.021	**-0.004**	-0.002	0.012	-0.006	-0.137
whole pod (°Brix)	G	-0.016	-0.145	0.210	0.042	-0.015	0.030	-0.008	-0.084	0.111	-0.021	-0.011	-0.332	0.013	-0.005	-0.077	**0.114**	-0.022	0.015	-0.041	-0.241*
Ascorbic acid	P	0.001	0.004	-0.001	-0.001	-0.002	0.001	0.001	0.000	0.008	-0.002	0.065	0.020	-0.004	-0.001	0.001	0.000	**-0.032**	0.003	-0.004	0.053
(mg/100g)	G	-0.013	0.049	-0.066	-0.011	0.012	0.070	0.003	0.000	-0.058	0.009	0.080	-0.041	-0.007	-0.003	0.015	-0.030	**0.084**	-0.006	-0.009	0.077
Protein content (%)	P	-0.002	0.001	-0.004	0.001	0.006	-0.001	-0.002	0.001	0.002	0.002	-0.007	0.065	-0.006	-0.001	0.007	0.001	0.001	**-0.061**	0.006	0.009
	G	-0.006	0.030	0.004	0.026	-0.028	-0.041	-0.007	0.010	-0.018	0.001	-0.175	0.185	-0.001	-0.006	0.027	-0.026	0.008	**-0.064**	0.023	-0.06
Total sugar (%)	P	0.000	0.002	-0.006	0.000	0.009	0.002	-0.002	0.000	0.002	-0.001	0.130	0.069	-0.007	-0.001	0.004	0.000	0.003	-0.007	**0.049**	0.249*
	G	0.000	0.026	-0.114	-0.007	-0.030	0.042	-0.005	0.012	-0.024	0.009	0.186	0.127	-0.008	-0.003	0.061	-0.043	-0.007	-0.014	**0.108**	0.317*

Unexplained variation (P): 0.07461; (G): -0.01495; *Significant at P≤0.05; r-correlation coefficient with pod yield per plant; bold values indicate direct effects.

CONCLUSION

Therefore, it was concluded that average pod weight and pods per plant were the main contributors directly and indirectly to the total association between yield and other component traits.

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