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Genetic Variability and Association of Quality Characters and Pod Yield in Garden Peas (*Pisum sativum* L.)

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Abstract

Ten garden pea landraces in a randomized complete block design with 3 replications over 2 winter seasons 2011 - 2012 and 2012 - 2013 were evaluated at the experimental field of Dara'a Center of Scientific Agricultural Research, GCSAR, Syria. The study showed high heritability (H) with high genotypic coefficient of variation (GCV) and genetic gain as percent of mean (GA %) for vitamin C, chlorophyll A, chlorophyll B, total carotenoids and pod yield plant^{-1} indicating good scope for selection. The genotypic (r_g) and phenotypic associations (r_{ph}) of pod yield plant^{-1} were significantly positive with protein content, fiber content and total carotenoids but significantly negative with soluble sugars. Path coefficient analysis confirmed that protein content and total soluble solids registered positive direct effects on pod yield plant^{-1} and negative indirect effects through each other. Protein content should be considered independently or in combination with total soluble solids and chlorophyll A while imposing selection for amelioration of quality and yield in garden peas.

Keywords: Chlorophyll A, garden pea seeds, gene effects, protein, vitamin C

Introduction

Legumes contribute about one-third of human's protein intake and also serving as an important source of fodder and forage for animals, edible and industrial oils. One of the most important attributes of legumes is their capacity for symbiotic nitrogen fixation, underscoring their importance as a source of nitrogen in both natural and agricultural ecosystems [1,2]. Legumes also accumulate natural products or secondary metabolites such as isoflavonoids that are considered beneficial to human health through anticancer and other health-promoting activities [3].

The visual appearance of grain legume seeds is an important determinant of perceived quality in the market place. A uniform green color is desirable in peas; however, wet weather or irrigation during maturation can lead to bleaching and loss of market value [4]. Peas can supply the required nutrients to various age groups owing to their high protein content and favorable composition of amino acids [5] and low trypsin inhibitor levels [6,7].

The evaluation of genetic variability is an essential prerequisite to know the source of genes for a particular trait within the available germplasm [8]. The most important tasks for pea breeding are development of high yielding varieties with stable productivity, with sufficiently good resistance to diseases and unfavorable environmental conditions, with a high rate of organic matter accumulated during the initial phases of growth, sufficiently high intensity of photosynthesis, increases in protein content, essential amino acids and favorable rations among them [9,10]. There is insufficient knowledge about the nature of gene action governing quality characteristics and their interrelationships in garden pea seeds. The present investigation was undertaken to know the genetic variability of quality characters along with pod yield in garden pea landraces.

Materials and methods

Ten landraces of garden peas *viz., 20533*, *20648*, 12401*, 12416*, *12420*, *12535*, *12831*, *12840*, *12859* and *12923* were grown in the experimental field of Dara'a Center of Scientific Agricultural Research (32 °45 ' N, 35 °39 ' E and *ca*. 440 meters above sea level), GCSAR, Syria in a randomized complete block design with 3 replications during the winter seasons of 2011 - 2012 and 2012 - 2013. Each landrace was represented by a plot which was 2.8 × 4 m with 4 rows spaced 70 cm apart with 20 cm between plants. Recommended cultural practices were adopted to maintain a healthy crop growth. Ten randomly selected plants were marked from each plot at each replication for data assessment. Pod yield plant^{-1} (g) and different quality characters *viz.,* protein content (%), total soluble solids (%), soluble sugars (%), fiber content (%), vitamin C (mg/100 g), chlorophyll A (µg/g), chlorophyll B (µg/g), total carotenoids (µg/g) were measured on fresh green milled seeds according to AOAC [11] at the Department of Horticulture, Faculty of Agriculture, Damascus University. The average data over 2 winter seasons of 2011 - 2012 and 2012 - 2013 were subjected to analysis of variance to test the level of significance among the landraces for the different characteristics under study [12]. Genetic parameters, genotypic and phenotypic correlation coefficients as well as path coefficients were computed according to the methods followed by Singh and Chaudhary [13].

Results and discussion

Analysis of variance (**Table 1**) revealed highly significant ($p < 0.01$) differences among the landraces for all the studied characters except for fiber content ($p < 0.05$) indicating the existence of variability among pea landraces.

Table 1 Analysis of variance (ANOVA) for quality characteristics and pod yield in 10 garden pea landraces over 2 seasons.

Sources of Variation	d.f.	Protein content (%)	Soluble solids (%)	Total sugars (%)	Fiber content (%)	Vitamin C (mg/100g)	Chlorophyll A (µg/g)	Chlorophyll B (µg/g)	Total carotenoids (µg/g)	Pod yield plant^{-1} (g)
Rep.	2	0.05	0.082	0.03	0.00	0.792	10.592	10.69	0.412	73.73
Treat.	9	0.24**	0.836**	0.63**	0.011*	213.00**	348.89**	1100	22.85**	4043**
Error	18	0.009	0.01	0.01	0.003	0.46	2.83	1.21	0.36	367.66

*, **: significant at p > 0.05 and p > 0.01, respectively

The mean values pooled over 2 growing seasons for quality characters and pod yield are presented in **Table 2**, where data pertaining to protein content revealed that the landraces *20648*, *12420*, *12535*, *12831* and *12923* recorded the highest values (5.68, 5.67, 5.65, 5.66 and 5.61 %), respectively. Total soluble solids showed the maximum mean in landrace *12840* (12.26 %) while the minimum mean was in *12923* (10.53 %). For soluble sugars, the landrace *12840* had the highest value (11.18 %) which differed significantly from all the other landraces. Data regarding fiber content indicated that all the landraces had high values except *12859* (1.36 %), which differed significantly from the rest. Considerable variability was observed for vitamin C among the studied landraces, however, 2 landraces *12420* (34.80 mg/100g) and *12923* (34.56 mg/100 g) had the highest content of vitamin C and differed statistically from all the other landraces. For chlorophyll A and chlorophyll B, the maximum estimates were observed in *12416* (47.08, 66.43 µg/g) whereas the minimum in *12831* (15.48, 13.42 µg/g), respectively. The highest content of total carotenoids were found in *12840* (13.64, µg/g) followed by *20533* and *20648* (12.81, 12.69 µg/g, respectively), with significant differences from the majority of the other investigated landraces. Data concerning pod yield plant^{-1} showed that the landrace *12923* produced the highest yield (195.33 g) while the landrace *12401* gave the lowest one (71.67 g) which differed statistically from most of the others. High genetic variability for quality characters in pea seeds was also earlier reported by Anil and Gupta [14] and McCallum *et al.* [15]

Table 2 Mean performance of 10 garden pea landraces for quality characters and pod yield over 2 seasons.

Landraces	Protein content (%)	Soluble solids (%)	Total sugars (%)	Fiber content (%)	Vitamin C (mg/100g)	Chlorophyll A (μg/g)	Chlorophyll B (μg/g)	Total carotenoids (μg/g)	Pod yield plant^{-1} (g)
20533	5.54	11.33	10.36	1.51	6.67	27.40	18.32	12.81	153.00
20648	5.68	10.55	10.12	1.56	16.93	39.70	51.09	12.69	132.67
12401	5.13	11.32	10.38	1.50	28.00	17.85	22.41	6.71	71.67
12416	5.54	10.67	9.84	1.55	25.60	47.08	66.43	12.11	155.67
12420	5.67	11.19	10.35	1.52	34.80	29.12	41.48	9.55	160.33
12535	5.65	11.47	10.70	1.56	19.76	19.49	30.69	6.59	114.33
12831	5.66	11.24	10.25	1.56	21.20	15.48	13.42	6.73	129.33
12840	5.51	12.26	11.18	1.49	25.15	40.98	44.68	13.64	143.00
12859	4.82	11.56	10.74	1.36	19.41	38.18	64.67	11.15	84.33
12923	5.61	10.53	9.57	1.53	34.56	30.94	21.69	11.53	195.33
L.S.D.$_{0.05}$	0.16	0.17	0.17	0.10	1.16	2.89	1.89	1.02	32.89
C.V. %	1.73	0.90	0.97	3.79	2.92	5.50	2.93	5.76	14.31

The estimated statistical and genetic parameters are shown in **Table 3**. The range of variation was maximum (50 - 250 g) for pod yield plant^{-1} followed by chlorophyll B (11.32 - 65.61 μg/g) and minimum (1.31 - 1.63 %) for fiber content. All characters showed a wide range of variation providing ample scope for selecting the desirable types.

The genotypic (GCV) and phenotypic coefficient of variation (PCV) where high (> 20 %) for chlorophyll B (51.04, 51.13 %), vitamin C (36.28, 36.41 %), chlorophyll A (35.08, 35.50 %), total carotenoids (26.47, 27.15 %) and pod yield plant^{-1} (26.13, 27.79 %) suggesting the presence of broad genetic and phenotypic variability among the landraces and sensitiveness of the attributes for making further improvement by selection. The PCV was higher than their respective GCV for all characters indicating that environmental factors influence their expression to some degree or other. The low estimates of ECV accompanied by a narrow difference between GCV and PCV for most of the characteristics suggested their relative resistance to environmental alteration.

The heritability in broad sense ranged from 50 % in fiber content to 99.67 % in chlorophyll B (**Table 3**). Such high values of heritability for the majority of characteristics clarified that they were least affected by environmental modification, and therefore, selection based on phenotypic performance would be reliable. Nemeskeri [16] recorded low estimates of heritability (0.32) for carotenoids in dry pea seeds owing to the high effects of temperature and water stress. The genetic gain as a percent of mean varied from (4.64 %) for fiber content to (89.09 %) for chlorophyll B. High estimates of genetic gain (> 20 %) were obtained for chlorophyll B (89.09 %), vitamin C (63.42 %), chlorophyll A (61.24 %), total carotenoids (45.22 %) and pod yield plant^{-1} (40.38 %), suggesting that they could be improved to a large extent through selection.

High heritability along with high GCV and genetic gain were noticed for vitamin C, chlorophyll A, chlorophyll B, total carotenoids and pod yield plant^{-1} which might be assigned to additive gene effects governing their inheritance and phenotypic selection for their improvement could be achieved by simple selection procedures like pure lines and mass selection or single seed descent following hybridization and selection in early generations. High estimates of heritability coupled with low GCV and genetic gain were observed for protein content, total soluble solids and soluble sugars which might be attributed to non-additive gene effects controlling their expression, and thus, simple selection would not be rewarding. Nevertheless, they could be improved by utilization of transgressive segregants in heterosis breeding programs. Singh *et al.* [17], Al-Aysh [18], Sirohi and Singh [19] found that both additive and non-additive gene actions were important for controlling total chlorophyll, chlorophyll A, and chlorophyll B. However, Rastogi [20] reported the presence of high non-additive variance for vitamin C content of garden pea seeds in F_1 generations. In addition, Singh and Sharma [21] revealed the significance of additive gene effects for total soluble solids and protein content, while non-fixable type of gene action was more important for the inheritance of ascorbic acid content.

Table 3 Genetic variability parameters, heritability, genetic advance for quality characteristics and pod yield in 10 garden pea landraces over 2 seasons.

Characteristics	Range	Mean±S.E	ECV (%)	GCV (%)	PCV. (%)	Hb (%)	GA	GA (%)
Protein content (%)	4.75-5.78	5.48±0.25	1.83	5.16	5.48	88.89	0.47	8.58
Soluble solids (%)	10.32-12.41	11.21±0.25	0.89	4.72	4.82	96.55	0.92	8.21
Total sugars (%)	9.45-11.24	10.35±0.25	0.97	4.43	4.54	95.46	0.79	7.63
Fiber content (%)	1.31-1.63	1.51±0.14	3.97	3.97	5.30	50.00	0.07	4.64
Vitamin C (mg/100g)	6.00-35.12	23.21±0.63	2.93	36.28	36.41	99.36	14.72	63.42
Chlorophyll A (μg/g)	13.30-49.00	30.62±0.95	5.49	35.08	35.50	97.61	18.75	61.24
Chlorophyll B (μg/g)	11.32-65.61	37.49±0.80	2.93	51.04	51.13	99.67	33.40	89.09
Total carotenoids (μg/g)	6.33-14.11	10.35±0.59	5.80	26.47	27.15	95.42	4.68	45.22
Pod yield plant^{-1} (g)	55-250	133.97±3.33	14.32	26.13	27.79	76.92	54.09	40.38

The estimates of genotypic and phenotypic correlation coefficients shown in **Table 4** revealed that genotypic correlations were higher than the corresponding phenotypic ones for most of the characters establishing a predominant role of heritable factors. Also, a narrow difference between genotypic and phenotypic correlation coefficient was noticed for almost all the pairs of studied characteristics showing that masking or modifying effect of the environment was little and indicating the existence of an inherent association among these characteristics.

The genotypic and phenotypic associations of pod yield plant^{-1} were significantly positive with protein content (0.71^{**}, 0.64^{**}), fiber content (0.45^{*}, 0.37^{*}) and total carotenoids (0.51^{**}, 0.45^{*}), but significantly negative with soluble sugars (-0.52^{**}, -0.50^{**}) respectively. The interrelationship among protein content with fiber content (0.85^{**}, 0.85^{**}), total soluble solids with soluble sugars (0.96^{**}, 0.92^{**}), chlorophyll A with chlorophyll B (0.85^{**}, 0.83^{**}), chlorophyll A with total carotenoids (0.86^{**}, 0.83^{**}) and chlorophyll B with total carotenoids (0.48^{*}, 0.47^{*}) were positive and significant at both genotypic and phenotypic levels respectively. The contrary associations at genotypic level between total soluble solids with both fiber content (-0.47^{*}) and pod yield plant^{-1} (-0.43^{*}), and between soluble sugars with fiber content (-0.47^{*}) depicted that simultaneous improvement of these 2 pairs of characteristics should not be possible. The trend of these results were in accordance with Al-Aysh [22] who recorded negative phenotypic correlation between pod yield and soluble sugars in garden pea seeds; Al-Aysh [18] who found a significantly negative association at both genotypic and phenotypic levels between protein content and soluble sugars in F_2 generations of garden pea seeds.

Table 4 Genotypic (r_g) and phenotypic correlation coefficients (r_{ph}) for quality characteristics and pod yield in 10 garden pea landraces.

Characteristics	r	Soluble solids	Total sugars	Fiber content	Vitamin C	Chlorophyll A	Chlorophyll B	Total carotenoids	Pod yield plant^{-1}
Protein content	r_g	-0.33	-0.33	0.85**	0.07	-0.10	-0.34	0.05	0.71**
	r_{ph}	-0.31	-0.28	0.85**	0.06	-0.11	-0.31	0.02	0.64**
Soluble solids	r_g		0.96**	-0.47*	-0.17	-0.13	-0.04	-0.06	-0.43*
	r_{ph}		0.92**	-0.33	-0.16	-0.13	-0.03	-0.05	-0.36
Total sugar	r_g			-0.47*	-0.28	-0.04	0.14	-0.03	-0.52**
	r_{ph}			-0.30	-0.27	-0.04	0.13	-0.03	-0.50**
Fiber content	r_g				0.08	-0.29	-0.44*	-0.27	0.45*
	r_{ph}				0.08	-0.18	-0.32	-0.13	0.37*
Vitamin C	r_g					0.03	0.05	-0.20	0.27
	r_{ph}					0.03	0.05	-0.19	0.25
Chlorophyll A	r_g						0.85**	0.86**	0.31
	r_{ph}						0.83**	0.83**	0.28
Chlorophyll B	r_g							0.48*	-0.12
	r_{ph}							0.47*	-0.10
Total carotenoids	r_g								0.51**
	r_{ph}								0.45*

*, **: significant at $p > 0.05$ and $p > 0.01$, respectively

The results of path coefficient analysis in **Table 5** revealed that protein content (0.99) and total soluble solids (0.99) had positive maximum direct effects on pod yield plant^{-1} followed by chlorophyll A (0.50). At the genotypic level, total soluble solids manifested significant negative correlation with pod yield plant^{-1} (-0.43*), but its direct effect was highly positive (0.99) and was diluted mainly due to negative indirect effects via soluble sugars (-1.26) and protein content (-0.33). Such inconsistencies suggest that a restricted selection model could be followed to nullify the undesirable indirect effects in order to make proper use of the direct effect. These findings suggest clearly that protein content, total soluble solids and chlorophyll A are the most important criteria in selection for higher quality and yield in garden peas. It could be noticed that most of the direct effects were less than unity indicating inflation due to multicollinearity was minimal [23]. The unexplained variation in genotypic paths was (0.22) which might be due to many reasons such as other characters not considered here, environmental factors and sampling errors [24]. These findings were in agreement with Singh *et al*. [25,26].

Table 5 Direct (diagonal) and indirect effects at the genotypic level of quality characteristics on pod yield in 10 garden pea landraces.

Characteristics	Protein content	Soluble solids	Total sugars	Fiber content	Vitamin C	Chlorophyll A	Chlorophyll B	Total carotenoids	r_g with Pod yield plant^{-1}
Protein content	**0.99**	-0.33	0.43	-0.41	0.003	-0.05	0.08	0.002	0.71**
Soluble solids	-0.33	**0.99**	-1.26	0.23	-0.007	-0.07	0.009	-0.002	-0.43*
Total sugar	-0.33	0.95	**-1.31**	0.23	-0.01	-0.02	-0.03	-0.001	-0.52**
Fiber content	0.84	-0.47	0.62	**-0.48**	0.003	-0.15	0.10	-0.008	0.45*
Vitamin C	0.07	-0.17	0.37	-0.04	**0.04**	0.02	-0.01	-0.01	0.27
Chlorophyll A	-0.10	-0.13	0.05	0.14	0.001	**0.51**	-0.19	0.03	0.31
Chlorophyll B	-0.34	-0.04	-0.18	0.21	0.002	0.43	**-0.22**	0.02	-0.12
Total carotenoids	0.05	-0.06	0.04	0.13	-0.008	0.44	-0.11	**0.03**	0.51**

Residual effect = 0.22

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