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Path Coefficient Analysis in Soybean in the Western Region of Saudi Arabia

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ABSTRACT. A one year study was made on variability of some morphological characters in 35 soybean [*Glycine max* (L.) Merril] genotypes which included cultivars of tropical, subtropical and temperate adaptation. Seed yield was studied in relation to seven other morphological characters. The F-test indicated that seven out of the eight traits were significantly different. Four tropical cultivars, *viz*, Jupiter, ISRA/IRAT 24/72, PR13 (114) and PR142(3), as well as one subtropical cultivar, *viz*, ICAL-132, gave the highest seed yield. All traits, except for harvest index, were positively and significantly correlated with seed yield and with one another. Path coefficient analysis emphasized that weight of pods plant^{-1}, number of branches plant^{-1} and plant height were, successively, the most important seed yield contributing traits. The direct role of shoot dry weight was moderate, but negative, while that of the number of pods plant^{-1} was very low and negative; whereas the role of harvest index was very low and positive.

Introduction

Review of the literature indicated that breeding for improved oil and protein contents (De-Cianzio *et al.* 1985), seed size (Bravo *et al.* 1980) and fatty acid composition (Hawkins *et al.* 1983) of soybean genotypes, adapted to temperate region (main production areas), required less time and showed to be more effective when practiced in tropical locations during the winter. At present, international efforts are focused on the improvement of soybean production and use in tropical and subtropical regions of the world, where protein, calorie, and nutritional problems are concentrated. Introductions of adapted cultivars in these regions require the assessment of the total variability in soybean germplasms of diverse origin, maturity and growth habit. Such information, coupled with those of inter-relationships of seed yield with its components, can be of great assistance to the plant breeder in making appropriate selections.

This study was, therefore, undertaken to assess variability and some inter-relationships of seed yield with some of its direct and indirect components in order to identify suitable cultivars and/or effective selection parameters for yield improvement in the Western Region of Saudi Arabia.

Material and Methods

Thirty-five genotypes, comprising twelve tropical, eleven subtropical and twelve temperate cultivars (Table 1) were grown in a randomized complete block trial with two replications in three-row plots, 1.50 × 5.0 m, and spacing at 50 cm between ridges and 7.5 cm between hills. The experiment was conducted for the season, 1986/1987, at the Agricultural Research Farm, King Abdulaziz University, Hada El-Sham near Jeddah. Planting was done on 10*th* of November, 1986. Nitrogen (100 kg ha^{-1}) and P_2O_5 (50 kg ha^{-1}) were applied at the time of planting. Irrigation water was applied whenever need arised. At maturity, three plants were randomly selected from the central row of each plot and were used for recording the varietal means for the following variables: plant height (cm), number of branches $plant^{-1}$, number of pods $plant^{-1}$, total biomass (leaves + stems + pods) $plant^{-1}$ (g), shoot dry weight (leaves + stems) in grams, weight of pods $plant^{-1}$ (g), seed yield $plant^{-1}$ (g) and harvest index %. The data were statistically analyzed as for a randomized complete block design. Simple correlation (Little and Hill 1978) and path coefficients (Dewey and Lu 1959) were worked out for the various character combinations, shown in Table 4.

TABLE 1. Cultivars names, maturity groups and environmental emplacement of 35 soybean genotypes grown at Hada El-Sham in winter season, 1986.

Sr. no.	Cultivar name	Maturity group	Environmental emplacement	Sr. no.	Cultivar name	Maturity group	Environmental emplacement
1	Duocrop	VII	Tropical	19	IBP 204-77	–	Subtropical
2	D75-9207	–	Tropical	20	PM-78-8-5-19	–	Subtropical
3	Hartz 9190	IX	Tropical	21	Dawson	–	Temperate
4	EGSY 91-7	–	Tropical	22	Douglas	IV	-do-
5	AGS-66	–	Subtropical	23	Egyptian	IV	-do-
6	BM-2	–	-do-	24	Elgin	II	-do-
7	Davis	VI	-do-	25	PR14 (9)	–	Tropical
8	Gordon	–	-do-	26	PR13 (114)	–	-do-
9	Century 84	II	Temperate	27	PR142 (3)	–	-do-
10	Weber	–	-do-	28	Wright	–	-do-
11	CN210	II	-do-	29	EPPs	V	Subtropical
12	Crawford	IV	-do-	30	Imp. Pelican	–	-do-
13	IAC-6	–	Tropical	31	Braxton	–	-do-
14	IAC-8	–	-do-	32	Hack	–	Temperate
15	ISRA/IRAT24/72	–	-do-	33	Harper	III	-do-
16	Jupiter R	IX	-do-	34	Hobbit	–	-do-
17	ICAL-131	–	Subtropical	35	Ozzie	–	-do-
18	ICAL-132	–	-do-				

Results

Mean Performance

The F-test indicated significant differences among the cultivar mean values for seven out of the eight traits evaluated in the study (Table 2). The range, the general mean, the standard error, and the coefficient of variation (c.v.) for these traits are shown in Table 2, whereas the average performance of each cultivar for the different traits as well as for each adaptation group are shown in Table 3. Apart from harvest index, the average performance of tropical cultivars in all traits was the highest, followed by that for the subtropical and the temperate groups. Temperate cultivars had the highest mean harvest index, whereas tropical cultivars had the lowest mean value (Table 3).

TABLE 2. Range, mean, standard error, coefficient of variation and *F*-values for seed yield and seven related traits in 35 soybean genotypes.

Character	Range	Mean	S.E.	C.V.	*F*-values
Plant height (cm)	13 - 40	21.9	3.2	20.8	5.1**
No. of branches plant^{-1}	1 - 6	2.9	0.9	44.1	3.3**
No. of pods plant^{-1}	11 - 62	26.7	5.5	29.3	5.7**
Weight of pods plant^{-1} (g)	13 - 70	34.0	8.3	34.3	3.1**
Shoot dry weight plant^{-1} (g)	6 - 50	17.9	6.1	48.0	4.4**
Seed yield plant^{-1} (g)	9 - 39	24.5	7.5	43.1	1.8**
Biomass plant^{-1} (g)	22 - 120	51.8	12.6	34.5	4.3**
Harvest index (%)	26 - 61	45.8	6.8	21.0	0.09

* And ** : Significant at 0.05 and 0.01, respectively.

TABLE 3. Average performance of 35 soybean cultivars for seed yield and seven related traits.

Cultivar code	Height (cm)	No. of branches	Plant^{-1} pods	Dry weight (g plant^{-1})				H.I. (%)
				Biomass	Shoot	Pods	Yield	
1	22	2	22	44	15	29	18	41
2	17	1	15	31	9	22	15	49
3	19	3	24	63	25	38	24	40
4	25	2	24	52	21	31	20	37
5	16	3	19	35	11	24	17	51
6	16	4	23	64	24	40	27	46
7	15	3	25	56	19	37	26	47
8	13	3	12	27	11	16	11	42
9	15	1	14	26	7	18	13	50
10	17	1	20	30	6	24	17	58
11	21	2	25	41	9	32	22	54

TABLE 3. Contd.

Cultivar code	Height (cm)	No. of branches	Plant⁻¹ pods	Dry weight (g plant⁻¹)				H.I. (%)
				Biomass	Shoot	Pods	Yield	
12	15	1	11	42	7	35	15	35
13	28	5	48	104	45	59	35	34
14	37	6	56	120	50	70	30	26
15	27	4	44	72	34	58	37	52
16	36	5	45	88	37	51	39	54
17	30	4	36	65	23	42	27	46
18	40	6	62	94	36	58	39	41
19	15	3	21	36	7	29	14	39
20	30	2	33	39	7	32	34	61
21	14	2	8	22	9	13	9	38
22	18	2	15	26	7	19	17	56
23	14	2	15	25	6	19	13	51
24	21	2	26	40	6	34	23	58
25	26	6	36	69	27	42	25	32
26	35	6	43	93	39	55	36	39
27	28	5	39	87	36	51	36	42
28	24	5	35	62	21	41	25	32
29	21	4	23	44	11	33	23	52
30	25	1	17	29	9	20	13	42
31	19	3	21	47	12	35	23	51
32	17	2	17	32	11	21	17	49
33	22	2	22	39	7	32	24	57
34	13	2	12	23	6	17	12	50
35	23	2	25	39	22	18	12	32
Overall performance of the three subgroups								
A* (12)	27.0	4.2	35.9	73.8	28.7	45.6	28.4	39.8
B (11)	21.8	3.3	26.5	48.7	17.4	30.1	23.2	41.1
C (12)	18.3	2.0	17.4	32.1	8.6	23.5	16.2	49.0
LSD (0.05)	9.2	2.6	15.8	36.2	17.5	23.8	21.5	19.5

*A, B, and C: Stand for tropical, subtropical and temperate subgroups, respectively. Number within parenthesis indicate number of cultivars within each subgroup.

Plant Height

Mean plant height was 21.9 ± 3.2 cm, while the range among the cultivars was from 13 cm (Gordon) to 40 cm (ICAL-132). A moderate c.v. value (20.8) was recorded for plant height.

Number of Branches Plant^{-1}

Number of branches plant^{-1} ranged from 1 for many cultivars (*e.g.*, Grawford) to 6 branches for ICAL-132. An overall mean value of 2.9 ± 0.9 branches and a high c.v. value (44.1%) was recorded for the trait.

Number of Pods Plant^{-1}

An overall mean value of 26.7 ± 5.5 and a range from 11 (Grawford) to 62 pods (ICAL-132) with a high c.v. value (29.3%) were recorded for this trait.

Weight of Pods Plant^{-1}

Weight of pods harvested plant^{-1} ranged from 13 g (Dawson) to 70 g (ICA-8) with an average mean value of 34.0 ± 8.3 g.

Shoot Dry Weight Plant^{-1}

Shoot dry weight plant^{-1} ranged from 6 g in the cultivars, Weber, Egyptian and Elgin, to 50 g in IAC-8 with a mean value of 17.9 ± 6.1 g and a high c.v. value of 48.0%.

Seed Yield Plant^{-1}

Seed yield plant^{-1} was highest (39 g) for cultivars, Jupiter and ICAL-132, and was lowest (11 g) for Dawson. Other cultivars, *e.g.*, ISRA/IRAT 24/72 (37 g), PR13 (114) and PR142 (3) (36 g plant^{-1} each) were also among the top yielders.

Biomass Plant^{-1}

Total biomass accumulated at the end of the season ranged from 22 g plant^{-1} (Dawson) to 120 g (ICA-8) with an average mean value of 51.8 ± 12.6 g and a c.v. value of 34.5%.

Harvest Index

Harvest index averaged 45.8 ± 6.8% over the cultivars and ranged from 26 to 61% for cultivars, ISRA/IRAT 24/72 and PM-78-8-5-119, respectively.

Simple Correlation Coefficients

Apart from harvest index, seed yield plant^{-1} was positively and highly significantly (**P** = 0.01) correlated with each of the traits evaluated in this study (Table 4). In this case, the *r*-values ranged between 0.554 and 0.814. Correlations of harvest index with all traits were generally low and insignificant, except for those with shoot dry weight plant^{-1} ($r = -0.296$) and number of branches plant^{-1} ($r = -0.249$). Plant height, number of branches plant^{-1}, number of pods plant^{-1}, pod dry weight and shoot dry weight plant^{-1}, beside being highly significantly correlated with seed yield, were positively and highly significantly correlated to one another (Table 4). Their *r*-values differed from 0.642 to 0.893.

TABLE 4. Simple correlation coefficients for seed yield and six other related traits in 35 soybean genotypes.

Characters	Plant height	No. of branches plant^{-1}	No. of pods plant^{-1}	Weight of pods plant^{-1}	Shoot dry wt. plant^{-1}	Harvest index
No. of branches plant^{-1}	0.642**					
No. of pods plant^{-1}	0.871**	0.789**				
Wt. of pods plant^{-1}	0.736**	0.731**	0.893**			
Shoot dry wt. plant^{-1}	0.670**	0.699**	0.796**	0.808**		
Harvest index	– 0.188	– 0.249*	– 0.212	– 0.218	– 0.296**	
Seed yield plant^{-1}	0.554**	0.727**	0.774**	0.814**	0.575**	– 0.162

* And ** : Significant at 0.05 and 0.01 probability levels, respectively.

Path Coefficients

Data presented in Table 5 indicated that weight of pods plant^{-1}, followed by number of branches plant^{-1}, had the highest direct and indirect effects on seed yield. Effects of plant height on seed yield were also positive, but lower compared to the former traits. The direct effect of shoot dry weight (– 0.396) on seed yield was comparable to the effect of the number of branches in magnitude, but was negative. Direct effect of number of pods plant^{-1} (– 0.034) on seed yield was negative, whereas its indirect effects through other traits, except for those via harvest index (– 0.001) and shoot dry weight (– 0.293), were positive. Direct and indirect effects effects of harvest index on seed yield were generally either very low or negative.

TABLE 5. Path coefficient analysis of correlations between seed yield and six of its components in 35 soybean genotypes.

1. Plant height vs. seed yield		
Direct effect	= P_{17} (a)	= 0.160
Indirect effect via No. of branches	= $P_{17}r_{12}$	= 0.103
Indirect effect via No. of pods	= $P_{37}r_{13}$	= – 0.030
Indirect effect via weight of pods	= $P_{47}r_{14}$	= 0.569
Indirect effect via shoot weight	= $P_{57}r_{15}$	= – 0.247
Indirect effect via harvest index	= $P_{67}r_{16}$	= – 0.001
Total		= 0.554**
2. No. of branches vs. seed yield		
Direct effect	= P_{27}	= 0.344
Indirect effect via plant height	= $P_{17}r_{12}$	= 0.103
Indirect effect via No. of pods	= $P_{37}r_{23}$	= – 0.027
Indirect effect via weight of pods	= $P_{47}r_{24}$	= 0.565
Indirect effect via shoot weight	= $P_{57}r_{25}$	= – 0.258
Indirect effect via harvest index	= $P_{67}r_{26}$	= – 0.001
Total		= 0.725**

TABLE 5. Contd.

3. No. of pods vs. seed yield		
Direct effect	= P_{37}	= − 0.034
Indirect effect via plant height	= $P_{17}r_{13}$	= 0.139
Indirect effect via No. of branches	= $P_{27}r_{23}$	= 0.271
Indirect effect via weight of pods	= $P_{47}r_{43}$	= 0.690
Indirect effect via shoot weight	= $P_{57}r_{53}$	= − 0.293
Indirect effect via harvest index	= $P_{67}r_{63}$	= − 0.001
Total		= 0.772**
Weight of pods vs. seed yield		
Direct effect	= P_{47}	= 0.773
Indirect effect via plant height	= $P_{17}r_{14}$	= 0.48
Indirect effect via No. of branches	= $P_{27}r_{24}$	= 0.251
Indirect effect via No. of pods	= $P_{37}r_{34}$	= − 0.030
Indirect effect via shoot weight	= $P_{57}r_{54}$	= − 0.298
Indirect effect via harvest index	= $P_{67}r_{64}$	= − 0.001
Total		= 0.813**
Shoot weight vs. seed yield		
Direct effect	= P_{57}	= − 0.369
Indirect effect via plant height	= $P_{17}r_{15}$	= 0.107
Indirect effect via No. of branches	= $P_{27}r_{25}$	= 0.240
Indirect effect via No. of pods	= $P_{37}r_{35}$	= − 0.026
Indirect effect via weight of pods	= $P_{47}r_{45}$	= 0.624
Indirect effect via harvest index	= $P_{67}r_{65}$	= − 0.001
Total		= 0.575**
6. Harvest index vs. seed yield		
Direct effect	= P_{67}	= 0.006
Indirect effect via No. plant height	= $P_{17}r_{16}$	= − 0.030
Indirect effect via No. of branches	= $P_{27}r_{26}$	= − 0.086
Indirect effect via No. of pods	= $P_{37}r_{36}$	= 0.007
Indirect effect via weight of pods	= $P_{47}r_{46}$	= − 0.168
Indirect effect via shoot weight	= $P_{57}r_{56}$	= 0.109
Total		= 0.162
Residual $1-R^2$		= 0.251

(a) P_{17} to P_{67} stand for path coefficients of characters 1 (plant height) up to character 6 (harvest index) with seed yield (7) as presented in the table.

**: Significant at 0.01 probability level.

Discussion

The F-test indicated significant differences among the cultivars for seven of the eight traits evaluated in this study, indicating a scope for improvement through selection. Similarly, some of the previous workers (*e.g.*, Kamendra and Ram 1983, Udoguchi and McCloud 1987, Cao *et al.* 1988, Osman *et al.* 1990, Samarrai *et al.* 1990) reported a wide range of phenotypic variability in most of the characters dealt with in the present study. On the average, the tropical cultivars had the highest mean seed yield, but the lowest harvest index among the three groups. In contrast, the temperate cultivars attained the lowest mean seed yield, but the highest harvest index. The negative or passive role of harvest index in seed yield was clearly indicated by the low and non-significant r-values observed. Similarly, Walker and Fioritlo (1984) observed a non-significant role for harvest index in accounting for the differences in the yielding ability of determinate and indeterminate soybean culivars within the same maturity group. In contrast to this, Tong (1986), in China, and Osman *et al.* (1990), in Saudi Arabia, reported significant associations between seed yield and harvest index. The highly significant positive correlation coefficients that were found between the morphological characters and seed yield were comparable to those reported by Dencescu (1982) and Simpson and Wildcox (1983) who reported significant positive association between seed yield and plant height. Zhou (1983) as well as Kamendra and Ram (1983) observed significant and positive correlation between seed yield and number of branches. Moreover, the importance of number of pods per plant on seed yield was recognized by Das *et al.* (1982), Mehortra and Chaudhary (1983), Simpson and Wilcox (1983) and Udoguchi and McCloud (1987). Meanwhile, pod weight was considered of prime importance by Mehortra and Chaudhary (1983). The other dry matter components; namely, total above ground dry matter (Kamendra and Ram 1983; Huck *et al.* 1986, Cao *et al.* 1988) and leaf dry weight (Cao *et al.* 1988) showed to be positively and significantly correlated with seed yield.

The path analysis gave a somewhat different picture than the simple correlation analysis did. For instance, the analysis using the correlation coefficients, as indices of effect, gave a misleading impression that all of the yield components (except harvest index) have more or less the same effect ($P = 0.01$) on seed yield. Whereas, path analysis exposed only the weight of pods and number of branches plant^{-1} as the most important yield contributing traits. Unlike the simple correlation, the path analysis exposed the number of pods and shoot weight to have direct opposing effects on seed yield and indirect effects through the other associated traits.

The apparent conflict between the results of the two analyses arises largely because the correlation analysis simply identifies mutual association between the various variables. Meanwhile, path analysis measures the direct influence of one variable upon another and gives the opportunity to analyze correlation coefficients into components with direct and indirect effects (Wright 1921, Dewey and Lu 1959). Path coefficient technique is, therefore, a more useful procedure where the goal is to establish direct and indirect inter-relationships among some of the variables as they affect yield components.

It is evident from this study that weight of pods plant^{-1} and number of branches plant^{-1} are the most important yield contributing traits and, hence, they may be used as selection parameters in yield improvement programmes. Jupiter, ISRA/IRAT 24/72, PR13 (114) and PR142 (3) cultivars all of tropical origin, in addition to cultivar, ICAL-132 (subtropical), being the top yielders, may deserve a special place in future germ plasm evaluation in the Western Region of Saudi Arabia.

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التحليل المساري لفـــول الصـــويا بالمنطقـــة الغربية بالمملكة العربية السعودية

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المستخلص . تمت دراسة التباين والعلاقة بين وزن محصول البذور وسبع صفات أخرى لخمسة وثلاثين صنفًا ذي تأقلم مداري وشبه مداري ومعتدل من فول الصويا لمدة عام واحد . وقد اتضح من التحليل الإحصائي F-Test وجود فروق مؤكدة بين الأصناف لسبع صفـات من بين الثـمانية التي درست . وقـد سجلت أربعـة أصنـاف مدارية هي : PR 142 (3), Pr 13 (114), Jupiter, ISRA/IRAT/24/72 وصنف شبه مداري ICAL/132 أعلى إنتاجية للبذور . كما كانت العلاقات بين ووزن محصول البذور وكل الصفات الأخرى – عدا دليل الحصاد – إيجابية ومؤكدة ، وكذلك كانت علاقة الصفات مع بعضها البعض . وقد أكد التحليل المساري Path Analysis أهمية وزن القرون وعدد الفروع بالنبات الواحد وطول النبات على التوالي كمكونات لمحصول البذور . أما دور الوزن الجاف للساق في التباين المرتبط بالإنتاجية فقد كان متواضعًا ولكنه سلبي ، بينما كان دور عدد القرون بالنبات ودليل الحصاد متدنيًا جدًا وسلبيًا .