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Soybean in the Western Region of Saudi Arabia: II. Interrelations of Yield Components

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ABSTRACT. Simple and multiple correlations, as well as simple and partial regression coefficients, were determined for seven morphological characters in sixteen soybean cultivars sown at three planting dates, *viz.*, November 19*th* 1984, May 15*th* 1985, and September 8*th* 1985, in Jeddah area. Number of pods per plant, plant height and biological yield (total dry matter) were positively and significantly ($p = 0.01$) correlated with each other at the three planting dates. The direction and magnitude of their associations with seed yield per plant, however, varied with the sowing date. The partial and simple regression and correlation analysis indicated that harvest index and biological yield were the most important yield contributing traits. Attempts should be made to find a suitable combination of biomass yield and seed yields that can maximize harvest index at the three dates of planting.

Introduction

Knowledge on relationship of yield in soybean [*Glycine max* (L.) Merr.] with its direct components (number of pods per plant, number of seeds per pod and seed size) and other morphological characters can be of great assistance to the plant breeder in making selections.

Many workers have found associations between morphological characters and the yield of soybean. Of the three components of single plant yield, number of pods per plant was considered the most important by Bains and Sood (1980), Guzhov and Patirana (1981), Malik and Singh (1982) and Das *et al.* (1982), Zhou (1983), whereas seed number was considered of prime importance by Dencescu (1982), Malik and Singh (1982) and Ma (1983). However, seed size (100 or 1000-seed weight) was also important in the opinion of Malik and Singh (1982), Muszynski and Jaranowski (1983) and Ma (1983). Of the morphological characters, the following have been associated with yield: Plant height (Green *et al.* 1977, Wilcox 1980, Dencescu 1982, Zhou 1983, Diaz *et al.* 1985, and Lin, Nelson 1988), plant top dry weight (Guzhov and Patirana 1981, Kamendra and Ram 1983), and days to flowering or maturity (Barbind *et al.* 1981, Diaz *et al.* 1985, Lin and Nelson 1988).

Although numerous yield correlation studies have been reported, most of these were conducted under optimum climates for soybean and were mostly limited to a single planting date.

The objective of this study was to determine the most important morphological plant characters in selection for yield in soybean, sown at different dates in an arid region of Saudi Arabia by the use of simple and multiple correlations as well as simple and partial regression analyses.

Material and Methods

Details of the materials and layout of the experiment were given in an earlier paper (Samarraie *et al.* 1990). Sixteen soybean cultivars were grown in a randomized complete block design with three to four replications at three planting dates, *viz,* November 19*th*, 1984 (P.D. 1), May 15*th*, 1985 (P.D. 2), and September 8*th*, 1985 (P.D. 3). Data were recorded for seven traits. The mean values of five plants, selected at random from each cultivar in the four replications at P.D. 1 and in three replications at P.D. 2 and P.D. 3, were used for computation of simple correlation and regression coefficients as well as multiple correlation and partial regression coefficient.

Results

Simple Correlations

The simple correlation coefficients for each planting date, in all possible combinations of pairs of characters, are presented in Table 1. Seed yield per plant was positively and highly significantly correlated ($p = 0.01$) with plant top dry weight and harvest index at the three planting dates. Correlations of such yield were also positive and significant with 100-seed weight at P.D. 2 and P.D. 3, number of pods per plant at P.D. 2 and P.D. 3, and plant height (P.D. 3). Furthermore, correlations of seed yield per plant with days to flowering was negative and highly significant at P.D. 1 ($r = 0.321$) but positive and nonsignificant at P.D. 2 and P.D. 3. Harvest index had also positive and significant correlations with 100-seed weight at P.D. 1 and P.D. 3, but negative and significant correlations with all other yield components at P.D. 1 and P.D. 2 and harvest index ($r = 0.360$) at P.D. 3. Plant height, number of pods per plant and plant top dry weight were highly significantly and positively correlated (P = 0.01) with each other at the three planting dates. However, seed size (100-seed weight) gave negative and highly significant correlations (P = 0.01) with plant height and number of pods per plant at P.D. 1, but positive and highly significant correlations (r = 0.596) with plant top dry weight at P.D. 3. Other correlations were either positive or negative and insignificant.

TABLE 1. Correlation coefficients between pairs of seven characters in soybean shown at different planting dates (P.D.).

Characters	Plant top dry wt (g)	Number of pods / plant	100 – seed weight (g)	Days to flowering	Harvest index (%)	Seed yield / plant (g)
				P.D. 1 (19-11-1984), n = 64		
Plant height, cm	0.431**	0.796**	-0.346**	0.492**	-0.671**	-0.189
Plant top dry wt., g		0.564**	0.035	0.069	0.501**	0.399**
Number of pods / plant			-0.453**	0.325**	-0.596**	-0.015**
100 – seed wt., g				-0.067	0.298*	0.384**
Days of flowering					-0.514**	-0.321**
Harvest index (%)						0.519**
				P.D. (15-5-1985), n = 48		
Plant height, cm	0.468**	0.445**	0.098	0.424**	-0.479**	0.064
Plant top dry wt., g		0.759**	0.217	0.376**	-0.378**	0.593**
Number of pods / plant			-0.001	0.280	-0.315**	0.488**
100 – seed wt., g				0.081	0.244	0.274
Days of flowering					-0.356*	0.048
Harvest						0.410**
				P.D. 3 (8-9-1985), n = 48		
Plant height, cm	0.435**	0.663**	0.382**	-0.256	0.334*	
Plant top dry wt., g		0.771**	0.596**	0.164	0.075	0.940**
Number of pods / plant			0.110	0.449**	-0.272	0.611**
100 – seed wt., g				-0.300*	0.573**	0.733**
Days of flowering					-0.360*	0.050
Harvest index (%)						0.391**

In all tables * and ** significant at p = 0.05 and 0.01, respectively.

Simple Regression

Simple regression coefficients (*b*) of seed yield per plant on the different characters were computed, together with their *sb* values (the sample standard deviation of the regression coefficient). The significance of coefficients obtained was tested by calculating *t* values (*i.e.*, by the *t* test), as shown in Table 2. Apart from days to flowering, all traits gave positive and significant *b* values at one or more planting date. Concerning days to flowering, the *b* value was negative and highly significant at P.D. 1 (-0.734), but positive and insignificant at P.D. 2 (0.027) and P.D. 3 (0.034). Otherwise, the *b* values were either positive or negative and insignificant (Table 2).

TABLE 2. Simple regression analysis between seed yield per plant and each of six other characters in soybean at three planting dates.

Character	*b*	*sb*	*t*
	P.D. 1 (19.11.1984)		
Plant height, cm	-0.378	0.250	1.514
Plant top dry weight, g	0.120	0.035	3.427**
Number of pods / plant	-0.002	0.016	0.122
100-seed weight, g	1.686	0.515	3.274**
Days of flowering	-0.734	0.275	2.668
Harvest index (%)	0.827	0.170	4.783**
	P.D. 2 (15.5.1985)		
Plant height, cm	0.058	0.133	0.437
Plant top dry weight, g	1.578	0.316	4.990**
Number of pods / plant	2.391	0.631	0.789**
100-seed weight, g	0.041	0.021	1.936
Days of flowering	0.027	0.082	0.327
Harvest index (%)	0.335	0.110	3.045**
	P.D. 3 (8.9.1985)		
Plant height, cm	0.571	0.237	2.404*
Plant top dry weight, g	1.811	0.097	18.608**
Number of pods / plant	2.502	0.478	5.234
100-seed weight, g	0.425	0.058	7.314**
Days to flowering	0.034	0.099	0.337
Harvest index (%)	0.347	0.120	2.882**

Partial Regression

The results presented in Table 3 showed that plant top dry weight and harvest index gave the highest significant and positive partial regression coefficients at all dates (ranging between 0.2467 and 1.7029) followed by 100-seed weight at P.D. 1 (0.5450) and plant height at P.D. 3 (0.0306). On the other hand, number of pods per plant had a negative and significant partial regression coefficient of 0.0243 at P.D. 3. Such a coefficient was either positive or negative in the other cases (Table 3).

Multiple Correlations

Multiple correlation coefficients (R) for seed yield per plant and its six contributing traits are presented in Table 4. The values of R were highly significant at all planting dates. The coefficients of determination (R^2) indicated that about 88.3, 83.5 and 98.8 percent of the variability in seed yield per plant was accounted for by its association with the six traits evaluated in this study (Table 4) at their respective dates.

Discussion

Harvest index, the ratio of the seed yield to the biological yield, is a calculated variable. In the present study, it was computed by using the seed yield per plant. There

TABLE 3. Partial regression coefficients for six characters and seed yield per plant in soybean at three planting dates.

Character	Regression coefficient	*sb*	*t*
	P.D. 1 (19.11.1984)		
Plant height, cm	0.1181	0.1716	0.688
Plant top dry weight, g	0.2467	0.0201	12.207**
Number of pods / plant	0.0163	0.0113	1.438
100-seed weight, g	0.5450	0.2560	2.129*
Days of flowering	0.2469	0.1348	0.830
Harvest index (%)	1.7029	0.1148	14.834**
	P.D. 2 (15.5.1985)		
Plant height, cm	0.0259	0.0927	0.287
Plant top dry weight, g	0.3122	0.0418	7.467**
Number of pods / plant	2.0200	0.0210	0.950
100-seed weight, g	-0.6610	0.4919	-1.344
Days to flowering	-0.0258	0.1302	-0.198
Harvest index (%)	0.9590	0.0977	9.619**
	P.D. 3 (8.9.1985)		
Plant height, cm	0.0306	0.0153	1.995*
Plant top dry weight, g	0.5101	0.0262	19.473**
Number of pods / plant	-0.0243	0.0168	-2.083*
100-seed weight, g	-0.0527	0.0663	-0.795
Days of flowering	0.0341	0.0315	1.083
Harvest index (%)	0.3709	0.0269	13.806**

TABLE 4. Multiple correlation coefficients (R) and coefficients of determination (R^2) for seed yield and five other characters in soybean at three planting dates.

	Multiple regression coefficient (R)	Coefficient of determination
P.D. 1 (19.11.1984)	0.940**	0.883
P.D. 2 (15.5.1985)	0.914**	0.835
P.D. 3 (8.9.1985)	0.994**	0.988

was a highly significant relationship between harvest index and seed yield (Tables 1 to 3), since the flower trait is the function of the latter one. Syme (1972) found harvest index to account for 72% of grain yield in wheat, and it was positively correlated with grain yield (Kulshrestha and Jain 1982). The positive relationships between seed yield and harvest index may suggest that such index measurements are unnecessary, as seed yield alone may be sufficient criterion for indicating the yielding ability of a crop. However, this is not always true as pointed out by Donald (1962) for rice cultivars grown under changing fertility conditions. In fact, the improvement in grain yields of Australian oats has been due, almost entirely, to an increased harvest index without an increase in biological yield (grain plus straw), according to Sims (1963). It has also been suggested that selection for harvest index may be valuable for improving grain yield of cereal crops (Nass 1973). In fact, the plant ideotype (Donald 1968) or plant architectural (Smith 1976) approach to plant breeding is primarily based on the concept of maximizing grain yield per unit of dry matter produced. Relatively limited efforts have been directed towards the evaluation of modern soybean cultivars on the basis of their harvest index.

Biological yield or total dry mattter (top plant weight), accumulated during the growing season, also was consistently and positively interrelated with seed yield per plant at the three sowing dates (Tables 1 to 3), but negatively correlated with harvest index only at the first and second planting dates (Table 1). Such trends to not necessarily mean a cause and an effect relationship. In fact, Khalifa and Al-Saheal (1984) attributed the high yielding ability of some wheat cultivars (*e.g.*, Mexipak and Penjamo, to their high total biological yield, while in other cultivars, *e.g.*, Super X, it was attributed to high harvest index. In soybean, significant and positive correlations of biological yield with seed yield were reported by Guzhov and Patirana (1981) and Kamendra and Ram (1983).

The importance of the direct yield components of soybean, *i.e.*, number of pods per plant, 100-seed weight and plant height, in relation to seed yield was not consistently indicated as that for biological yield and harvest index, in the present study. Apparently, the relationship between these traits varied with the environment planting dates as reported by Mehorata (1983), and the number of characters included in the partial regression analysis. For example, the number of pods per plant, when considered alone, was highly significantly and positively interrelated with seed yield per plant (Table 2) at the second and third planting dates, but not at the first. However, when other characters were kept constant at their present levels, the increase in pod number per plant resulted in a significant reduction in seed yield per plant at the third planting date, but it had no significant effect at the first and second dates (Table 3). Many of the previous workers, such as Bains and Sood (1980), and Malik and Singh (1982), observed positive correlations between seed yield and number of pods per plant.

On the other hand, days to flowering had a negative and significant effect on seed yield under short-day conditions, (P.D. 1), but it was independent at other plantings (Table 1). Furthermore, plant height proved to be an important yield contributing trait at intermediate day-length and moderate temperature conditions (P.D. 3), but not at the others (Tables 1-3). Lin and Nelson (1988) indicated that days to flowering were relatively more important in determining soybean yields than did plant height. The highly significant simple correlations between plant height, plant top dry weight, and number of pods per plant (Table 1) indicated that, as the height of plants increased, plants tended to have larger number of pods, and, consequently, higher biological and seed yield, and vice versa at each of the three plantings. Thus, if these traits proved to be controlled by a few genes, selection for their desirable combination should not be difficult. On the contrary, each of these three traits, in turn, was negatively and highly significantly ($p = 0.01$) correlated with harvest index at the first and second planting dates, but not at the third one (Table 1). Since harvest index is significantly correlated with seed yield in this investigation, a selection index may need to be established so that it may not stress the extremes, especially at the first and second planting dates.

The total contribution of the six characters to seed yield per plant (Table 4) was rather high, and it was environmentally dependent. For example, at intermediate day-length and moderate temperatures (P.D. 3), the six characters contributed about 99% of the variability in seed yield. Their contribution, being 88 and 84%, at P.D. 1 and P.D. 2, respectively, indicating that other characters such as number of fruiting nodes (Zhou 1983) and growth habit (Lin and Nelson 1988) may prove to be important under these conditions.

Thus, two variables, namely harvest index and biological yield, should be considered together in selecting for increased yield in arid regions of Saudi Arabia. Similarly, Donald and Hamblin (1976) suggested the use of biomass and harvest index as selection criteria in cereal breeding programmes. In this respect, grain yield can be improved either by increasing biomass yield, without changing harvest index, improving harvest index and keeping biomass unchanged, or by increasing both biomass and harvest index. High harvest index, however, would be more desirable for better conversion of biomass into grain, as indicated by Sharma and Smith (1986).

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فول الصويا بالمنطقة الغربية :
٢ – العلاقات المتداخلة بين مكونات المحصول

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تم حساب معامل الارتباط البسيط والضربى ، وكذلك معامل الارتداد البسيط والجزئى لسبع صفات ظاهرية لستة عشر صنفا من فول الصويا التى ذكرت فى المقالة الأولى ، زرعت على ثلاثة تواريخ هى ١٩ نوفمبر ١٩٨٤ ، ١٥ مايو و ٨ سبتمبر ١٩٨٥ بمنطقة جدة . ولقد أوضحت الدراسة ارتباطا إيجابيا (P=0.01) بين عدد القرون للنبات ، طول النبات ووزن المادة الجافة فى كل من تواريخ الزراعة الثلاثة . أما مقدار ارتباط هذه الصفات واتجاهه (سلبًا وإيجابًا) بوزن الحبوب ، فقد اختلف باختلاف تاريخ الزراعة . وقد اتضح من مُعامل الارتداد الجزئى والبسيط ومعامل الارتباط البسيط أن دليل الحصاد وكمية المادة الجافة من أهم الصفات المشاركة فى وزن الحبوب ، وبالتالى فلابد من المحاولة لإيجاد أمثل الاتحادات بين إنتاج المادة الجافة ووزن المحصول اللازمة للحصول على أعلى قيمة لدليل الحصاد فى كل من البيئات الثلاث .