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Genotype-Sowing Date Interaction in Soybean in Western Saudi Arabia

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ABSTRACT. The photoperiodic response of soybean [*Glycine max* (L) Merr.] is a major factor determining the latitude and the sowing date at which soybean cultivars are grown. In order to elucidate the effect of sowing date on phenotypic performance and stability of soybean, 16 genotypes of diverse origin were grown in three different seasons: summer, fall and winter in a randomized complete block design experiment with three replications. Data recorded on days to 50% flowering, plant height, seed size , harvest index (HI) and seed yield in each season as well as over the three seasons were analyzed and the different variance components were obtained. Stability parameters were also estimated for seed yield and HI. Sowing date effects and sowing date-genotype interactions were found to be highly significant for all traits mean while genotype effects were found to be significant for plant height and 100 seed weight. Seed yield showed to be more stable than HI and this could be due to the dependence of seed yield on diverse source of assimilates. November sown cultivars had moderate HI but they were significantly shorter, and had significantly larger seed size and higher seed yield than May and September sown cultivars. Cultivars Jupiter, ICAL 124 and Alamo proved to be stable and are considered to be best suited for the region.

Introduction

Genotype-environment interactions pose important problems in developing improved cultivars. Relative ranking of genotypes often differ when compared over several environments, making it difficult to judge the genetic potential of a genotype.

The only control a plant breeder has over GE interactions is the replication of the breeding material over time and location. Genotype × season interactions are always of major importance in developing improved varieties. Genotypes × location interactions, on the other hand, are of relatively little importance in selecting cultivars for local adaptation but often assume a dominant role in selecting wide adaptation.

Photoperiodic response of soybean is a major factor determining the latitude at which soybean cultivars are grown (Cregan and Hartwig 1984). Soybean adapted to temperate climates are often unproductive when grown under short day ($<$ 14h) conditions. Under such conditions, Hartwig (1970) indicated that a minimum of 45 days from emergence to early bloom, is required to permit adequate vegetative growth necessary for moderate seed yields and optimum stature suitable for machine harvest. The cultivation of day neutral genotypes and/or genotypes with delayed flowering under short day conditions is likely to provide these requirements (Garner and Allard 1930). The length and the life cycle of the long season varieties vary with planting date, therefore, achieving the desired duration of growth requires careful synchronization of planting date and variety.

The objectives of the current work are to (1) evaluate the performance of 16 soybean genotypes under three short days ($<$ 14) subtropical environment with respect to their photoperiodic responses, plant height, seed yield and some yield related components, (2) estimate the stability parameters for harvest index (HI) and seed yield and (3) identify superior soybean cultivars for cultivation at one or more planting dates in the western region of Saudi Arabia.

Material and Methods

Sixteen soybean genotypes [*Glycine max* (L) Merr.] obtained from the international soybean programme at the University of Illinois, Urbana, U.S.A., were seeded in the Agricultural Experiment Station, King Abdulaziz University, Jeddah on 15/5/85 (E_1), 8/9/85 (E_2)and 9/11/85 (E_3). The experimental design was randomized complete block with three replications. Plots consisted of three rows 5.0m long at a row distance of 0.5m. Plants within each row were spaced 30cm apart, *i.e.*, at a population density of about 66,600 plants/ha. Trials at E_2 and E_3 were planted in the open field while that E_1 was sown under a polyethylene netting offering full sunlight.

At maturity, one sample consisting of five plants (1.5m row segment) was harvested from the central row of each plot with a hand sickle at the ground level. The sickle harvested samples were air dried and biomass (weight of above ground plant parts harvested) of each sample was recorded. After threshing, seed weight of individual samples was recorded. The HI value for each sample was calculated as the ratio of seed weight to biomass weight × 100. Days to 50 percent flowering (on plot basis) and plant height (5 plants per plot) were recorded during the growing season. Seed size (100 seed weight) was obtained from the air-dried sample.

A separate analysis of variance for each trait within each sowing date as well as the combined analysis over the three dates were performed (Little and Hills 1978). Date on seed yield and harvest index (HI) were used to calculate stability parameters for each genotype using the regression procedure of Eberhart and Russel (1966). One stability parameter was estimated as the linear regression coefficient (b), of an entry mean of an environmental index. The other stability parameter was deviations from regression (S_d^2) for each genotype. The environmental index for each of the two traits was obtained by subtracting the grand mean from the environmental (sowing date) mean. Deviations from unity of the regression coefficient were tested by the t test. The appropriate F-test was used to evaluate deviations from regression for each genotype (Eberhart and Russell 1966).

Results and Discussion

Mean Performance

The means and ranges for plant height, days from emergence to 50% flowering, 100-seed weight (seed size), seed yield and HI at each of three planting dates are presented in Table 1, whereas the analysis of variances for different traits is shown in Table 2. When planted on 15 May (longest days and highest temperatures), soybean plants grew taller, flowered later and attained higher seed yields than when planted in September. However, yields recorded from May planting were lower than those obtained from November planting ($P \leq 0.01$, Table 2). Moreover, the average seed

TABLE 1. Means and ranges for five traits in 16 soybean genotypes, temperature, relative humidity and day length in the experimental area.

	Planting date					
	First 15/5 (E_1)		Second 8/9 (E_2)		Third 19/11 (E_3)	
	Range	Mean	Range	Mean	Range	Mean
Days to flowering	46.3 – 80.0	60.3	38.3 – 50.7	43.1	33.6 – 60.0	48.5
Plant height (cm)	60.0 – 94.1	72.4	29.9 – 60.9	44.9	14.1 – 37.5	22.9
100 – seed weight (g)	8.2 – 12.0	10.1	6.4 – 16.9	12.8	6.7 – 22.5	18.1
Seed yield (g)	19.0 – 51.1	34.7	9.4 – 24.8	17.4	21.4 – 75.8	46.9
H.I. (%)	14.8 – 52.9	32.2	40.5 – 56.9	50.3	13.5 – 47.0	34.2
R.H. (%)	5 – 100	57.5	3 – 100	64.0	7 – 100	60.5
Temperature (°C)						
Min.	24.1 – 26.9	25.6	19.4 – 26.0	22.8	18.5 – 22.0	19.7
Mean	29.7 – 32.0	31.0	24.3 – 30.8	27.7	24.0 – 26.9	24.6
Max.	35.6 – 37.9	36.8	29.6 – 36.0	33.3	28.6 – 32.6	30.1
			Day length (h)			
Range	12 : 57 – 13 : 27		10 : 52 – 11 : 59		11 : 57 – 11 : 42	
Mean		13 : 12		11 : 26		11 : 20

size attained at the May planting was, however, smaller than that recorded at either of the two other sowing dates. Full season soybean in higher latitudes is generally planted between mid-May and early June. Planting later than this, specially in non-irrigated areas, was observed to reduce seed yield (Heatherly and Elmore 1986, Heatherly 1988). Such yield reductions (in contrast to those observed in this study) were mostly associated with the early induction of flowering and reproductive growth before adequate vegetative growth was attained (Cregan and Hartwig 1984). Hot and dry weather encountered during the seed filling stage (E_1 and E_2) were also reported to reduce seed size, seed quality and consequently seed yield (Green *et al.* 1965, Whigham *et al.* 1978) as observed in this study. The higher seed yields observed at E_3, in contrast to those recorded at E_1 and E_2, were thus most probably attributed to the large seed size associated with favourably cool temperatures prevailing at the seed filling stage. Late plantings, elsewhere, were reported to produce heavier seeds (Heatherly 1988).

TABLE 2. Summary of the combined analysis of variance for harvest index and seed yield for 16 soybean genotypes at three sowing dates.

Source	*df*	Days to flowering	Plant height	100 Seed weight	Harvest index	Seed yield
Date (D)	2	3481.27**	9844.08**	262.39**	1575.82**	3513.51**
Genotype (G)	15	64.28	163.36*	11.33*	85.29	181.11
$G \times D$	30	56.21**	66.66**	5.35**	80.74**	148.66**
Pooled error	96	9.41	31.30	1.80	27.21	52.55

*Significant at $P = 0.05$; **Significant at $P = 0.01$

Flowering behaviour observed in the different planting seasons (Table 1) was partially due to the fact that in May planting (E_1), day lengths, following seed emergence, were progressively increasing while, in September (E_2) and November (E_3) plantings, they were progressively decreasing (Table 1). Maximum vegetative growth rates were reported to occur at 30°C (Brown 1960) while adverse effects on plant growth rate were associated with temperatures exceeding 40°C (Whigham *et al.* 1978). Hence, progressively shorter plants were recorded in this study as the planting date was advanced from May to November. The higher yields attained by the comparatively shorter plants of November planting (E_3) in contrast to those of May (E_1) and September (E_2) plantings indicated that time of flowering and consequently the prevailing photoperiods and temperatures afterwards were relatively more important than plant height in determining seed yields of the genotypes evaluated in this study. Similarly, Lin and Nelson (1988) in U.S.A. indicated that plant height was relatively less important than early flowering in determining high seed yields in determinate soybean genotypes.

Combined Analysis of Variance

It is evident from Table 2 that variances due to date of planting as well as that for the first order interaction (Genotype × sowing date) were highly significant in all of the studied traits. Genotypes were only significant ($P = 0.05$) for plant height and 100-seed weight. In case of HI and seed yield, the sum of squares due to environments (dates) and environments × genotypes were further partitioned according to Eberhart and Russell (1966) stability model and were presented in Table 3.

TABLE 3. Mean squares and significance levels from complete analysis of variance for harvest index and seed yield.

Source	*df*	Mean squares	
		Harvest index	Seed yield
Genotypes (G)	15	85.29	181.11
Env. + ($G \times$ Env.)	32		
Env. (Linear)	1	31.49.80	7029.73**
$G \times$ Env. (Linear)	15	68.00**	162.26**
Pooled deviations	16	87.75**	126.44**
Pooled error	96	27.21	52.55

**Significant at $P = 0.01$

Stability Analysis

Most previous stability studies in soybean were confined to seed yield. Harvest index is a ratio of seed yield to total biomass (Donald 1962) and is considered as a potential criterion in selecting indirectly for increased seed yield in cereals (Nass 1980). Therefore, stability parameters were estimated for both HI and seed yield of this study and are presented in Table 4. In the stability analysis, each genotype was defined by three values: (1) mean yield over all environments; (2) regression coefficient (b); and (3) deviation mean square (S_d^2). Eberhart and Russell (1966) defined a stable genotype as a one with $b = 1.0$ and $S_d^2 = 0$. However, according to these workers, an ideal cultivar would have both a high average performance over a wide range of environments plus stability. Regression coefficients were non-significant for HI of all 16 genotypes and for seed yield for 14 of the 16 genotypes. Deviations from regression, on the other hand, were non-significant for seed yield in all genotypes while those for HI were significant for 7 of the 16 genotypes (Table 4). ICAL 124, with the highest HI of all entries had non-significant b and S_d^2 values. The yielding ability of ICAL 124 was 5.1% above the grand mean and also had a non-significant regression coefficient values ($b = 1.09$) and S_d^2. Jupiter showed the highest seed yield among the 16 genotypes as well as a high HI (42%) and also had non-significant b and S_d^2 values with respect to both HI and seed yield. Alamo, the second top yielding variety, had also a relatively high HI (41%). However, the regression coefficient values for this cultivar differed for the two traits. For HI the regression coefficient was equal to one, while for seed yield its regression coefficient was significantly higher than one. It is evident from the estimates of stability parameters and above average performance presented in Table 4 that of the 16 genotypes studied, only ICAL 124 and Jupiter can be classified as stable and desirable for both HI and seed yield. Choo *et al.* (1984) defined a desirable genotype as one with high performance and at least average perfor-

TABLE 4. Stability parameters for seed yield per plant and harvest index for 16 soybean genotypes at three sowing dates.

Genotype		Seed yield (a)			Harvest index		
Name	Group & habit	Mean	b	S_d^2	Mean	b	S_d^2
Siasta 194	V	23.6	- 0.10	- 50	31.0	1.46	85*
Ecudor	VII	23.5	- 0.88	- 8	38.6	1.46	128**
Bossier	VII, *D*	34.8	0.60	301	35.4	1.16	65*
Braxton	VII, *D*	23.4	0.46	97	28.8	0.92	189**
CEP 7717	V	35.8	0.42	944	33.5	1.07	293**
ICAL 124	VII	34.7	1.09	- 31	48.6	0.10	27**
HMI	VII	33.5	1.37	- 13	43.7	0.97	85*
Essex	V, *ID*	28.4	1.30	151	38.1	0.91	77
PK 7386	VI	30.4	0.89	- 41	41.5	0.94	3
Jupiter	IX, *D*	49.0	1.61	92	42.0	0.47	22
PK 7394	VI, *D*	27.9	1.28	31	40.7	0.56	- 7
Foster	VIII, *D*	36.9	1.05	92	33.5	1.74	- 85
Alamo	IX, *D*	48.0	1.48*	- 52	41.0	1.10	- 25
G 2120	VII, *D*	39.4	1.82	493	39.1	1.69	356**
Davis	VI, *D*	29.9	0.97	106	42.4	0.90	103*
Williams 82	III, *ID*	28.9	0.90	- 25	44.8	0.56	29*
Mean	32.99	–	–	38.92	–	–	

*And **significant at $P = 0.05$; **Significant at $P = 0.01$,

a = yield (t/ha) = yield per plant × 0.066,

D = Determinate ; ID = Indeterminate growth habit,

S_d^2 = Deviation from regression.

mance in all environments, while an undesirable genotype either had low mean or below average performance in all or some environments. On the basis of Choo *et al.* (1984) definition, cultivars Alamo and ICAL 124 appeared to be desirable for both HI and seed yield as they maintained average or above average values for both traits at each of the three sowing dates (data not presented). On the same basis, cultivars Williams and Jupiter also proved to be desirable for both HI and seed yield, respectively, at each of the three environments.

The results of this study indicate that both HI and seed yield were significantly influenced by changes in the environmental conditions. Highest HI values and lowest seed yields were obtained from September planting while highest seed yields and acceptable HI values were recorded from November planting. For the 16 genotypes reported herein, highest seed yields were mostly harvested from cultivars having above average HI values rather than from these with highest values. Further, phenotypic stability for seed yield among the 16 genotypes was more prominent than that of for HI. Consequently, selection for seed yield *per se* might be less effective as selection for HI in highly diverse environments in the Western Region of Saudi Arabia. This is at variance with Sharma *et al.* (1987) who observed that selection for seed yield in wheat *per se* was equally effective as that for HI in highly adverse environments. On the other hand, selecting genotypes with higher HI might not necessarily result in high yields. Hence under such circumstances, cultivars like ICAL 124, Alamo and Jupiter which proved to be desirable deserve a place in both commercial production and future breeding programme in Western Saudi Arabia or in similar latitudes. Planting of soybean as late as mid-November, *i.e.*, at relatively lower temperatures and progressively increasing photoperiods following flower induction may result in the highest seed yield appropriate for the Western Region.

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التفاعل بين التركيب الوراثي وموعد زراعة فول الصويا بالمنطقة الغربية بالمملكة العربية السعودية

صالح مهدي السامرائي ، حسين الجزولي عثمان ، حبيب الرحمن عيان ،
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المستخلص . يعتبر طول الفترة الضوئية عاملاً رئيسًا لتحديد المنطقة والموعد الملائمين لزراعة فول الصويا . استهدف البحث دارسة أثر موعد الزراعة على سلوك وثبات الإنتاجية في ١٦ صنفًا ذات أطوال متباينة ، وسجلت البيانات : تاريخ ٥٠٪ للإزهار ، طول النبات ، حجم البذرة ، دليل الحصاد ، ووزن المحصول وحللت إحصائيًا ، كذلك قُدِّر معامل الثبات لوزن المحصول ودليل الحصاد . بينت الدراسة أن هناك أثرًا إحصائيًا (عالي المعنوية) لموعد الزراعة وللتفاعل بين الموعد والأصناف على كُل الصفات التي درست ، بينما كان هنالك أثرًا معنويًا اقتصر على طول النبات ووزن المائة بذرة .

أوضحت الدراسة أن وزن المحصول كان أكثر ثباتًا من دليل الحصاد ، وقد يُعزي ذلك لاعتمادة على مصادر غذائية متعددة أدت الزراعة في نوفبر إلى قصر النباتات وزيادة حجم البذرة ووزن المحصول مع اعتدال قيمة دليل الحصاد . وقد برهنت الأصناف « جوبتر » ، « اكال ١٢٤ » و « المو » على أنها أكثر ثباتًا وملاءمة للمنطقة الغربية من غيرها .