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Relationships between Seed Yield and Other Characters of Different Maturity Types of Soybean Grown in Different Environments and Levels of Fertilizer

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ABSTRACT: A two-season field experiment was conducted to determine the association between yield and yield components, morphological and physiological traits of soybean. This study was conducted at the Suranaree University of Technology Experimental Farm, Nakhon Ratchasima, in the dry and late rainy seasons of 2002. Six soybean varieties were chosen to represent early (CM2 and NS1), medium (KUSL20004 and KKU67) and late maturing varieties (LJ4 and KKU35). The fertilizer formula 12-24-12 respective for N, P_2O_5, K_2O was applied at the rates of 187.5 and 375 kg/ha, plus a control (without fertilizer) to create different soil fertility levels. A split-plot in a randomized completed block design with four replications was used, having fertilizer levels as the main plots and soybean varieties as the sub-plots. The results showed that the late maturing soybean varieties produced higher yield, total dry matter (TDM), leaf area index (LAI), crop growth rate (CGR), branches per plant, pods per plant and nodes per plant than the medium and early maturing varieties. Correlation coefficients between yield and pods per plant, TDM at R5 and LAI at R5 of the three types of soybean were strong and positive in both seasons. This indicated that the soybean yield improvement in the future could be made possible by increasing these characters. However, the correlations between yield and nodes per plant, yield and branches per plant, and yield and seed size were quite variable among levels of fertilizer, seasons and maturity types. Thus these yield components could not be used effectively in selection for seed yield.

KEYWORDS: Correlations between characters, yield components, soybean breeding, total dry matter.

INTRODUCTION

Many characters of crops are associated with others. This association may be an aid to selection aimed at changing the character with which it correlates[1]. Previous research has shown that seed yield of soybean is associated with yield component traits including pods per plant, seeds per pods and seed size[2, 3], with morphological traits such as plant height, total dry matter (TDM), harvest index (HI) [4, 5, 6] and with physiological traits such as leaf area index (LAI)[7] and crop growth rate (CGR)[8, 9]. Soybean breeders sometimes use these traits for indirect selection for yield. However, the association between yield and some of these characters might be variable among environments, soil fertilities and maturity types of soybean. There are two causes of correlation between characters, namely genetic and environmental factors. The variation is high if the cause is highly affected by environments. Parvez[6] reported positive correlations between yield and TDM and LAI for both early (May) and late (July) growing seasons but the correlations in the late-planted materials was greater. A seasonal difference in association between yield and branch dry matter of soybean was reported by Board and Harville[8]. Therefore, the effectiveness of indirect selection is dependent on the strength and stability of the association between yield and related traits.

The objective of this study was to determine the association between yield and yield components, morphological and physiological traits of different maturity types of soybean.

MATERIALS AND METHODS

This research was conducted at the Suranaree University of Technology Experimental Farm, Nakhon Ratchasima, NE Thailand in the dry season (planted on 14 January) and late rainy season (planted on 11 September) of 2002. The soil type was Chatturat clay loam (Typic Haplustalts), containing 3.25% OM, 29 ppm P_2O_5, 300 ppm K_2O, and pH 6.4. Six soybean varieties were chosen to represent early (Chiangmai 2 (CM2) and Nakhonsawan 1 (NS1), medium (KUSL20004 and KKU67) and late (Long Juvenile 4, LJ4 and KKU35) maturing soybeans. A fertilizer formula 12-24-12 (N-P_2O_5-K_2O) was applied at two different rates of 375 (F2) and 187.5 (F1) kg/ha plus a control (without fertilizers, F0) to create three levels of soil fertility.

A split plot arrangement of treatments in a randomized completed block design with four replications was used. Fertilizer levels were the main plots and varieties of soybean were the sub-plots. Each plot consisted of six rows containing two middle rows used for yield measurement and character determination. The next two outside rows were used for physiological trait determination. Rows were 5 m long with spacings of 50 cm between rows and 20 cm between hills with 2 plants per hill. This resulted in the population of 200,000 plants/hectare. Each plot was over-planted and thinned to 2 plants per hill at 12 days after planting. Recommended herbicide, insecticides and fungicides were used to control weeds, insects and fungi, respectively[10]. Supplemental overhead sprinkler irrigation was applied periodically in the late rainy and regularly in the dry seasons.

Developmental growth stages were determined using a sample of five plants per plot based on the method proposed by Fehr and Caviness[11]. Physiological traits which included leaf area index (LAI), total dry matter (TDM) and crop growth rate (CGR) were measured in F1 treatment in the dry season and three fertilizer treatments in the late rainy season. Data collection was determined at V3, V5, R1, R3 and R5 stages. LAI and TDM were determined by taking 0.5 m^2 samples from each variety of soybean at the same stage of growth from the outside rows of each plot. Leaf area was determined using a Li-Cor (LI-3100) leaf area meter. Plant samples used to determine LAI were separated into leaf and shoot (stem, pod and seed) fractions and then dried in a forced air dryer at 60 °C for 48 hrs. Leaf area index was calculated by the equation,

$$LAI = \frac{L_A}{AG}$$

where L_A is leaf area and AG is ground area which supports the leaf area.

TDM was determined on kilograms per hectare basis using the sum of all plant parts above ground. CGR was estimated by linear regression analysis where TDM was regressed against time[12].

Plant height, branches per plant, pods per plant and nodes per plant were determined from a random sample of 10 plants per plot. Yield was measured by harvesting two-center rows of each plot at maturity. Seed size was estimated by counting and weighing 100 seeds randomly taken from the seeds harvested for yield measurement.

Analysis of variance was performed on the data with the SAS General Linear Models procedure[13]. Duncan Multiple Range Test (DMRT) was used in the mean comparison. Varieties and fertilizer rates were considered random effects since they were representing maturity types and rates of fertilizer.

For each maturity type and fertilizer level, all possible pairs of characters were analysed by analysis of covariance, and individual characters by analysis of variance methods. From the analysis, estimates of variances and covariances to be used for calculating phenotypic and genotypic correlations were estimated by the method outlined by Singh and Chaudhary[14]. Phenotypic correlations were estimated in the following manner:

$$r_{ph} = \frac{M_{12}}{\sqrt{(M_{11})(M_{22})}}$$

where M_{12} is the mean product for pair of characters

Table 1. Results from F-tests of significance of mean squares obtained from analyses of variance.

Sources of Variation	df†	Yield	Seed size	Pods/ plant	Branches/ plant	Nodes/ plant	TDM‡	Days to flowering	Days to maturity	Plant height
Seasons (S)	1	**	**	**	**	**	**	*	*	**
Fertilizers (F)	2	**	*	**	*	ns	*	ns	ns	ns
Varieties (V)	5	**	**	**	**	**	**	**	**	**
S x F	2	**	*	ns	ns	*	*	ns	ns	ns
S x V	5	*	**	**	**	**	**	*	**	**
F x V	10	ns	ns	ns	*	ns	ns	ns	ns	ns
S x F x	10	ns	*	ns	ns	*	ns	ns	ns	ns
VCV (%)		10.4	4.9	15.2	14.0	5.6	12.1	8.6	10.7	10.4

*, ** Mean squares significant at 0.05 and 0.01 levels of probability, respectively; ns = not significant.
† Degrees of freedom.
‡ Total dry matter.

Table 2. Yield, agronomic and physiological traits of six soybean varieties grown in two seasons.

Maturity type	Variety	Yield (kg/ha)	TDM[‡] (kg/ha)	LAI[¶]	CGR[§] (g/m²/d)	Days to flowering (no.)	Days to maturity (no.)
Early	NS1	1,778 d[†]	3,437 d	3.8 c	10.3 d	29 d	80 d
	CM2	1,850 d	3,380 d	2.9 d	10.8 d	28 d	79 d
Medium	KUSL20004	2,197 b	4,263 c	5.1 b	12.4 c	31 cd	87 c
	KKU67	2,117 c	4,159 c	5.8 b	12.9 c	32 c	87 c
Late	LJ4	2,240 b	5,655 a	7.1 a	14.1 b	43 a	118 a
	KKU35	2,576 a	5,277 b	7.7 a	15.6 a	36 b	107 b

[†] Means within a column followed by the same letter are not significantly different at $P \le 0.05$ according to DMRT.
[‡] Total dry matter.
[¶] Leaf area index (means at R5 stage measured in F1 fertilizer treatment).
[§] Crop growth rate.

and M_{11} and M_{22} are the mean squares for each character under consideration.

The genotypic correlations were estimated in a similar manner:

$$r_g = \frac{\sigma_{g12}}{\sqrt{(\sigma^2_{g1})(\sigma^2_{g2})}}$$

where σ_{g12}, σ^2_{g1} and σ^2_{g2} are estimates of genotypic covariances and genotypic variances of characters 1 and 2, respectively.

Results and Discussion

Analysis of Variance

Analyses of variance showed significant differences between seasons and among varieties for all characters measured (Table 1). Fertilizer rates were significantly different for all characters except nodes per plant, days to flowering, days to maturity and plant height. The variety by season interaction was significant for all traits, indicating that soybean varieties responded differently to the climate they were grown. On the other hand, the variety by fertilizer interaction was not significant for most traits except for branches per plant.

Characters of Soybean Varieties

Lengths of growth period (number of days from planting to flowering and to maturity) for the early, medium and late maturing varieties are given in Table 2, with the early maturing varieties being the shortest in length and the late the longest. In the dry season, each type of soybean variety tended to flower and mature earlier than in the late rainy season (data not shown). Daylength in mid January in the location of this experiment is about 30 minutes shorter than in mid September[15]. Because soybean is sensitive to photoperiod, it is likely that this difference affected both days to flowering and days to maturity. Seed yield, TDM, LAI, CGR, plant height, pods per plant and nodes per plants of the early, medium and late maturing varieties were in an ascending order (Tables 2 and 3). Therefore, these characters were closely related to maturity and length of the reproductive period. Averaged across fertilizer levels, KKU35 gave the highest seed yield of 2,576 kg/ha. This variety was intentionally developed by Khon Kaen University as a late maturing variety for full season planting[16]. On the other hand, the early maturing varieties, NS1 and CM2, gave the lowest seed yield which was associated with small plant stature, low TDM and reduced branching.

Association between Seed Yield and Other Characters of Soybeans

Phenotypic and genotypic correlation coefficients

Table 3. Agronomic traits of six soybean varieties grown in two seasons.

Maturity type	Variety	Seed size (g/100 seeds)	Plant height (cm)	Branches/ plant (no.)	Pods/plant (no.)	Nodes/plant (no.)
Early	NS1	19.75 a	42 d	3.3 c	32 c	10 d
	CM2	13.89 d	39 d	3.5 bc	37 bc	10 d
Medium	KUSL20004	15.22 c	65 c	3.5 bc	42 b	13 c
	KKU67	15.70 c	73 c	3.8 b	38 bc	13 c
Late	LJ4	15.93 c	98 a	3.7 b	45 b	21 a
	KKU35	16.90 b	86 b	4.4 a	53 a	18 b

[†] Means within a column followed by the same letter are not significantly different at $P \le 0.05$ according to DMRT.

between seed yield and all characters that might be related to yielding potential of different types of soybean are shown in Table 4. In general the genotypic correlations were slightly higher than the phenotypic ones. Among the two primary yield component traits of soybean, namely pods per plant and seed size, pods per plant exhibited strong phenotypic and genotypic correlations with seed yield for all maturity types across fertilizer rates and seasons. On the other hand, the phenotypic correlation between yield and seed size was found from as low as r = -0.29^{ns} for the medium maturing varieties at low fertilizer rate to 0.86** for the late maturing varieties at the highest fertilizer level. Poelhman[17] reported that both phenotypic and genotypic correlations between seed yield and pods per plant were high over a wide range of genetic materials and environments. On the other hand, correlation between seed yield and seed size of the crop ranged from significantly negative to positive. The associations between yield and seed size were variable, and more than 70% of the cases were not significant. It cannot be concluded in this study that seed size can

Table 4. Phenotypic and genotypic correlations of yield with other characters in three maturity types of soybean varieties applied with three fertilizer rates in the dry and late rainy seasons.

Maturity type	Characters	Dry season			Late rainy season		
		F0	F1	F2	F0	F1	F2
Early	Nodes/plant	0.14	0.63*	-0.06	0.34	-0.03	0.03
		(0.31)	(0.54)	(-0.18)	(0.41)	(-0.18)	(0.22)
	Branches/plant	0.55*	0.63*	0.63*	0.18	0.10	0.85**
		(0.59)	(0.65)	(0.67)	(0.34)	(0.28)	(0.71)
	Pods/plant	0.72**	0.74**	0.82**	0.71**	0.88**	0.66*
		(0.78)	(0.80)	(0.83)	(0.76)	(0.68)	(0.60)
	Seed size	-0.05	-0.02	-0.17	0.32	-0.06	0.68*
		(-0.15)	(-0.23)	(-0.32)	(0.45)	(-0.26)	(0.57)
	TDM (R5)	0.79**	0.84**	0.88**	0.82**	0.86**	0.49
		(0.83)	(0.76)	(0.73)	(0.62)	(0.74)	(0.52)
	LAI (R5)	na	0.87**	na	0.62*	0.72**	0.87**
		na	(0.89)	na	(0.65)	(0.73)	(0.75)
	CGR	na	0.63*	na	0.47	0.51	0.57*
		na	(0.68)	na	(0.53)	(0.57)	(0.61)
Medium	Nodes/plant	0.44	0.67*	-0.05	-0.50	0.04	0.42
		(0.49)	(0.52)	(-0.11)	(-0.37)	(0.28)	(0.55)
	Branches/plant	0.19	0.66*	-0.40	0.68*	-0.39	0.39
		(0.32)	(0.53)	(-0.48)	(0.63)	(-0.48)	(0.45)
	Pods/plant	0.83**	0.74**	0.96**	0.72**	0.69*	0.75**
		(0.85)	(0.78)	(0.82)	(0.73)	(0.71)	(0.77)
	Seed size	0.43	-0.29	0.71**	0.09	0.13	0.19
		(0.47)	(-0.36)	(0.68)	(0.14)	(0.23)	(0.31)
	TDM (R5)	0.95**	0.77**	0.91**	0.81**	0.89**	0.96**
		(0.82)	(0.79)	(0.78)	(0.70)	(0.78)	(0.76)
	LAI (R5)	na	0.88**	na	0.72**	0.86**	0.88**
		na	(0.83)	na	(0.74)	(0.83)	(0.82)
	CGR	na	0.55*	na	0.38	0.53*	0.68*
		na	(0.62)	na	(0.46)	(0.66)	(0.75)
Late	Nodes/plant	0.02	0.72**	0.38	0.48	-0.39	0.63*
		(0.24)	(0.53)	(0.41)	(0.52)	(-0.41)	(0.67)
	Branches/plant	0.71**	0.77**	0.39	-0.40	0.09	0.69*
		(0.73)	(0.74)	(0.46)	(-0.43)	(0.37)	(0.72)
	Pods/plant	0.88**	0.74**	0.86**	0.73**	0.76**	0.96**
		(0.75)	(0.76)	(0.79)	(0.77)	(0.79)	(0.84)
	Seed size	0.18	0.56*	0.86**	0.66*	0.12	0.12
		(0.24)	(0.58)	(0.76)	(0.64)	(0.30)	(0.23)
	TDM (R5)	0.57*	0.92**	0.90**	0.87**	0.81**	0.65*
		(0.62)	(0.78)	(0.81)	(0.84)	(0.79)	(0.68)
	LAI (R5)	na	0.80**	na	0.42	0.83**	0.72**
		na	(0.83)	na	(0.55)	(0.80)	(0.75)
	CGR	na	0.68*	na	0.68*	0.62*	0.51*
		na	(0.74)	na	(0.76)	(0.69)	(0.60)

*, ** Significant at the 0.05 and 0.01 probability level, respectively; na = not available.
Genotypic correlation coefficiens are in parenthesis.

be used for indirect selection for yield. The phenotypic correlation between seed yield and branches per plant was high and significant in 50% of the cases. The application of these characters for indirect selection for yield may be successful, especially for branching types of soybean.

All the three physiological traits including TDM, LAI and CGR were found to show moderate to strong associations with seed yield. The association between seed yields and TDM was significant for all types of varieties both in the late rainy and dry seasons and for all fertilizer levels, except for the early maturing varieties at the high fertilizer rate in the late rainy season. This was true also for LAI and CGR. In the USA, it was shown similarly that TDM was found to be correlated with seed yield of soybeans[4]. These characters, especially TDM, may be employed effectively for indirect selection for yield. The associations between seed yield and nodes per plant and branches per plant were quite variable. Many of which were weak and tended to be negative.

Conclusion

Many traits such as yield potential, days to flowering, days to maturity, TDM, yield components and physiological traits of the early maturing varieties, were lower than those of the medium and late maturing varieties. Yield of soybean was found to be significantly correlated with many characters, particularly pods per plant, TDM and LAI. These associations were high for all maturity types and stable across fertilizer rates and seasons. In soybean improvement, the selection for these characters might result in the increase of yield.

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