Songklanakarin J. Sci. Technol.
33 (4), 365-368, Jul. - Aug. 2011

SJST SONGKLANAKARIN JOURNAL OF SCIENCE AND TECHNOLOGY
http://www.sjst.psu.ac.th

Original Article

Path coefficient analysis for yield of early maturing soybean

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Received 23 July 2009; Accepted 28 July 2011

Abstract

Fourteen soybean lines/varieties were evaluated at Suranaree University of Technology experimental Farm, Nakhon Ratchasima, Thailand, in 2006-2007 using a randomized complete block design with 3 replications. The objectives of the study were to investigate the correlations among some characters of soybean and to verify direct and indirect effects which will be used for the selection for seed yield. Eight characters were evaluated for phenotypic- genotypic correlations and path co-efficients. These were days to flowering, branches per plant, nodes per plant, pods per plant, seeds per plant 100 seeds weight, days from flowering to maturity and yield. Means for yield and its components were significantly different among all genotypes for all characters. Significantly positive phenotypic correlation was observed between seed yield and days to flowering. Further-more, genotypic correlation showed that seed yield was positively correlated with all characters except 100 seeds weight. Pods per plant gave the highest positive direct effect on seed yield, followed by branches per plant. In addition, the indirect effects of most characters were high through pods per plant. The results obtained from genotypic correlations and path analyses showed that the efficiency in the selection for seed yield in early maturing soybean should increase through the selection of pods per plant.

Keywords: soybean, correlation coefficient, path coefficient analysis, indirect selection, early maturing soybean.

1. Introduction

In Thailand, soybean [*Glycine max* (L.) Merr.] is usually grown for the extraction of oil and production of meal for animal feed. Soybean seed contains 38-42% good quality protein and 18-22% oil content. In 2007, about 176,000 ha in Thailand was used for the crop giving seed yields of 218,000 tons (Office of Agricultural Economics, 2007). However, production is not sufficient for national consumption and the production area grown is now in a decreasing trend.

Seed yield of soybean, as well as other crops, is controlled by quantitative genes with low heritability that makes the response to selection for yield *per se* low (Burton, 1987). In breeding to improve yield of crops, the breeder has the option to select yield directly or indirectly through yield-related traits. The correlations of yield with yield components and morphological traits has been studied extensively and used as a tool to improve seed yield of soybean (Board *et al.,* 1997; Arshad *et al.,* 2006; Malik and Ashraf, 2006). Genetic correlations should be more useful than phenotypic correlations in the selection for seed yield as the environmental effects are excluded. Furthermore, correlations between seed yield and related characters could be partitioned through path analysis into direct and indirect effects to identify characters most responsible for the increase of seed yield (Dewey and

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Lu, 1959). Many researchers used path analysis to identify characters responsible for increasing seed yield in soybean (Akhter and Sneller, 1996; Board *et al.,* 1997; Iqbal *et al.,* 2003). However, none of these authors have identified character most related with yield in early maturing soybeans.

The objectives of this study were to investigate the genotypic and phenotypic correlations between seed yield and yield-related traits and to partition these correlations into direct and indirect effects of early maturing soybean.

2. Materials and Methods

Eleven early maturing soybean lines with long vegetative periods and three check varieties were evaluated in three seasons including the late rainy season of 2006, early rainy season and late rainy season of 2007. The lines were C-2101, C-2109, C-3105, C-3108, C-3110, C-3117, M-2209, M-3202, M-3213, M-3215, M-3217 as described by Machikowa *et al.* (2007). Soybean varieties Chiangmai 2 (CM 2) and Nakhonsawan 1 (NS 1) were early maturing checks and SJ 5, a widely adapted variety, was the standard check. These lines and varieties were evaluated in a randomized complete block design (RCBD) with 3 replications at Suranaree University of Technology Experimental Farm (SUT Farm), Nakhon Ratchasima, in the northeastern region of Thailand. The soil type at the experimental site was Chatturat clay loam (Typic Haplustalts).

The experiment was made in 4–row plots. Each row was 5 meters in length. Row to row and plant to plant distances were 50 and 20 cm, respectively. Each plot was overplanted and after emergence of seedling, thinned to have two plants per hill (i.e. 20 plants m^{-2}). Fertilizer formula 12-24-12 (N, P_2O_5 and K_2O) was applied at the rate of 187.5 kg ha^{-1} at planting and 25 days after germination. Recommended herbicides were used to suppress weeds. Diseases and insects were controlled by regular applications of fungicides and insecticides. Overhead sprinkler irrigation was used if there was no rain in the planting seasons. Eight characters were collected including days to flowering, days from flowering to maturity (DF-DM), branches per plant, nodes per plant, pods per plant, seeds per plant, 100 seeds weight and seed yield. Days to flowering was recorded as days from planting to the days when 10% of plants in each plot bloomed. DF-DM was recorded as days from days to flowering to at least 95% of pods turned brown. Ten randomly sampled plants were taken from the central rows of each plot for recording data for number of branches per plant, nodes per plant, pods per plant and seeds per plant. The weight of 100 seeds was recorded as the average of three 100-seed samples. Two central rows were harvested for measuring seed yield.

Phenotypic and genotypic correlation coefficients were determined as described by Singh and Chaudhry (1979) over three seasons. Direct and indirect effects of the agronomic characters on yield were determined by the path coefficient analysis using the method outlined by Wright (1921) and applied by Dewey and Lu (1959).

3. Results and Discussion

3.1 Correlation coefficients

Means for seed yield and other traits of lines and varieties of soybean are shown in Table 1. Yield levels of all entries were quite satisfactory with four lines outyielding the early maturing checks. Phenotypic and genotypic correlation coefficients among all characters are presented in Table 2. The genotypic correlation coefficients were higher as compared to phenotypic correlation in most of the cases. A highly significant phenotypic correlation coefficient was found between seed yield and days to flowering (0.422**). The phenotypic correlations of all characters with seed yield were positive except for branches per plant and DF-DM. These results are in agreement with other reports by Akhter and Sneller (1996) and Board *et al.* (1997) who found strong positive correlations between seed yield with pods per plant and seeds per plant. Significant positive correlations were also found between nodes per plant and all characters except 100 seeds weight. In addition, the associations of most characters with 100 seeds weight were negative while association between 100 seeds weight and days to flowering was positive.

Highly positive genotypic correlation coefficients of seed yield with nodes per plant (0.679), pods per plant (0.431), seeds per plant (0.556), days to flowering (0.568) DF-DM (0.465) were observed, while the association of seed yield with 100 seeds weight was negative (-0.641). Many researchers (Nakawuka and Adipala, 1999; Iqbal *et al.,* 2003; Malik and Ashraf, 2006) also found high genotypic correlations of seed yield with pods per plant and branches per plant. Genotypic correlation coefficients among other characters were high and positive, except for the association between those and 100 seeds weight. One-hundred seeds weight gave highly significant negative correlations with branches per plant (-0.628), nodes per plant (-0.754), pods per plant (-0.827) and seeds per plant (-0.434). Negative correlations between 100 seeds weight and some of these characters were also found by others (Nakawuka and Adipala, 1999; Arshad *et al.,* 2006). This might indicate in general that 100 seeds weight contributes no value for selection for seed yield in soybean.

3.2 Path analysis

The genotypic correlation coefficients shown in Table 2 were subjected to path analysis to partition into direct and indirect effects on seed yield through various characters as shown in Table 3. The direct effects of branches per plant, pods per plant and 100 seeds weight on seed yield were positive while those of nodes per plant, seeds per plant, days to flowering and DF-DM on seed yield were negative. The highest positive direct effect on seed yield was exhibited by pods per plant (1.203) and it was followed by branches per plant (0.344). For other types of soybean, positive direct

Table 1. Means for yield and other characters of soybean lines and varieties.

Lines	Br[1]	Nd	Pd	Sd	100-SW	DF	DF-DM	Yield
	no. plant^{-1}				g/100 seeds	no.	no.	kg ha^{-1}
NS1	2.1 e[2]	13 d	36 c	82 d	18.87 ab	29 f	54 e	2,463 de
CM2	2.2 de	13 d	37 c	84 cd	16.44 d	29 f	53 f	2,337 ef
SJ5	2.7 ab	15 b	44 ab	100 ab	16.82 c	35 a	63 a	2,663 cd
C-2101	2.6 abc	13 d	41 abc	95 abc	18.35 b	34 b	54 e	2,188 f
C-2109	2.3 cde	13 d	37 c	86 bcd	19.10 a	34 b	54 e	2,363 ef
C-3105	2.4 bcd	14 c	41 abc	93 abc	15.63 d	32 d	57 b	2,438 de
C-3108	2.3 cde	15 b	40 abc	89 bc	17.24 c	33 c	56 c	3,175 a
C-3110	2.4 bcd	15 b	44 ab	98 ab	16.81 c	34 b	55 d	2,581 de
C-3117	2.5 bc	13 d	40 abc	85 bcd	16.59 c	33 c	56 c	2,225 ef
M-2209	2.3 cde	13 d	39 bc	84 cd	16.91 c	33 c	51 h	2,588 de
M-3202	2.2 de	15 b	42 abc	95 abc	16.62 c	31 e	52 g	2,525 de
M-3213	2.3 cde	15 b	45 a	107 a	14.97 d	33 c	56 c	2,919 b
M-3215	2.8 a	16 a	46 a	98 ab	15.36 d	33 c	55 d	2,806 bc
M-3217	2.7 ab	15 b	37 c	85 bcd	16.98 c	33 c	51 h	2,963 b
F-test	*	*	*	*	*	**	**	**

*, ** Significant difference at 0.05 and 0.01 levels, respectively.
[1] Br = Branches per plant, Nd = Nodes per plant, Pd = Pods per plant, Sd = Seeds per plant, 100-SW = 100 seeds weight, DF = Days to flowering, DF-DM = Days from flowering to maturity.
[2] Means within a column followed by the same letters are not significantly different at P < 0.05 according to DMRT.

Table 2. Phenotypic and genotypic (in parenthesis) correlation coefficients between character of soybean line and varieties.

Characters	Nd	Pd	Sd	100-SW	DF	DF-DM	Yield
Br[1]	0.555**	0.660**	0.680**	0.004	0.046	0.658**	-0.038
	(0.862)	(0.583)	(0.492)	(-0.628)	(0.781)	(0.340)	(0.338)
Nd		0.895**	0.899**	-0.042	0.469**	0.563**	0.288
		(0.951)	(0.969)	(-0.754)	(0.538)	(0.408)	(0.679)
Pd			0.971**	-0.034	0.234	0.674**	0.108
			(0.992)	(-0.827)	(0.780)	(0.839)	(0.431)
Sd				-0.092	0.296	0.675**	0.120
				(-0.434)	(0.746)	(0.684)	(0.556)
100-SW					0.025	-0.054	0.154
					(-0.099)	(-0.261)	(-0.641)
DF						0.024	0.422**
						(0.538)	(0.568)
DF-DM							-0.151
							(0.465)

[1] Br = Branches per plant, Nd = Nodes per plant, Pd = Pods per plant, Sd = Seeds per plant, 100-SW = 100 seeds weight, DF = Days to flowering, DF-DM = Days from flowering to maturity.

effects of pods per plant (Ball *et al.,* 2001; Sudaric and Vrataric, 2002; Iqbal *et al.,* 2003; Arshad *et al.,* 2006) and branches per plant (Nakawuka and Adipala, 1999) on seed yield of soybean were also reported. The direct effect of 100 seeds weight on seed yield was also positive (0.292). However, the direct effect on seed yield of nodes per plant, seeds per plant, days to flowering and DF-DM were negative (-0.179, -0.090, -0.288 and -0.295, respectively). Among yield components and agronomic characters, indirect effects through pods per plant and branches per plant were found

Table 3. Direct (diagonal) and indirect (off diagonal) effects of yield components and agronomic characters on seed yield of soybean lines and varieties.

Characters	Br	Nd	Pd	Sd	100-SW	DF	DF-DM	Correlation
Br	0.344	-0.154	0.701	-0.044	-0.183	-0.225	-0.100	0.338
Nd	0.296	-0.179	1.144	-0.087	-0.220	-0.155	-0.120	0.679
Pd	0.200	-0. 170	1.203	-0.089	-0.241	-0.225	-0.247	0.431
Sd	0.169	-0.173	1.193	-0.090	-0.127	-0.215	-0.202	0.556
100-SW	-0.216	0.135	-0.995	0.039	0.292	0.029	0.077	-0.641
DF	0.268	-0.096	0.938	-0.067	-0.029	-0.288	-0.158	0.568
DF-DM	0.117	-0.073	1.009	-0.061	-0.076	-0.155	-0.295	0.465

Br = Branches per plant, Nd = Nodes per plant, Pd = Pods per plant, Sd = Seeds per plant, 100-SW = 100 seeds weight, DF = Days to flowering, DF-DM = Days from flowering to maturity.

to be important. These results are in agreement with those reported by Iqbal *et al.* (2003) who found high indirect effects through pods per plant. The results suggest that yield of early maturing soybean could be increased by selecting for high pods per plant and branches per plant. In contrast, the direct effects of nodes per plant, seeds per plant, 100 seeds weight, days to flowering and DF-DM on seed yield were low or negative. These were unexpected as all of these traits are important components of yield. However, they were mostly counterbalanced by indirect effect on yield. Direct effect of DF-DM on yield was negative (-0.295). It indicated for these soybean lines that DF-DM was not important for seed yield. The results of this experiment, which are also supported by other researchers (Ball *et al.,* 2001; Arshad *et al.,* 2006) who suggested that the selection for seed yield of early maturing soybean, should be facilitated by selection for pods per plant. However, the negative association of 100 seeds weight with these characters will become a problem in combining these important characters for high seed yield.

4. Conclusion

In this study, significant positive genotypic correlations were found between seed yield with all characters except 100 seeds weight. The partitioning of these correlations showed that high direct and indirect contributions were exhibited via pods per plant. It can be concluded that pods per plant can be used directly or indirectly as the selection criterion for identification of high yielding genotypes in early maturing soybean.

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