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Soybean Yields Response to Planting Dates and Climatic Factors[1]

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ABSTRACT

Yield and seed quality of soybean varied significantly in response to planting dates in Taiwan, but little research has been conducted to compare and clarify such differences. This study was carried out to clear up the variations of soybean yields from an annual cultivation at Wufeng, Taiwan, on a loamy soil. Twelve crops of soybeans (*Glycine max.* L.) with four genotypes, Kaohsiung selected 1 (KS1), Kaohsiung 2 (K2), Kaohsiung 3 (K3) and Kaohsiung selected 10 (KS10), were planted at density of 250,000 plants ha^{-1} each month in 1994. Climatic conditions during the growing periods indicated that all twelve growing periods were unique and distinctly different. The tested soybeans showed a significant response to planting date, genotype, and planting date-genotype interaction in grain and seed yields. There was, however, no consistent trend of planting date effect on yields. Results revealed that seed yields increase with the increasing of grain yields in soybeans. The 100-seed weight did not changed dramatically to planting dates as compared to yields. However, there was an uneven distribution of seed size in the tested genotypes to annual cultivation. The regression analyses showed that changes of grain and seed yields and 100-seed weight had correlation with climatic factors. Base on these results, soybean yields appeared to be varied greatly owing to planting date effect. The distribution of seed size was also affected by planting date. This variability was due partly to genotypic characteristics and climatic variations.

Key words: Soybean, Yield, Planting date, Climatic factor, Seed size, Genotype.

栽培期及氣象因子對大豆產量之影響[1]

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摘　要： 臺灣地區大豆產量及種子品質的表現明顯受到栽植期的影響，惟甚少研究澄清其間的差異及原因。本文研究乃針對此一問題進行週年栽培試驗，期以探討產量及種子大小因栽植期的變異性。週年試驗係於 1994 年在臺灣省農業試驗所農場實施，參試基因型（品種）爲高雄選一號 (KS1) 、高雄二號 (K2) 、高雄三號 (K3) 、及高雄選十號 (KS10) ，栽植密度爲每公頃 250,000 株。由氣象資料顯示，不同栽植期生育期間的氣象條件皆不相同。由變方分析結果得知，栽植期、基因型、及兩者交感之籽粒與種子產量均呈顯著差異，惟栽植期效應在基因型間並未呈現一致趨勢。

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試驗又顯示，籽粒產量與種子產量之間呈顯著正相關。種子百粒重雖隨栽植期而異，然未如產量般出現極大的落差。種子大小分佈亦具差異性，且因基因型而不同。再由迴歸分析結果，顯示籽粒與種子產量及種子百粒重均和氣象因子相關。本文據此結論，栽植期對大豆產量及種子大小均有影響，此一差異影響因子包括基因型特性及氣象條件在內。

關鍵詞：大豆，產量，栽植期，氣象因子，種子大小，基因型。

Table 1. Planting and harvesting dates of the four soybean genotypes in 1994.

Month	KS1 Period	KS1 Days	K2 Period	K2 Days	K3 Period	K3 Days	KS10 Period	KS10 Days
Jan	1/10- 5/ 1#	122	1/10- 5/15	126	1/10- 5/21	132	1/10- 5/23	134
Feb	2/ 8- 5/20	102	2/ 8- 5/27	109	2/ 8- 6/ 2	115	2/ 8- 6/ 5	118
Mar	3/ 8- 6/25	110	3/ 8- 6/30	115	3/ 8- 7/ 5	120	3/ 8- 7/ 7	122
Apr	4/ 8- 7/ 7	91	4/ 8- 7/23	107	4/ 8- 7/29	113	4/ 8- 8/ 4	119
May	5/11- 8/15	97	5/11- 8/20	102	5/11- 8/23	105	5/11- 9/ 5	118
Jun	6/ 7- 9/ 5	91	6/ 7- 9/15	101	6/ 7- 9/22	108	6/ 7- 9/27	113
Jul	7/ 8-10/ 3	88	7/ 8-10/ 8	93	7/ 8-10/13	98	7/ 8-10/14	99
Aug	8/13-10/29	78	8/13-11/ 5	85	8/13-11/ 7	87	8/13-11/ 9	89
Sep	9/ 8-11/30	84	9/ 8-12/ 2	86	9/ 8-12/ 7	91	9/ 8-12/ 7	91
Oct	10/ 6- 1/ 5	92	10/ 6- 1/11	98	10/ 6- 1/16	103	10/ 6- 1/11	98
Nov	11/ 4- 2/ 6	95	11/ 4- 2/ 6	95	11/ 4- 2/ 6	95	11/ 4- 2/ 6	95
Dec	12/ 5- 4/ 8	117	12/ 5- 4/15	124	12/ 5- 4/17	126	12/ 5- 4/19	128

#: month/day.

INTRODUCTION

Soybean is one of the major dryland crops once occupied an area of 50,000 hectares in Taiwan. Limited by high production cost and the tremendous commercial importation, cultivation acreage of soybean currently has decreased to only one-tenth of its peak. Of concern today is its yield stability and quality to planting date.

Huang and Tsaur (1994) showed that planting date effect can affect the growth and yield of either determinate or indeterminate soybeans in Taiwan. Sinclair and Rawlins (1993) pointed out that soybean has higher potential yield and greater variability under future changed global environments. Knowledge of crop-climate relations becomes an important issue for the purpose of crop management and food supply. The season-to-season variation in crop yields needs also to be clarified for a proper adjustment of cultivation strategy and stabilized production.

The objective of this study was to investigate the potential influence of planting date and climatic factors on the yield and the seed size of various soybean genotypes for future applications.

MATERIALS AND METHODS

Field experiments were conducted from January to December in 1994 at Experimental Farm of Taiwan Agricultural Research Institute (TARI), Wufeng, Taiwan. The dates for planting and harvesting were listed in Table 1.

Table 2. Mean air temperature (Ta) and amounts of irradiance (Rs), precipitation (Pr) and sunshine hours (Sh) during the months of growing periods of soybeans in 1994-1995.

Month	Ta (℃)	Rs (MJ m^{-2})	Pr (mm)	Sh (hr)
1994				
Jan	16.5	271.10	31.0	146.4
Feb	17.5	226.08	125.0	95.0
Mar	17.6	279.25	57.5	82.5
Apr	24.6	431.37	16.0	86.4
May	25.1	413.31	317.0	143.5
Jun	27.1	422.76	28.0	175.8
Jul	28.1	436.53	289.5	143.5
Aug	27.4	381.83	395.0	147.5
Sep	25.8	427.68	114.0	160.3
Oct	23.1	376.61	6.5	172.4
Nov	21.3	306.17	0.0	192.1
Dec	20.4	238.55	11.0	125.4
1995				
Jan	15.9	273.40	8.0	158.6
Feb	15.2	214.47	82.5	77.4
Mar	18.6	137.77	37.0	36.5
Apr	23.3	339.74	50.5	59.1

The soil was a well-drained loam soil (mixed, nonacid, hyperthermic, Fluvaquentic Dystrochrept) with pH of 5.1 and organic matter of 1.49%.

The experimental design was a split-plot randomized complete block design with three relicates. Main plots were planting dates and subplots were soybean genotypes (KS1, K2, K3 and KS10). Each subplot, received same cultural practices over the experimental period, had 12 rows of soybean (7.5 m long and 0.4 m apart). The soybeans were planted at a density of 250,000 plants ha^{-1}. Fertilizer Tai-Fei 39(N:P:K=12%:18%:12%) was applied at a rate of 400 kg ha^{-1} at planting. Mancozeb (Mn^{+2} 16%, Zn^{+2} 2%, Ethylene bisdithiocarbamate ion 62%, 80% WP) at 2.5 kg ha^{-1} (active ingredient) and Methomyl(S-methyl-N-[(methylcarbamoyl)-oxy] thioacetimidate, 90% WP) at 0.5 kg ha^{-1} were applied at the early vegetative stage to control soybean rust and insects, respectively. Weeds were removed twice by handweeding and hoeing for every growing period to avoid unexpected interferences of herbicides.

Grain yields were estimated from an area of 3.0 m^2 in each subplot at harvest. Moisture content was adjusted to 7 ± 0.5%. Seed yields were determined after the removal of damaged and incompleted grains. Analyses of variance were conducted on yields. Mean comparisons for planting dates and genotypes were made using DMRT and LSD calculated at either 0.05 or 0.01 significant level. Regression analyses were conducted between yields and 100-seed weight and climatic factors.

RESULTS AND DISCUSSION

Monthly climatic data of growing periods in 1994-1995 are listed in Table 2. As indicated, all twelve grow-

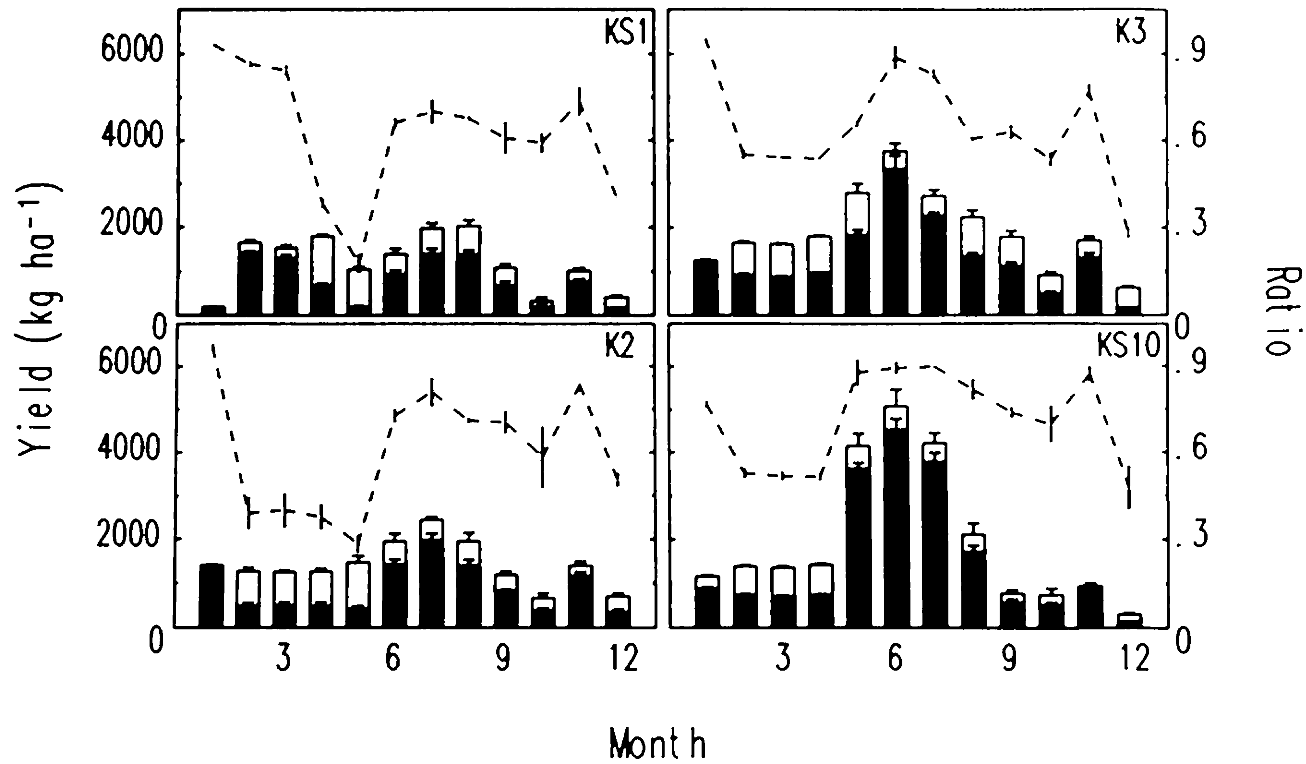

Fig. 1. Effect of planting date on grain (open column) and seed (closed column) yields and seed yield/grain yield ratio (curve) of soybeans in 1994.

Table 3. Analyses of variance for grain and seed yields of soybeans planted from January to December in 1994.

SV	Yield	
	Grain	Seed
Planting date (P)	**	**
Genotype (G)	**	**
P x G	**	**

**: P<0.01.

ing periods were unique and distinctly different. The monthly mean air temperature was cool (<=20 ℃) from January to March and warm (>=25℃) from May to September. Precipitation was high (>=100 mm) in February, May, July, August and September, and low in the rest of months. Solar radiation was plenty for the growth of soybeans.

Planting date, genotype, and planting date-genotype interaction showed significant responses to grain and seed yields (Table 3). However, there was no consistent trend of planting date effect on soybean yields among different genotypes (Fig. 1). Therefore, the results were presented on the basis of each growing periods and genotypes obtained.

As shown in Fig. 1, variability in grain and seed yields existed in the tested genotypes through annual cultivation. Since soybeans were grown under the same growth habitat and cultural practices, the varied yields therefore can be attributed to environmental variations during the growing period. The growth and development of crop can be significantly affected by any variable of environmental conditions as that reported in many studies (Cooter, 1990; Sinclair and Rawlins, 1993; Tompson, 1986, 1988; Wilks,

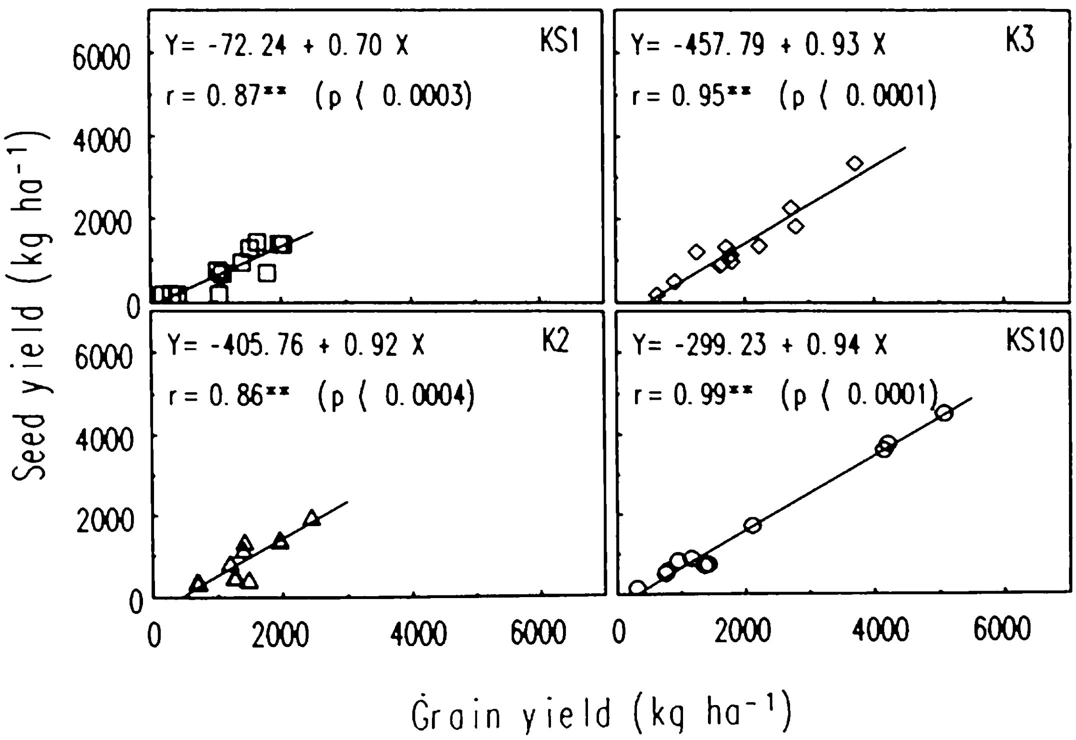

Fig. 2. The correlations between grain yield and seed yield of soybeans.

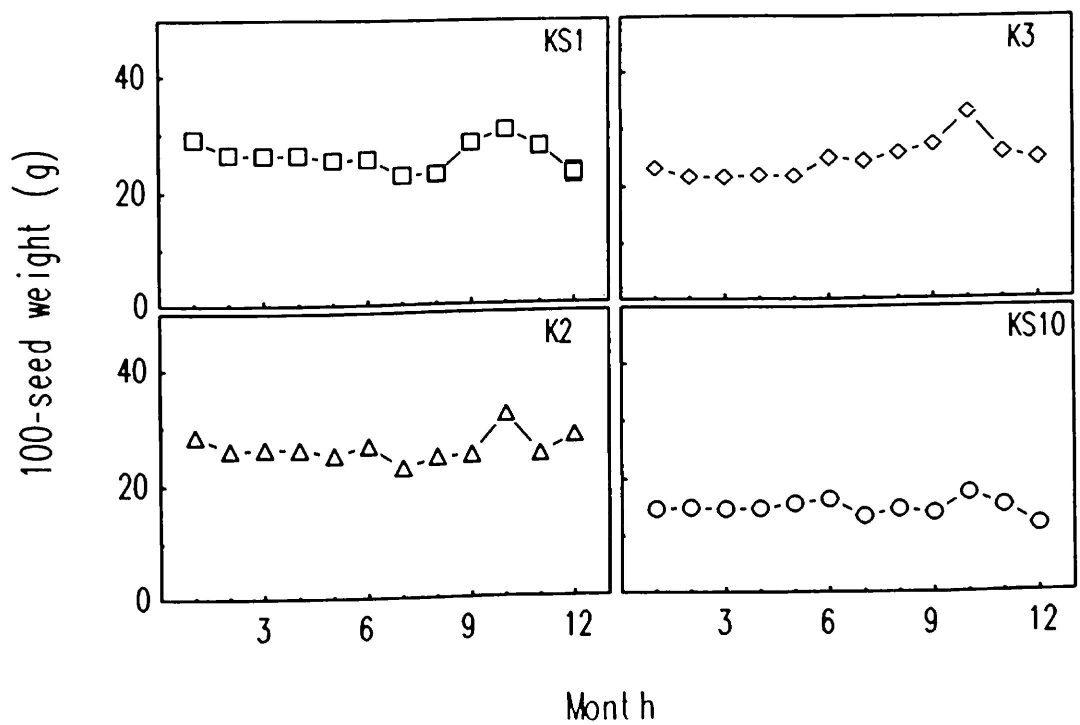

Fig. 3. Effect of planting date on 100-seed weight of soybeans in 1994.

1988; Yang, 1994).

In other crops, M'Khaitir and Vanderlip (1992) found no consistent effect of planting date on yields of sorghum and pearl millet, though sorghum showed a significant yield increase with population increase at favorable environmental conditions. Planting date effect on wheat yield in the Southern High Plains of USA was due to the amount of soil water supply to production need during the

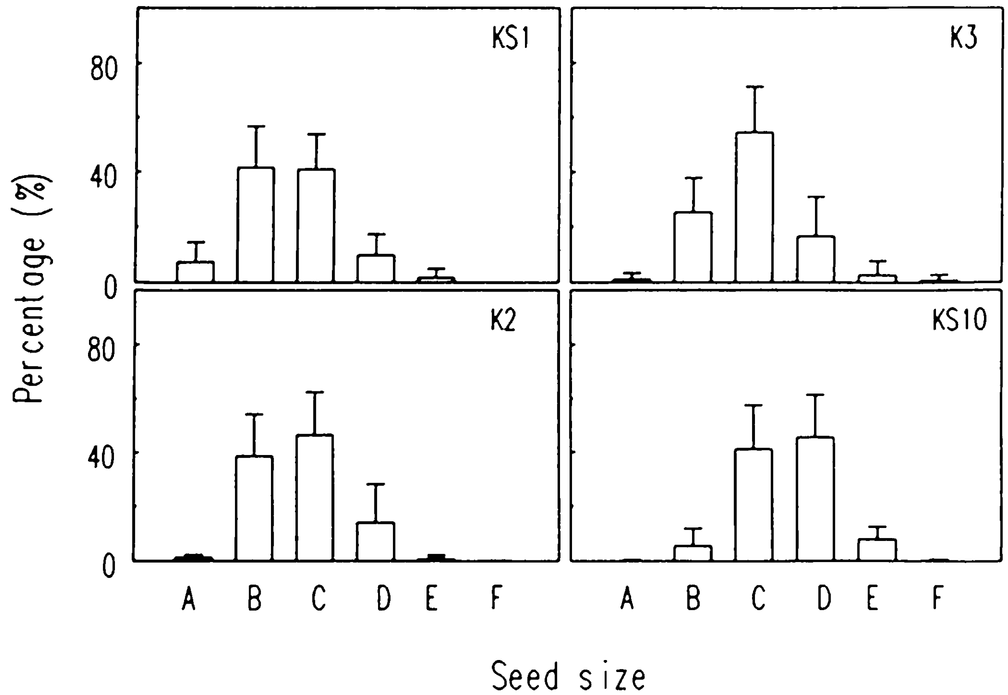

Fig. 4. The distribution of seed size of soybeans.

Table 4. Classification of seed size of the four soybean genotypes.

Genotype	Class	Range (g)	Genotype	Class	Range (g)
KS1	A	<0.1701	K3	A	<0.1301
	B	0.1701-0.2700		B	0.1301-0.2300
	C	0.2701-0.3700		C	0.2301-0.3300
	D	0.3701-0.4700		D	0.3301-0.4300
	E	0.4701-0.5700		E	0.4301-0.5300
	F	>0.5700		F	>0.5300
K2	A	>0.1501	KS10	A	<0.0501
	B	0.1501-0.2500		B	0.0501-0.1000
	C	0.2501-0.3500		C	0.1001-0.1500
	D	0.3501-0.4500		D	0.1501-0.2000
	E	0.4501-0.5500		E	0.2001-0.2500
	F	>0.5500		F	>0.2500

growing period (Winter and Musick, 1993).

Results revealed that seed yields increase with the increase of grain yields in soybeans (Fig. 2). A positive correlation was found in all genotypes. Thus, increase grain yield is one way leading to produce more seeds. The 100-seed weight did not changed dramatically by planting dates as compared to yields (Fig. 3). It implies that 100-seed weight is a stable yield component of soybean response to environmental changes. However, there was an uneven distribution of seed size in the tested genotypes to annual cultivation (Fig. 4), depending on the random classification listed in Table 4. It suggests that changes of seed size contributed

Table 5. Regression analyses of soybean yields and climatic factors during the growing periods of soybeans planted in 1994.

Yield	Climatic factor	Regression equation	r
GY	ADMT	GY= -1352.667+ 1.227 ADMT	0.472**
	ADIR	GY= -846.351+ 2.057 ADIR	0.467**
	ADPR	GY= 900.096+ 1.649 ADPR	0.578**
	ADMT,ADIR	GY= 12497.000-35.467*ADMT+ 50.500*ADIR-0.006*ADMT*ADIR+ 0.009*ADMT² -0.016*ADIR²	0.759**
	ADMT,ADPR	GY= -10724.000+ 14.470*ADMT-24.945*ADPR+ 0.014*ADMT*ADPR-0.004*ADMT² -0.007*ADPR²	0.696**
	ADIR,ADPR	GY= -9049.461+ 20.497*ADIR-12.736*ADPR+ 0.012*ADIR*ADPR-0.010*ADIR² -0.001*ADPR²	0.754**
	ADMT,ADIR,ADPR	GY= -1021.693-9.418*ADMT+ 29.313*ADIR-19.455*ADPR-0.013*ADMT*ADIR+0.016*ADMT*ADPR-0.009*ADIR*ADPR+0.004*ADMT² + 0.002*ADIR² -0.007*ADPR²	0.819**
SY	ADMT	SY= -1158.883+ 0.946*ADMT	0.381**
	ADIR	SY= -724.770+ 1.551*ADIR	0.369**
	ADPR	SY= 544.075+ 1.351*ADPR	0.496**
	ADMT,ADIR	SY= 12657.000-32.215*ADMT+ 43.403*ADIR-0.004*ADMT*ADIR+ 0.008*ADMT² -0.015*ADIR²	0.685**
	ADMT,ADPR	SY= -10043.000+ 23.258*ADMT-16.088*ADPR+ 0.016*ADMT*ADPR-0.012*ADMT² -0.003*ADPR²	0.662**
	ADIR,ADPR	SY= -9049.461+ 20.497*ADIR-12.736*ADPR+ 0.012*ADIR*ADPR-0.010*ADIR² -0.001*ADPR²	0.730**
	ADMT,ADIR,ADPR	SY= -2700.407-8.087*ADMT+ 30.287*ADIR-21.839*ADPR-0.011*ADMT*ADIR+0.014*ADMT*ADPR-0.002*ADIR*ADPR+0.003*ADMT² -0.002*ADIR² -0.008*ADPR²	0.771**
HSW	ADMT	HSW= -1158.883+ 0.946*ADMT	0.336*
	ADIR	HSW= -724.770+ 1.551*ADIR	0.288*
	ADPR	HSW= 544.075+ 1.351*ADPR	0.186
	ADMT,ADIR	HSW= 12657.000-32.215*ADMT+ 43.403*ADIR-0.004*ADMT*ADIR+ 0.008*ADMT² -0.015*ADIR²	0.445**
	ADMT,ADPR	HSW= -10043.000+ 23.258*ADMT-16.088*ADPR+ 0.016*ADMT*ADPR-0.012*ADMT² -0.003*ADPR²	0.343*
	ADIR,ADPR	HSW= -9049.461+ 20.497*ADIR-12.736*ADPR+ 0.012*ADIR*ADPR-0.010*ADIR² -0.001*ADPR²	0.423**
	ADMT,ADIR,ADPR	HSW= -56.102+ 0.128*ADMT-0.101*ADIR-0.025*ADPR	0.518**

GY: grain yield; SY: seed yield; HSW: 100-seed weight; ADMT, ADIR and ADPR: accumulated daily mean temperature, irradiance and precipitation for the growing period, respectively; * and **: $P<0.05$ and $P<0.01$, respectively.

partially the variation of soybean yields.

The regression analyses showed that changes of grain and seed yields and 100-seed weight were correlated with climatic factors (Table 5). The correlation coefficients increased as more climatic facotrs were incorporated into the regression equations. However, it needs more sets of climate data to weigh the magnitude of the influence of the individual climatic factor on yields and seed weight (Yang, 1994).

Based on these results, yields of soybean appear to be varied greatly owing to planting date effect. The size and distribution of seeds was also affected by planting date. This variability is due partly to genotypic characteristics and climatic variations.

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