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Effects of Corn Residues on Soybean Yield[1]

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Abstract : Field experiments were conducted to determine the corn (*Zea mays* L. cv. Tainung No.1) residues on the yield of the subsequent soybean [*Glycine max* (L.) Merr.] crops in 1992—1994. The results suggest that there is a beneficial effect in direct incorporation of corn residues into soil on soybean yield. Pod and grain yields of both Summer and Spring crops were significantly different in varieties and treatments in the study. For Nungyu 7, it showed that pod and grain yields of double amounts of corn residue were in average the highest among treatments in both crops. Pod and grain yields of 1993 were higher than that of 1992 in the summer growing season, but only grain yield of 1994 was superior than that of 1993 in the spring growing season. Grain yield increased by ca. 27 and 41% in average for the Summer and the Spring, respectively. Similar results were found for Kaohsiung sel. 10. It was 19 and 9% increase of grain yield for the Summer and the Spring, respectively. From the combined analysis of variance, 100-grain weight was the only yield component significant in residue treatments of two varieties in all years. Results of the correlation analysis showed that pod yield was the only factor positively correlated with grain yield in both varieties in both crops. This demonstrates that as pod yield increased, grain yield showed a corresponding increase.

Key words : Residue, Corn, Soybean, Yield, Environment, Crop season.

INTRODUCTION

The allelopathic effects of various perennial weeds and crops have been intensively studied [4, 5, 6, 7, 10, 17]. Plants influence each other growth by means of exudates [13], leachates from residues [8, 10], residues incorporated into the growing medium [2, 3, 5, 6], or residues in natural environment [14]. Lynch (1977) observed that acetic acid produced from anaerobic fermetation of wheat straw inhibited the growth of roots of barley seedling. Cochran *et al.* (1977) found that when residues of lentils, peas, wheat, and barley were spread over bare soil toxins were released which inhibited root growth of wheat seedling.

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On the other hand, plant residues are considerd to be good resources for enhancing soil properties and reducing soil erosion and as a reserve for crop nutrients [9, 11]. The storage and use of precipitation can be greatly improved through the proper management of plant residues from the previous crops [16, 19]. Such practices can also decrease the dependence of crop production on the declining groundwater supply [16]. Crops are benefited from the previous crop residues through the improvement of weed control and the availability of soil nutrients [1, 15, 18, 19].

Baldock and Musgrave (1980) and Shrader *et al.* (1966) pointed out that corn was benefited from proper rotations to increased availability of nitrogen. Yang *et al.* (1993) reported an increase of soybean yield when double amouts of chopped corn residues were incorporated into the soil. Later, Yang *et al.* (1994) further demonstrated that soybean yield was significantly improved as double amounts of corn residues were directly incorporated with soil after ear harvest. There is not certain, however, the existence of beneficial effects in varieties and the relative effects in years. The correlation of yield components with grain yield needs also to be established.

The objectives of this study were to confirm the results of the previous experiments and to determine whether there would be any relative difference of the magnitude of the benefit between cropping seasons and varieties. The effects of corn residue on the correlation of yield components with grain yield were also analyzed.

MATERIALS AND METHODS

The experiments were conducted on the experimental farm of Taiwan Agricultural Research Institute (TARI) at Wufeng, Taichung Hsien, Taiwan (ROC) in 1992-1994. The soil was a silt loam (fine-loamy, mixed, nonacid, hyperthermic, Fluvaquentic Dystrochrept). The organic matter of this soil varied from 1.55 to 1.90% and pH value was from 4.6 to 5.5 in the testing periods. Fertilizer Taifei-39 (N : P : K=12% : 18% : 12%) was applied at 400 kg/ha two weeks after planting. Weeds were controlled by handweeding and hoeing periodically and pesticides 1-naphthyl-N-methyl-carbamate (50% WP, 2.5 kg/ha) and Mn^{2+} 16%/Zn^{2+} 2%/Ethylene-bisdithiocarbamate ion 62% (80% WP, 2.5 kg/ha) were sprayed at flowering and between R5-R7 stages for pest control.

Experiments consisted of 2 soybean varieties and 4 residue treatments arranged in a randomized complete blook design with 4 replications. Data were subjected to analysis of variance and the Duncan multiple range test at the 5 and 1% probability levels. Because there was significant difference between varieties and residue treatments in nearly all years, yields and yield components were compared and discussed separately for differnt varieties in different crop seasons.

Soybean varieties, Nungyu 7 and Kaohsiung sel. 10, were obtained from Soybean Research Ladoratory of TARI and corn hybrid Tainung No.1 was purchased from Taiwan Seed Service at Shinshieh, Taichung Hsien. There were 4 residue treatments (Table 1). The full amount (X) of corn crop was planted at a rate of 57,100 plants/ha^{-1} and plant residues of the aboveground remaining were directly plowed into soil after ear removal. The soil was

plowed again a week before planting with a rotary. Separate plots were selected for not cropping corn in at least a year prior to the experiments. Planting and harvest dates varied according to seasonal conditions (Table 2).

Table 1. The residue treatments for studying the effect of direct incorporation of corn residues on soybean yield in 1992—1994.

Label	Treatment
CK	no corn residues incorporated into soil
X	full amount of corn residues (57,100 plants/ha) icorporated
2X	double amounts of corn residues incorporated
4X	quadruple amounts of corn residues incorporated

Table 2. Weather conditions during the growing seasons of soybeans, Nungyu 7 and Kaohsiung sel. 10, at the experimental farm of TARI, Taichung Hsien, Taiwan (1992—1994) .

Crop	Growing period	Heat sum	Precipitation	Irradiance	Sunshine Hour
		°C	mm	MJ m^{-2}	h
Summer					
1992	8/4 —11/4	2,310.8	679.0	1,206.18	457.7
1993	7/26—10/19	2,312.2	334.8	1,285.32	560.6
Mean		2,311.5	506.9	1,245.75	509.2
Spring					
1993	1/28—6/2	2,632.1	682.0	1,515.28	620.7
1994	1/17—5/23	2,585.6	504.5	1,367.22	438.9
Mean		2,608.9	593.3	1,441.25	529.8

The subplots were 4.5 m wide (8 rows) and 10.0 m long with row spacings of 0.55 m and planting density of 25 seeds/m. Yields of pod and grain (oven-dried at 35°C for 96 h) were estimated from the central two rows at harvest by hand. Yield components were determined at harvest by sampling 10 plants from the near rows. The weather data were obtained from the weather station of TARI (24°02' N, 120°40' E, elevation 85 m) as listed in Table 2.

RESULTS AND DISCUSSION

From Table 2, data showed that generally Summer crop had higher daily values but lower seasonal sums of temperature, precipitation, irradiance and sunshine hour than Spring crop. When compared with field performance of soybean, no simple relations between climatic factors and soybean yield under the influence of corn residues can be concluded. It is not surprising because environment as a whole is a complex of weather, soil, pests, and management practices. Any simple assumptions made and conclusions drawn from a natural system is too oversimplify to the issue.

Pod and grain yields of both Summer and Spring crops of soybean were significantly different in variery and treatment in the study (Table 3). The data were therefore analyzed separately according to variety in different treatments in different years. For Nungyu 7 (Table 4a), it showed that pod and grain yields were significantly increased when double amounts of corn residue incorporated into the soil and were in average the highest among treatments in both crops. Pod and grain yields of 1993 were higher than that of 1992 in the summer growing season, but only grain yield of 1994 was superior than that of 1993 in the spring growing season. Grain yield increased by ca. 27 and 41% in average for the Summer and the Spring, respectively. Thus in regard of yield increase, double amounts treatment obtained the highest value in Nungyu 7.

Similar results were found in variety Kaohsiung sel. 10 (Table 4b). It was 13—26 and 6—12% increase of grain yield in double amounts treatment for the Summer and the Spring, respectively. It is worth noting that full amount of residue made a considerable increase of yield in Spring 1993. The results confirm the findings as that reported by Yang *et al.* (1994). The present data further showed that, in addition to Kaohsiung sel. 10, Nungyu 7 obtained the same effects of residue treatments.

Table 3. Combined analysis of variance on the effects of direct incorporation of corn residues to the yields of soybeans, Nungyu 7 and Kaohsiung sel. 10, in the summer (1992—1993) and the spring (1992—1994) crops.

Crop season	S.V.	D.F.	Mean square	
			Pod yield	Grain yield
			..... kg ha^{-1}	
Summer	Block (B)/Y	6	61,751	51,042
	Year (Y)	1	148,871**	34,318
	Variety (V)	1	2,815,264**	630,436**
	Treatment (T)	3	57,910**	128,067*
	Y×V	1	1,386,211**	142,506*
	Y×T	3	2,409	38,082
	Y×T	3	2,733	23,356
	Y×V×T	3	26,283	6,770
	Error	42	27,419	28,974
Spring	Block (B)/Y	6	2,754	8,168
	Year (Y)	1	2,441,406**	3,932,289**
	Variety (V)	1	2,335,548**	514,448**
	Treatment (T)	3	1,032,127**	455,591**
	Y×V	1	4,427,868**	1,243,783**
	Y×T	3	500,435**	231,798**
	Y×T	3	551,216**	206,217**
	Y×V×T	3	679,660**	301,331**
	Error	42	30,868	17,876

* and ** indicate significance at 5 and 1% levels, respectively。

Table 4a. Means for yields of soybean, Nungyu 7, under the effect of direct incorporation of corn residues in the summer (1992—1993) and the spring (1992—1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields	
			Pod	Grain
			..... kg ha^{-1}	
Summer	1992	CK	2,930 a	1,840 a
		X	3,270 a	1,840 a
		2X	3,280 a	1,930 a
		4X	3,210 a	1,760 a
	1993	CK	3,490 a	1,860 a
		X	3,810 a	1,990 a
		2X	4,020 a	2,020 a
		4X	3,750 a	2,060 a
Spring	1993	CK	3,050 a	1,680 a
		X	2,990 a	1,630 a
		2X	3,150 a	1,710 a
		4X	2,970 a	1,630 a
	1994	CK	2,160 c	1,390 c
		X	2,690 b	1,730 b
		2X	4,030 a	2,620 a
		4X	2,730 b	1,780 b

In a column of the same crop season, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 4b. Means for yields of soybean, Kaohsiung sel.10, under the effects of direct incorporation of corn residues in the summer (1992—1993) and the spring (1993—1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields	
			Pod	Grain
			..... kg ha^{-1}	
Summer	1992	CK	2,800 a	1,670 a
		X	3,060 a	1,720 a
		2X	3,300 a	1,890 a
		4X	3,010 a	1,670 a
	1993	CK	2,790 a	1,490 a
		X	3,130 a	1,710 a
		2X	3,230 a	1,880 a
		4X	3,070 a	1,680 a
Spring	1993	CK	2,810 a	1,490 a
		X	2,870 a	1,560 a
		2X	3,050 a	1,670 a
		4X	2,850 a	1,540 a
	1994	CK	3,700 b	2,230 b
		X	4,080 a	2,510 a
		2X	3,850 ab	2,370 ab
		4X	3,620 b	2,250 b

In a column of the same crop season, means followed by a common letter are not significantly different at the 5% level by DMRT。

By analyzing the yield components, results indicated that 100-grain weight was the only element significant in Year, Variety, and Treatment in both growing seasons (Table 5). In separately, 100-grain weight of Nungyu 7 increased considerably in Summer 1993 by residue treatments (Table 6a) while Kaohsiung sel. 10 was significant in the summer crops (Table 6b). It was shown that growth characters such as leaf number and leaf area were stimulated by corn residues as well [19].

Results of the correlation analysis among yields and yield components were summarized in (Table 7.) Pod yield was the only factor positively correlated with grain yield in both varieties in both growing seasons. This demonstrates that as pod yield increased, grain yield showed a corresponding increase. For the tested varieties, grain number per pod was negatively correlated with 100-grain weight for Kaohsiung sel. 10 but not for Nungyu 7 (Table 8a and 8b).

Table 5. Combined analysis of variance on the effect of direct incorporation of corn residues to the yield components of soybeans, Nungyu 7 and Kaohsiung sel.10, in the summer (1992—1993) and the spring (1993—1994) crops.

Crop season	S.V.	D.F.	Mean square		
			Pod no.	Grain no.	100-g wt
			no. pl^{-1}	no. pod^{-1}	g
Summer	Block (B)/Y	6	2.1094*	49.7258	0.0160
	Year (Y)	1	180.8353**	52.0202	5.0794**
	Variety (V)	1	60.0238**	790.3127**	0.0749*
	Treatment (T)	3	3.8995**	33.8902	0.0630*
	Y×V	1	49.9142**	835.9327**	0.9629**
	Y×T	3	0.6640	64.0093*	0.0457*
	Y×T	3	1.3778	0.6243	0.0214
	Y×V×T	3	1.8055*	12.9660	0.0280
	Error	42	0.3364	20.7235	0.0140
Spring	Block (B)/Y	6	39.7591*	0.0140	0.5415
	Year (Y)	1	374.4709**	13.0321**	100.5006**
	Variety (V)	1	540.1557**	0.0012	82.7645**
	Treatment (T)	3	21.9745	0.0086	3.1794*
	Y×V	1	106.2703**	0.1702**	12.5139**
	Y×T	3	15.4635	0.0253	0.8326
	Y×T	3	3.7288	0.0052	0.5113
	Y×V×T	3	9.9722	0.0056	0.5179
	Error	42	8.5398	0.0155	0.8776

* and ** indicate significance at 5 and 1% levels, respectively。

Table 6a. Means for yields components of soybean, Nungyu 7, under the effect of direct incorporation of corn residues in the summer (1992-1993) and the spring (1993-1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields components		
			Pod no.	Grain no.	100-g wt
			no./pl	no./pod	g
Summer	1992	CK	46.4 a	1.5 a	17.34 a
		X	42.6 a	1.5 a	17.76 a
		2X	50.4 a	1.5 a	18.23 a
		4X	42.7 a	1.4 a	18.25 a
	1993	CK	35.4 a	2.2 a	14.89 b
		X	42.7 a	2.3 a	17.30 a
		2X	39.7 a	2.5 a	16.51 a
		4X	41.5 a	2.2 a	16.49 a
Spring	1993	CK	26.0 a	2.3 a	17.05 a
		X	24.8 a	2.3 a	17.74 a
		2X	26.0 a	2.4 a	18.07 a
		4X	24.6 a	2.3 a	17.79 a
	1994	CK	25.5 a	1.4 a	20.47 a
		X	27.8 a	1.3 a	21.05 a
		2X	29.7 a	1.3 a	21.18 a
		4X	27.4 a	1.4 a	21.51 a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 6b. Means for yield components of soybean, Kaohsiung sel. 10, under the effects of direct incorporation of corn residues in the summer (1992—1993) and the spring (1993—1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields components		
			Pod no.	Grain no.	100-g wt
			no./pl	no./pod	g
Summer	1992	CK	31.3 a	1.8 a	17.21 b
		X	30.5 a	1.8 a	17.60 ab
		2X	33.4 a	1.9 a	18.38 a
		4X	29.8 a	1.7 a	17.71 ab
	1993	CK	37.2 a	1.9 a	12.26 b
		X	41.5 a	2.1 a	11.93 b
		2X	41.5 a	2.2 a	12.64 ab
		4X	40.8 a	2.2 a	13.55 a
Spring	1993	CK	27.5 a	2.1 a	15.95 a
		X	27.7 a	2.3 a	16.00 a
		2X	31.7 a	2.2 a	17.25 a
		4X	27.5 a	2.2 a	15.88 a
	1994	CK	32.9 a	1.4 a	16.95 a
		X	37.9 a	1.4 a	18.52 a
		2X	35.9 a	1.4 a	18.19 a
		4X	37.3 a	1.5 a	17.92 a

In a column of the same crop seaeon, means followed by a common letter are not significantly different at the 5% level by DMRT。

Table 7. Correlation analysis among yields and yield components of soybean, Nungyu 7, and Kaohsiung sel. 10, under the effects of direct incorporation of corn residues in the summer (1992—1993) and the spring (1993—1994) crops.

Variable	Pod no.	Grain no.	100-g wt	Pod yield	Grain yield
Summer crop					
Pod no.	1.000	−0.128	−0.050	0.265	0.432
Grain no.		1.000	−0.538*	0.575*	0.295
100-g wt			1.000	0.184	0.378
Pod yield				1.000	0.858**
Grain yield					1.000
Spring crop					
Pod no.	1.000	−0.536*	−0.034	0.758**	0.778**
Grain no.		1.000	−0.700	−0.345	−0.629*
100-g wt			1.000	−0.028	0.275
Pod yield				1.000	0.940**
Grain yield					1.000

* and ** indicate significance at 5 and 1% levels, respectively.

Table 8a. Correlation analysis among yields and yield components of soybean, Nungyu 7, under the effects of direct incorporation of corn residues in the summer (1992-1993) and the spring (1993-1994) crops.

Variable	Pod no.	Grain no.	100-g wt	Pod yield	Grain yield
Summer crop					
Pod no.	1.000	−0.658	−0.793*	−0.519	−0.092
Grain no.		1.000	−0.725	0.910**	0.750*
100-g wt			1.000	−0.440	−0.292
Pod yield				1.000	0.811*
Grain yield					1.000
Spring crop					
Pod no.	1.000	−0.740	0.733	0.543	0.832*
Grain no.		1.000	−0.965**	0.085	−0.368
100-g wt			1.000	−0.058	0.382
Pod yield				1.000	0.894**
Grain yield					1.000

* and ** indicate significance at 5 and 1% levels, respectively.

Table 8b. Correlation analysis among yields and yield components of soybean, Kaohsiung sel. 10, under the effects of direct incorporation of corn residues in the summer (1992-1993) and the spring (1993-1994) crops.

Variable	Pod no.	Grain no.	100-g wt	Pod yield	Grain yield
Summer crop					
Pod no.	1.000	0.971**	−0.901**	0.293	0.094
Grain no.		1.000	−0.813*	0.384	0.195
100-g wt			1.000	0.068	0.273
Pod yield				1.000	0.876*
Grain yield					1.000
Spring crop					
Pod no.	1.000	−0.880*	0.976**	0.932**	0.946**
Grain no.		1.000	−0.808*	−0.955**	−0.967**
100-g wt			1.000	0.904**	0.907**
Pod yield				1.000	0.996**
Grain yield					1.000

* and ** indicate significance at 5 and 1% levels, respectively.

It is apparently from the results of this series of experiments, there is no negative effects of corn residues on the growth and yield of soybean up to quadruple amounts. In the routine field practice, therefore, incorporation of plant residues from the former corn crops before soybean is better than removal of them. Double amounts of residue is the best choice for yield concern, yet full amount treatment may also be selected when the production cost is taken into consideration.

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摘 要

本項研究係於1992—1994年在臺灣省農業試驗所農場進行田間試驗，以探討期作及年份間之玉米殘留物效應對大豆產量之影響。玉米（*Zea mays* L.）爲飼料玉米臺農一號，大豆〔*Glycine max*（L.）Merr.〕則爲高雄選十號及農育七號。當前作玉米收獲後，即依設計倍量將玉米植株地地上殘留物分置田面，直接以迴轉犁犁入土中，並於大豆播種前一週再予耕犁一次。殘留物計有0（對照組）、X（全倍量、相當於57,100株／公頃）、2X（兩倍量）、及4X（四倍量）等四種處理，期作分爲夏作及春作兩種。試驗顯示，直接將玉米植株殘留物混入土中對後作大豆產量具有正面作用。無論夏作或春作，莢果及籽粒產量在品種及處理間均呈現顯著差異，本文因此針對各別品種在不同期作及年份間進行分析與討論。對農育七號而言，處理間兩期作均以兩倍量殘留物對莢果及籽粒的增產效果最高；夏作時，1993年之莢果及籽粒產量皆高於1992年者；春作時，1994年之籽粒產量大於1993年者。兩倍量殘留物處理之籽粒產量在夏作及春作分別平均增產約27及41%。玉米殘留物對高雄選十號也具有類似增產效果，惟兩倍量殘留物處理之籽粒在夏作及春作分別平均增產19及9%。從合併變方分析的結果發現，產量性狀中僅百粒重在品種、處理、及期作間同時顯著差異。而相關分析的資料則顯示，唯有莢果產量與籽粒產量在兩參試品種及期作間呈顯著正相關，即籽粒產量隨著莢果產量的增加而升高。

關鍵詞：殘留物、玉米、大豆、產量、環境、期作。

1. 臺灣省農業試驗所 研究報告第 1748 號。本研究承蒙行政院農業委員會補助試驗經費〔81—農建—12.2—糧—31 (9)，82—科技—2.1—糧—39 (6)，及83—科技—2.1—糧—48 (6)〕，特以誌謝。
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