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Yield Loss in No-till Corn Due to Weed Interference and Environmental Impact[1]

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Abstract: Field experiments over 4 years (1991-1994) were conducted at Taiwan Agricultural Research Institute Experimental Farm to evaluate the effects of weed interference and environmental impact on yield loss of corn (*Zea mays* L. cv. Tainung No.1) under no-till condition. A significant effect was indicated in weeding treatments, environmental impact, and their interaction. Generally yields were reduced by 20% when multiple weed populations were allowed to interfere for 6 and 8 weeks after planting for the fall and the spring crops, respectively. Kernel yields were further reduced to 33 (Fall 1992) and 56% (Spring 1993), respectively, of weed-free plots in a full-season weed interference. Regression analysis showed that there was a linear relationship between weed dry weight and kernel yield. Yet, no such relationships were found between kernel yield and heat sum, precipitation, irradiance and sunshine hour, which implied a more complicated interactions than simple effects in environmental impact.

Key words: Corn, Yield, Weed interference, Environmental impact, Climatic factors, No-till.

INTRODUCTION

Corn is the major dryland crop sown on more than 80,000 ha annually for livestock forage and grain in Taiwan. In addition to the increase of yield potential and better quality, the decrease of production cost is another primary concern in producing this crop currently. No-till cultivation is one of the solutions while little works has been done to study the production strategy.

In no-till condition, weed and pest control as well as cultivation practices is the key to the success of crop management. Numerous reports have shown that yields were reduced if weeds were allowed to compete with crops in the field [1, 5, 6, 8, 10, 12]. But there are few studies in the literature of the ecomomic threshold duration of weed interference by multiple species in no-till corn. Weeding effort can be greatly improved when control practice is applid at this critical period.

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Sheu and Chu (1991) reported that there was a 15% short of kernel yield yet the expenditure was 13% less in no-till corn. Yang *et al.* (1993b) showed that acceptable yield may be maintained when weed interference was less than 6 weeks after planting under no-till. The magnitude of yield loss across years by weed interference and the effects of climatic factors on yield potential, however, are needed to be clarified.

This study estimate the degree of corn yield loss under no-till attributable to weed interference by multiple weed infestations and compare the environmental impact on such deficiency. Whether yield potential is related to weed density and climatic factors is also analyzed.

MATERIALS AND METHODS

Experiments were conducted at the Taiwan Agricultural Research Institute (TARI), Taichung Hsien, Taiwan (ROC) in 1991-1994. The loam soil was a Fluvaquentic Dystrochrept with a pH of 5.3 and 1.44% organic matter. The experimental plots were layout more than 6 months before planting (Table 1) and weeds were naturally occurring populations (Table 2). Fertilizer (N-P_2O_5-K_2O) was applied at 60-90-60 kg/ha each crop and additional nitrogen was applied at 3, 6 and 9 weeks after planting at a rate of 30 kg/ha. Pesticide 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methyl-carbamate was applied on soil surface after planting at 30 kg/ha (3% granule) and was sprayed on the canopy using 40.64% fluid at 1.2 L/ha in both 5 and 7 weeks after planting.

Table 1. The experimental layout for studying weed interference on no-till corn, "Tainung No.1", in 1991-1994.

Label	Treatment
Weed-free	weed-free throughout the growing season
W-1	1-week weed interference after planting
W-2	2-week weed interference after planting
W-4	4-week weed interference after planting
W-6	6-week weed interference after planting
W-8	8-week weed interference after planting
W-10	10-week weed interference after planting
Weedy	weedy throughout the growing season

Table 2. Naturally occurring populations of weed species and their proportions (>=5%) surveyed at 50% of tasseling in no-till corn field in 1991—1994.

Crop season	Weed species	Proportion
		%
Fall 1991	*Aqeratum houstonianum* Miller	57.7
	Echinochloa Colonum (L.) Link	10.8
	Cyperus rotundus L.	6.8
	Eleusine indica (L.) Gaertn.	6.3
	Aqeratum conyzoides L.	6.3
Spring 1992	*Diqitaria* spp.	35.0
	Aqeratum houstonianum Miller	30.0
	Echinochloa Colonum (L.) Link	23.5
Fall 1992	*Diqitaria* spp.	47.5
	Ageratum houstonianum Miller	20.0
	Echinochloa colonum (L.) Link	17.5
Spring 1993	*Ageratum houstonianum* Miller	37.5
	Digitaria spp.	15.0
	Ageratum conyzoides L.	12.0
	Polygonum lapathifolium L.	5.0
Fall 1993	*Ageratum houstonianum* Miller	45.0
	Echinochloa colonum (L.) Link	20.0
	Echinochloa Crus-galli (Beauv.) L.	15.0
	Diqitaria spp.	10.5
Spring 1994	*Aqeratum houstonianum* Miller	59.5
	Digitaria spp.	11.0
	Ageratum conyzoides L.	10.0
	Chenopodium serotinum L.	8.5

Seeds of corn cultivar Tainung No.1 were planted 0.04 m deep and subplots size was 7.0 m by 5.5 m (8 rows) with row and plant distance of 0.7 and 0.25 m, respectively, by hand. Population density was 57,100 plants ha^{-1}.

A square meter of weeds were sampled from the weedy subplots periodically throughout the growing season and their dry weights were recorded after oven-dried at 80°C for 72 h. The center 2-3 rows of plants were taken at harvest and yields were estimated by dry weights of ear (without husk) and kernel. The yield index was calculated as yield from weed interference divided by yield from weed-free check. The weather data were obtained from the weather station located at the experimental farm of TARI (24°02′ N, 120°40′ E, elevation 85 m) (Table 3) .

Table 3. Weather Conditions during the growing seasons of Corn, 'Tainung No.1', at the experimental farm of TARI, Taichung Hsien, Taiwan (1991—1994) .

Crop	Growing season	Heat sum	Precipitation	Irradiance	Sunshine hour
		°C	mm	MJ m^{-2}	h
Fall					
1991	7/15-10/18	2,581.2	443.5	1,654.1	482.3
1992	7/15-10/8	2,319.3	755.0	1,167.3	434.1
1993	7/15-10/18	2,575.9	228.0	1,460.6	634.0
Mean		2,492.1	475.5	1,427.3	516.8
Spring					
1992	1/8-5/20	2,558.3	643.0	1,307.9	455.5
1993	2/2-6/4	2,612.3	702.0	1,449.3	567.2
1994	1/5-5/11	2,478.4	507.0	1,284.4	419.9
Mean		2,549.7	617.3	1,347.2	480.9

The experiment was arranged as a randomizd complete block design with 3 replications. Duration of weed interference ranged from 0 (weed-free), 1, 2, 4, 6, 8 and 10 weeks after planting to full-season (weedy). Weeds were removed by hand at the desired periods and the subplots were handweeding every 2 weeks to keep weed free since then. The growing periods over 4 years were listed in Table 3. Data were subjected to analysis of variance and the appropriate testing was applied for statistics.

RESULTS AND DISCUSSION

Information on the economic threshold period of weed control is required to develop an integrated weed management system [7, 13]. It provides evidence of the length of time weeds can remain in a crop before they interfere with crop growth and reduce yield [9]. Whether such critical period varied with crop seasons and years is interested to verified.

Analyses of variance over years indicated that the effects of weed interference (Treatment, T) and environmental impact (Year, Y) to corn yields (ear and kernel) were significant in both the fall and the spring crops in all years (Table 5). A significant year by treatment interaction was also found for all data. Thus, yields were analyzed and presented separated for each year and weeding treatment (Tables 6a and 6b). As indicated, weeding treatments affected kernel yield and the magnitude varied with years (the environmental impact). Within years, generally reductions in corn yields increased as the duration of weed interference increased. Also, weed dry weight (Table 4) was significantly negatively correlated with kernel yield, graph is plotted using weedy check results (Figure 1). The importance of the individual weed species on corn yield, however, needs to be further studied.

Table 4. Mean and standard deviation of dry weights of weeds collected from no-till weedy corn field during the growing seasons of 1991-1994.

Crop	Growing season	Dry weight of weeds
		g m^{-2}
Fall	1991	500.1± 68.5*
	1992	518.7±135.2
	1993	259.6± 35.7
	Mean	426.1
Spring	1992	364.5± 42.3
	1993	294.4± 39.1
	1994	237.2± 40.4
	Mean	298.7

* Value is averaged over samplings from the growing season.

Table 5. Combined analysis of variance on the yield of Corn, 'Tainung No.1', under no-till Condition (1991-1994) .

Crop	S.V.	D.F.	Mean square Yield Ear	Mean square Yield Kernel
Fall	Block/Year	6	133,324	74,761
	Year(Y)	2	130,572,397 **	113,834,458 **
	Treatment(T)	7	4,731,545 **	4,793,954 **
	Y X T	14	982,744 **	638,149 **
	Error	42	160,565 **	106,946
Spring	Block/Year	6	72,625	117,987 *
	Year(Y)	2	15,295,616 **	10,008,609 **
	Treatment(T)	7	6,247,527 **	4,720,154 **
	Y X T	14	514,719 **	352,310 **
	Error	42	66,456	38,844

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

Table 6a. Means for yields of corn, 'Tainung No.1', in the fall crop under no-till condition (1991-1993) .

Teratment(T)	Year (Y) 1991	1992	1993	T-Mean
	.... kg ha^{-1}			
Ear				
Weed-free	4,260 a	6,070 a	8,440 a	6,260
W-1	4,040 ab	5,360 b	8,100 ab	5,830
W-2	3,980 ab	4,670 c	7,960 ab	5,540
W-4	3,580 ab	4,890 bc	7,960 ab	5,480
W-6	3,400 bc	3,700 d	7,910 ab	5,000
W-8	3,440 bc	2,850 e	7,730 abc	4,670
W-10	3,310 bc	2,830 e	7,620 bc	4,590
Weedy	2,760 c	2,290 e	7,140 c	4,160
Y-Mean	3,600	4,080	7,860	5,180
Kernel				
Weed-free	3,580 a	4,790 a	7,450 a	5,270
W-1	3,320 ab	4,240 b	7,050 ab	4,870
W-2	3,270 ab	3,880 b	7,000 ab	4,720
W-4	2,860 bc	3,820 b	6,870 b	4,520
W-6	2,600 cd	2,460 c	6,860 b	3,970
W-8	2,610 cd	1,960 cd	6,580 bc	3,720
W-10	2,510 cd	1,990 cd	6,300 cd	3,600
Weedy	2,060 d	1,580 d	5,790 d	3,140
Y-Mean	2,850	3,090	6,740	4,230

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

Table 6b. Means for yields of corn, 'Tainung No.1', in the spring crop under no-till condition (1992-1994) .

Teratment(T)	Year (Y)			T-Mean
	1992	1993	1994	
	....	kg ha^{-1}	....	
Ear				
Weed-free	5,230 a	6,410 a	7,100 a	6,250
W-1	5,330 a	6,390 a	6,920 ab	6,210
W-2	4,750 b	6,140 a	6,980 a	5,960
W-4	4,630 bc	6,140 a	6,780 ab	5,850
W-6	4,570 bc	6,050 a	6,480 b	5,700
W-8	4,260 cd	5,570 b	5,170 c	5,000
W-10	3,910 d	3,910 c	5,110 c	4,310
Weedy	3,980 d	3,700 c	4,780 c	4,150
Y-Mean	4,580	5,540	6,170	5,430
Kernel				
Weed-free	4,270 a	5,350 a	5,720 a	5,110
W-1	4,280 a	5,250 ab	5,660 a	5,060
W-2	3,860 b	5,080 ab	5,630 a	4,860
W-4	3,760 b	5,030 ab	5,500 a	4,760
W-6	3,660 b	4,960 b	5,130 b	4,580
W-8	3,300 c	4,550 c	4,060 c	3,970
W-10	3,110 c	3,160 d	4,000 c	3,420
Weedy	3,140 c	3,000 d	3,760 c	3,300
Y-Mean	3,670	4,550	4,930	4,380

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

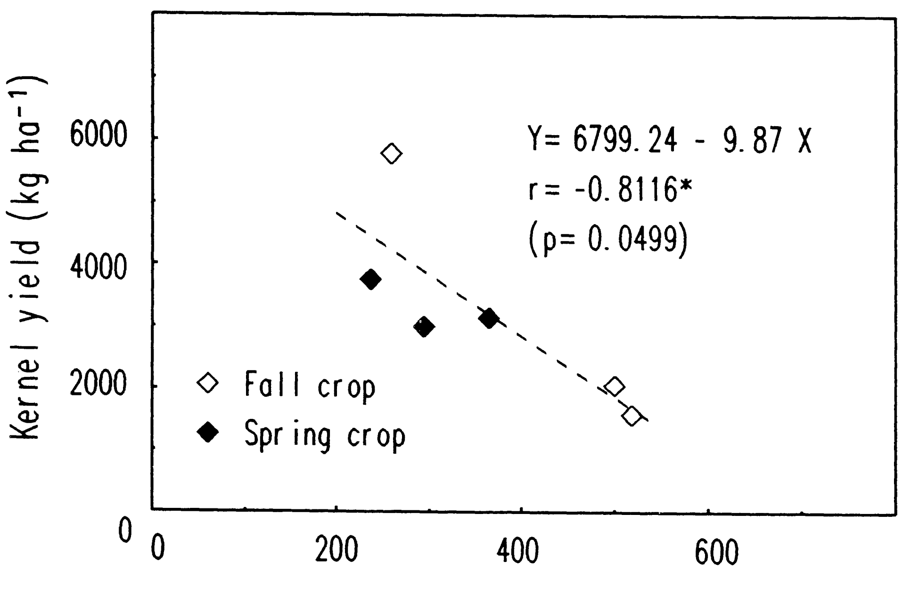

Fig. 1. Relationship between weed dry weight and kernel yield of weedy check of corn, Tainung No.1, under no-till condition in 1991-1994.

It showed that yields were reduced 20% when multiple weed populations were allowed to interfere for 6 and 8 weeks after planting for Fall and Spring, respectively (Figures 2a and 2b). The maximum reduction in corn ear and kernel yields were greater in Fall 1992 (62 and 67%) and Spring 1993 (42 and 44%) than in other years. The importance of weed interference duration to crop yields also has been reported in single weed species [1, 2, 3, 6, 9].

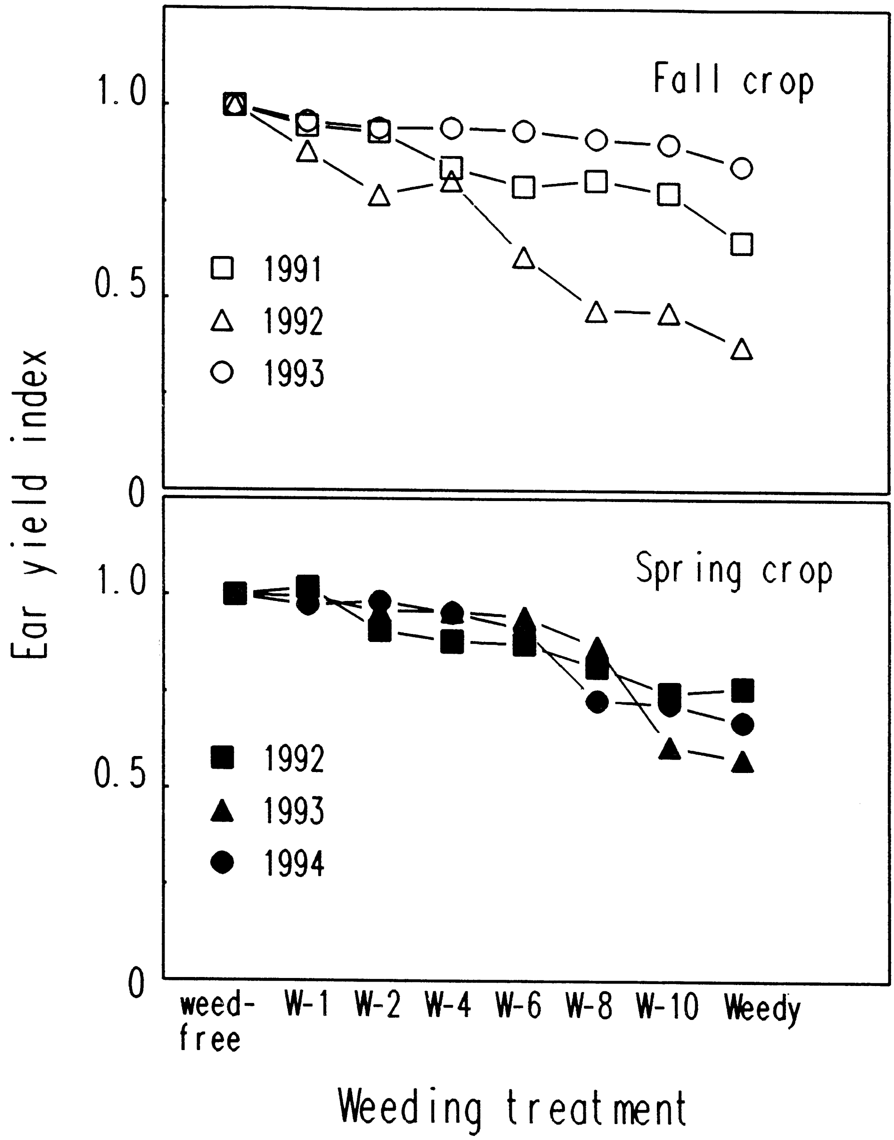

Fig. 2a. Effects of weeding treatment on ear yield index in the fall and the spring crops of corn, Tainung No.1, under no-till condition in 1991-1994.

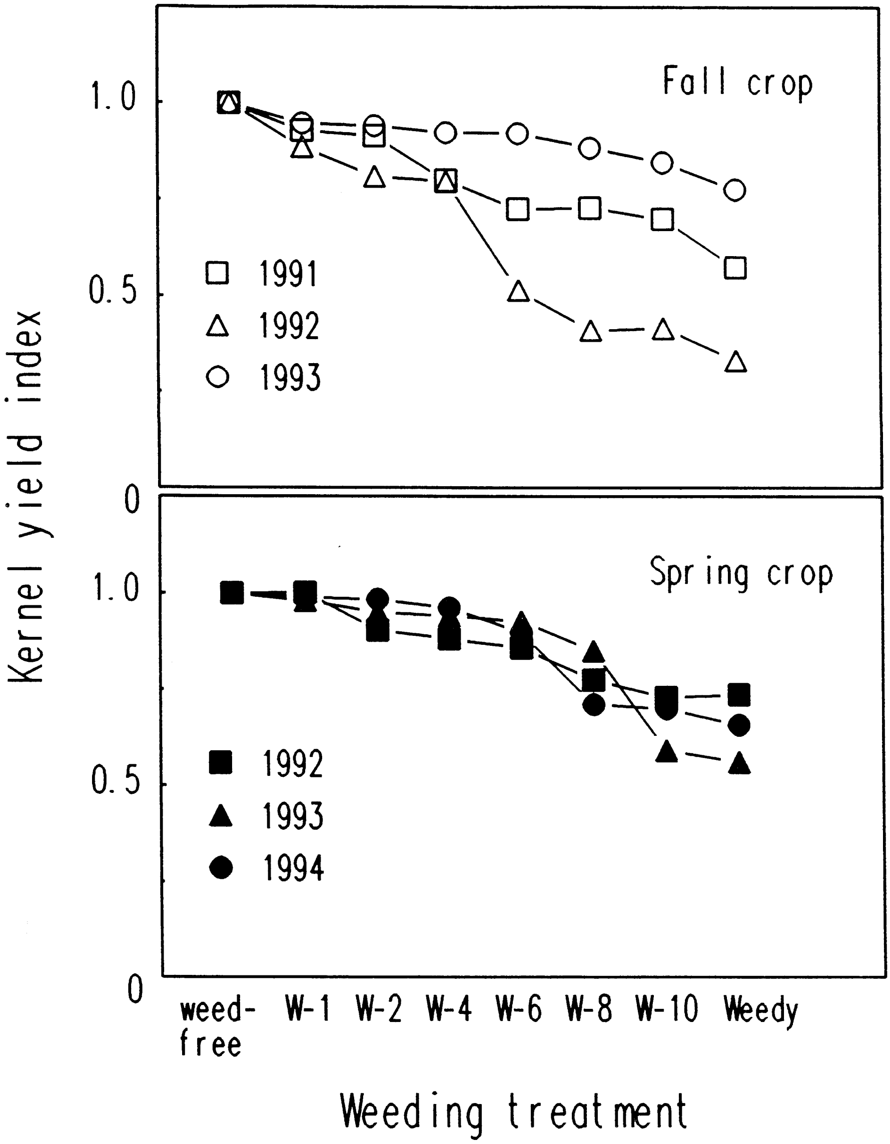

Fig. 2b. Effects of weeding treatment on kernel yield index in the fall and the spring crops of corn, Tainung No.1, under no-till condition in 1991-1994.

The previous report has shown the deleterious effect of multiple weed species, typically be faced by farmers, on no-till corn yields through the decreases of photosynthetic capacity (leaf area) and plant weight [12]. Hall *et al.* (1992) further pointed out that weed interference reduced corn leaf area by reducing the expanded leaf area of each individual leaf and accelerating senescence of lower leaves. The present study confirms the results and demonstrates that kernel yield was affected by weed density and can be lowered to less than 33%

(Fall crop) and 56% (Spring crop) of weed-free control for weedy check.

The weather conditions during the growing seasons of 1991-1994 were summarized in Table 3. It appeared that the growing period of Fall crops was shorter than Spring crops but the climatic factors were varied among growing seasons. By graphing the climatic factors with kernel yields of weed-free check, no simple linear relationships were established (Figure 3). A more complicated interactions among climatic factors rather than a simple one -to-one relationship is implied in delineating environmental impact. The result is no surprise since environment is the mixture of all variables as a whole and others such as soil properties, pests and weed species and densities may also exert great influence on corn growth and hence yield. The growth processes and yield mechanisms are so complicated that can not be correlated with a single factor. A more thorough study and analysis is required to clarify these relations.

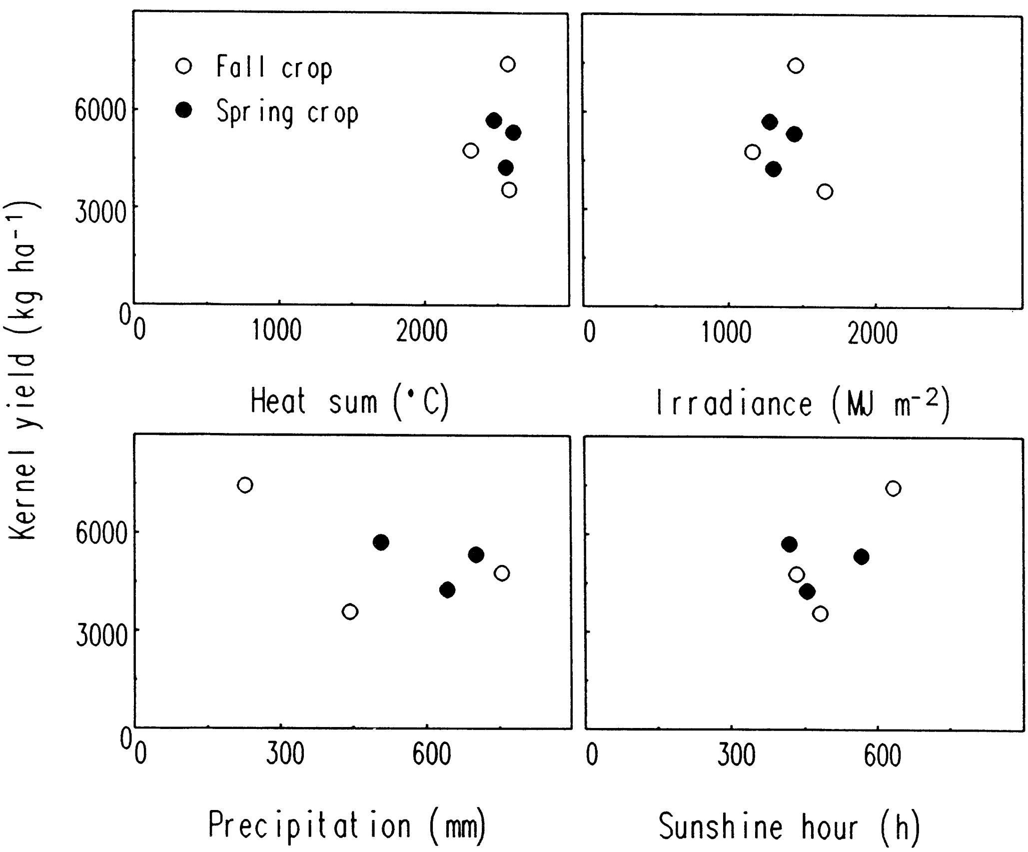

Fig. 3. Correlation between climatic factors and kernel yiels of weed-free check of corn, Tainung No.1, under no-till condition in 1991-1994.

As weed interference is proved to be a severe problem to no-till corn production, a cost effective weed control program is necessary and is recommended to be applied by 6 weeks after planting to prevent excessive yield loss.

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雜草干擾及環境效應對不整地栽培玉米減產之影響[1]

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摘　　要

本項研究係於1991-1994年在臺灣省農業試驗所農場進行田間試驗，以探討雜草干擾及環境效應對不整地栽培玉米減產之影響。參試品種爲飼料玉米臺農一號（*Zea mays* L. cv. Tainung No.1），雜草族群爲田間自然生長之不同種類者，除草措施則爲人工除草。雜草干擾處理計有八種，分別爲雜草干擾0（全期無草），1，2，4，6，8，及10週與全期雜草干擾等。根據試驗結果，雜草干擾時期長短、環境效應、及兩者交感均具有顯著差異。在試驗期間，大致上玉米之減產程度受到雜草干擾時期的影響。秋作雜草干擾六週、春作雜草干擾八週，玉米產量將減少約20%。全期雜草干擾最低可造成籽粒產量分別僅及全期無草處理區之33%（秋作）及56%（春作）。迴歸分析顯示，雜草乾重（雜草密度）與玉米籽粒產量呈直線關係，然而籽粒產量與全期熱位累積、降水量、日射量、及日照時數等氣象因子間並無此關係。顯然的，環境效應爲一多變因的複雜交感作用，玉米產量無法與個別氣象因子做出簡單的直線關係。

關鍵詞：玉米、產量、雜草干擾、環境效應、氣象因子、不整地。

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1. 臺灣省農業試驗所　研究報告第 1749 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-47(4)，82-科技-2.1-糧-33(4)，及83-科技-2.1-糧-11(4)〕，特此誌謝。
2. 本所農藝系副研究員及研究員。臺灣省　臺中縣　霧峰鄉。