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CORN GRAIN YIELD RESPONSES TO TILLAGE SYSTEMS AND PLANT DENSITIES

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ABSTRACT

An increasing shift from conventional systems of tillage to reduced-or no-tillage system has been recorded in many parts of the world. Limited research information is available on the interaction of plant density and tillage systems in corn (*Zea mays* L.). A two-year field study was conducted to evaluate the grain yield and yield components of corn in response to four tillage systems as plant density increased from 3 to 12 plants m^{-2}. Tillage treatments were moldboard plowing and disking (PD), chisel-plowing (CP), double disk (DD), and no-tillage (NT). Tillage method did not affect either biomass or grain yield; however, there were tillage effects on some yield components within particular years. Plant density significanty affected grain yield and all components of yield. Kernel number per row showed the highest sensivity to increasing plant density. Interaction of tillage systems and density on grain yield was not significant in 1987 but was significant in 1988. However, the effect of plant density on the grain yield response to tillage system was not considerable. In both years, NT produced slightly higher or equal grain yield as other tillage systems.

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پاسخ عملکرد دانه ذرت به روش های خاک ورزی و تراکم بوته

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به ترتیب دانشجوی سابق دوره دکترا (اکنون استادیار مجتمع عالی آموزشی و پژوهشی کشاورزی رامین، دانشگاه شهید چمران اهواز، ایران)، و استاد بخش علوم گیاهی و خاکشناسی دانشگاه ماساچوست، آمریکا.

چکیده

در بسیاری از نقاط د نیا تمایل به استفاده از روش های حد اقل شخم یا بدون شخم، بجای روش های مرسوم خاک ورزی، افزایش یافته است. اطلاعات تحقیقی اندکی در خصوص اثر متقابل تراکم بوته و روش های خاک ورزی در کشت ذرت دردست است. در یک آزمایش مزرعه ای دوساله پاسخ عملکرد دانه ذرت و اجزاء تشکیل دهنده آن نسبت به چهار روش خاک ورزی و سه میزان مختلف تراکم بوته مورد ارزیابی قرار گرفت. تیمارهای خاک ورزی عبارت بودند از شخم با گاو آهن برگردان دار و سپس دیسک (PD)، شخم با گاو آهن قلمی (CP)، دوبار دیسک (DD)، و بدون شخم (NT). تراکم بوته ۳، ۷/۵ و ۱۲ بوته در متر مربع بود تیمار خاک ورزی تاثیری بر بیوماس ویا عملکرد دانه نداشت، با این حال اثر روش خاک ورزی بر

بعضی از اجزاء عملکرد به سال انجام آزمایش بستگی داشت .تراکم بوته بر عملکرد و تمامی اجزاء عملکرد دانه تاثیرگذاشت. در میان اجزاء عملکرد، تعداد دانه در هر ردیف از حساسیت بیشتری بر خوردار بود. اثر متقابل روش های خاک ورزی و تراکم بوته در سال ۱۳۶۷ از نظر آماری معنی دار نبود ، در حالی که در سال ۱۳۶۸ معنی دار بود. در هر صورت، در هر دوسال ، تیمار بدون شخم (NT) درمقایسه با سایر روش های خاک ورزی عملکرد مشابه یا حتی اندکی بالاتر داشت.

INTRODUCTION

Tillage has traditionally been performed to prepare a seed bed, incorporate fertilizer, and control weeds. However, the use of minimum tillage practices is increasing in many parts of the world with increasing concern for soil and energy conservation (17).

Conservation tillage is a system of managing crop residue on the soil surface with minimum or no-tillage. Crop residues left on the soil surface usually reduce soil erosion and increase soil-moisture content when compared with conventional tillage systems (15). Organic matter levels in soil surface also tends to increase when no-till management replaces plowing (2, 3, 17, 18).

Many studies have shown that corn grain yield under minimum tillage practices can be equal to or even greater than yields under conventional practices(4, 13, 19, 20). However, it seems that satisfactory grain yield depends on soil type (6, 9), hybrid (1, 12), and planting date (11).

Elmore (5, 7) reported that, to achieve maximum yields for no-tillage and reduced-tillage in soybean, [(*Glysine max* (L.) Merrill], a planting rate of 57.3 seeds m^{-2} was necessary. This was 32% greater than the planting rate required to achieve equivalent yields in conventional tillage. Although tillage systems for corn have been studied intensively, much less research has been done to evaluate tillage systems at different plant densities. The research reported here was conducted to study the effect of planting rate on the response of corn grain yield to tillage systems.

MATERIALS AND METHODS

The study was conducted in 1987 and 1988 in a non-irrigated field in the Connecticut River Valley at the University of Massachusetts, Agricultural Experiment Station Farm at Deerfield. The soil type was a Hadley fine sandy loam (Typic Udifluvent, coarse-silty, mixed,nonacid, mesic). In 1987, the experimental site received 2200 kg ha^{-1} lime. A basal application of 66 kg N ha^{-1}, 30 kg P ha^{-1}, and 23 kg K ha^{-1} was broadcasted prior to planting and 100 kg N ha^{-1} as NH_4NO_3 was applied as a side dressing 4 weeks after planting. In 1988, the experimental site tested high for P and K, thus only N was added as NH_4No_3; 75 kg preplant N ha^{-1} and 95 kg sidedress N ha^{-1}. Weed control was similar both years and consisted of a pre-emergence application of 1.8 kg a.i ha^{-1}cyanazine {2-[[4-choro-6-(ethylamino)-1, 3, 5-triazin-2-yl]amino]-2-methyhlpropanenitrile} and 2.2 kg a.i. ha^{-1} alachlor {2- chloro-*N*-(2, 6-diethylphenyl)- *N*- (methoxymethyl) acetamide}.

A single-ear late maturity corn hybrid (Agway 584s) was planted on 10 May 1987 and 13 May 1988. A split-plot treatment arrangement with four replications in a randomized complete-block design was used. Tillage systems were assigned to main plots, and plant densities were assigned to sub-plots.The same main-plot randomization was used in both 1987 and 1988; i.e., position of the tillage plots was the same in both years. Four primary tillage systems consisted of: (i) mold board-plow (PD), (ii) chisel-plow(CD), (iii) double disking (DD), and (iv) no-tillage (NT). Disk was used as the secondary tillage for the PD, CD, and DD treatments.

Sub-plots consisted of 9 rows with a row spacing of 76 cm and length of 7 m. All plots were over-seeded, using a corn planter, and then thinned to desired densities of 3, 7.5, and 12 plants m^{-2} at 18 days after emergence (DAE). The final harvest area for measurement of grain and stover yields at maturity was 3 m^2 taken from the central row. Grain harvesting occurred after physiological maturity; 130 and 134 DAE in 1987 and 1988, respectively. The ears of all plants in the final harvest area were hand-picked and length and number of rows in each ear were measured. All ears were shelled, using a hand-sheller, cobs and kernels were dried in a forced-air oven at 70° C for at least 72 hr and weighed separately. Weight per kernel was determined from 1000 kernel sub-samples. Stover dry weight was measured by harvesting all plants (minus harvested ears) in the final harvest area. A three-plant sub-sample was chopped in the field before drying to determine moisture content.

Analysis of variance was performed using statistical analysis systems (SAS) software (16). The analysis of variance was determined using the general linear model (GLM).The mean separation among treatment was obtained by using a least significant difference (LSD) test.

RESULTS AND DISCUSSION

Year Effects

The results for 2 years were compared, considering year as a random variable (8). Grain yield in both years did not show a significant difference (Table 1). However, in 1988 grain yield was slightly higher than in 1987. This could be attributed to the differences in climatic conditions between the two years. In 1988, accumulated growing degree days (GDD) and total precipitation were higher than those for 1987 (Table 2).

Table 1. Year effects on grain yield and yield components of corn†.

Variable	1987	1988	LSD§	CV (%)
Yield (Mg ha^{-1})	7.03	7.29	NS	15
Kernel yield (g $plant^{-1}$)	117.6	121.2	NS	12
Ear $plant^{-1}$	0.90	0.94	0.02	6
Rows ear^{-1}	13.5	13.6	NS	3
Kernel row^{-1}	32.8	34.0	1.1	8
Kernel size (mg)	283.0	257.2	6.2	5

† Means of four tillage systems and three densities.

§ Fisher's least significant difference (P=0.05).

Table 2. Monthly means of growing degree days (GDD) † and precipitation during the corn growing season of 1987 and 1988.

	GDD		Precipitation (mm)	
Month	1987	1988	1987	1988
May	181	247	29.7	27.1
June	294	227	104.6	28.7
July	401	429	41.7	146.1
August	317	391	97.5	140.7
September	120	179	108.7	53.6
Total	1313	1517	382.3	441.2

†GDD was calculated by the following equation:

$$GDD = \sum [(T_{max} + T_{min})/2] - 10\,^{\circ}C$$

Yield components responded differently in the 2 years (Table 1). The number of productive ears per plant as well as the number of kernels per row in 1988 were greater than those in 1987. However, kernels were significantly heavier in 1987 compared to 1988. The latter could be partly due to fewer number of kernels produced in 1987. Reduction in the number of kernels provided more assimilate for the remainder of the seeds. Number of rows per ear was the most consistent component and did not change between the 2 years.

Tillage Effects

When averaged over densities, grain as well as biomass yields were not influenced by tillage systems, neither within years nor when averaged over the 2 years. Table 3 shows the results of analysis of variance for grain yield and the components of yield.

Yield components averaged over the 2 years also were not affected by tillage system; however, there were tillage effects on some yield components within aspecific year. For instance, tillage showed a significant effect on productive ear number in 1987 and individual kernel size in 1988.

Although the experiments were conducted in years that were climatologically different as reflected in Table 2, NT produced similar grain yields to other tillage systems. In fact, NT tended to out-yield other tillage systems within each plant density, even though the difference was not statistically significant (Table 4).

Results obtained in this study indicate that with good weed control, no-tillage system (NT) produces better or similar grain yield compared to the other three tillage systems used in this study. Wagger and Denton (19) reported a 32% higher yield in NT than conventional tillage (CT) in wheat. The advantage of NT over CT, however, was grater in the drier conditions where plant water stress symptoms were observed in the CT system. Similarly, Griffith *et al.* (9) showed that the relative advantage for no-till planted corn usually occurs in low organic matter soils. Other reports also show that NT usually produces higher grain yield than other tillage systems (14, 21).

Density Effects

Differences among plant densities were evident for all measured variables (Table 3). Density effects on grain yield were relatively consistent in both years. Regression analysis indicated that a parabolic response of grain yield occurs as density incrases. However, the response of biomass to increasing

Table 3. Analyses of variance for grain yield and yield components of corn in 1987 and 1988 as affected by tillage systems and plant density.

Source	df	1987				1988			
		Grain yield	Ear number	Kernel number	Kernel size	Grain yield	Ear number	Kernel number	Kernel size
Block	3	NS[†]	NS	NS	*	NS	NS	*	NS
Tillage(T)	3	NS	*	NS	NS	NS	NS	NS	*
Error A	9								
Density (D)	2	**	**	**	**	**	**	**	**
T X D	6	NS	NS	NS	NS	*	NS	NS	NS
Error B	24								

[†] NS Indicates nonsignificant ($p>0.05$).

*,** Indicates significant effect at a probability level of 0.05 and 0.01, respectively.

Table 4. Tillage systems† and plant density effects on corn grain yield and yield components (averaged over 2 years).

Density	Grain yield($Mg\ ha^{-1}$)				Ear plant $^{-1}$				Kernel row^{-1}				Kernel size(mg)			
(plant m^{-2})	PD	CD	DD	NT	PD	CD	DD	NT	PD	CD	DD	NT	PD	CD	DD	NT
3	5.63	5.55	5.05	5.84	1.00	1.00	0.99	1.00	42.9	43.3	39.2	41.2	316	312	310	333
7.5	7.42	8.38	7.98	8.20	0.93	0.96	0.96	0.95	31.7	32.9	31.7	32.9	251	261	261	258
12.0	7.26	7.61	8.56	8.46	0.77	0.80	0.86	0.82	25.5	26.1	26.6	26.7	237	231	234	239
mean	6.77	7.18	7.20	7.50	0.90	0.92	0.94	0.92	33.4	34.1	32.5	33.6	268	268	268	277
$LSD_{(0.05)}$		0.75				0.05				1.8				8.6		
CV,(%)		15.00				6.00				8.0				6.0		

† See the text for the definition of tillage systems.

Table 5. Effect of plant density on grain yield components. Results are average of 4 tillage systems.

	Ear plant^{-1}		Row ear^{-1}		Kernel row^{-1}		Weight kernel^{-1} (mg)	
Density (Plants m^{-2})	87	88	87	88	87	88	87	88
							mg	
3.	1.00a	1.00a	14.0a	13.9a	40.3a	43.0a	336a	300a
7.5	0.92b	0.98a	13.6b	13.6a	31.3b	33.3b	271b	245b
12	0.79c	0.84b	13.1c	13.2b	26.8c	25.6c	244c	227c

†Means within columns followed by the same letter are not significantly different.($p= 0.05$)

density was asymptotic (data not shown). Kernel number per row was the yield component affected most with increasing plant density (Table 5). The amounts of reduction in kernel number averaged over tillage systems were 34% and 40% in 1987 and 1988, respectively, as density increased from 3 to 12 plants m^{-2}. Other yield components such as number of productive ears per plant were reduced with increasing plant density. For the highest plant density the percent of barren stalks were 21 and 16%, in 1987 and 1988, respectively. Kernels of high density plants were approximately 25% lighter by weight compared to low density plants. Although significant, the reduction in kernel row number per ear was less than 6% between low density and high density in both years. This is in agreement with our earlier report (10) that the number of kernel rows per ear is the most stable yield component in density increase.

Plant Density Effects on Tillage Systems

In this study, plant density had little effect on the grain yield response to tillage systems. There was no density x tillage interaction for grain yield and/ or other yield components in 1987 (Table 3). However, in 1988 plant density affected the pattern of grain yield response to tillage systems. While PD resulted in slightly higher yields in low densities, reduced tillage (DD and NT) produced higher grain yields in denser plant populations.

In summary, no-tillage (NT) produced similar grain yield compared to the other tillage system used in this study. Plant density showed very little effect on the grain yield response to tillage system.

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