Korean J. Crop Sci. 47(5): 384~389(2002)

Growth and Yield Performance in no-till Cultivation of *sugary* and *shrunken-2* Corn Hybrids

Myoung Hoon Lee†

Dept. of Plant Resources, Dongguk Univ., Seoul 100-715, Korea

ABSTRACT: No-tillage (NT) practice for corn production has advantages of reduction of soil erosion and energy conservation. Research on effects of NT for sweet corn or super sweet corn is very limited. Hybrids of *sugary* (*su*) and *shrunken-2* (*sh2*) were tested under NT and conventional tillage (CT) practices to investigate plant characters, ear characters, fresh yield, and grain yield. *Sugary* hybrids were Golden Cross Bantam 70 (GCB70), Sprint, Geumdanok, and Danok3. *Shrunken-2* hybrids were BSS9472, Cambella90, GSS9299, Jubilee, KS-Y-65, and Chodangok1. Emergence rates under NT were lower than those under CT for *su*, while there was no difference between tillage systems for *sh2*. There were no differences between CT and NT for days to tasseling and silking, plant height, and ear height for both *su* and *sh2*. Ear characters such as ear length, number of kernel rows, number of kernels per row, and 100-kernel weight under NT were not significantly different from those under CT. There were no differences between two tillage practice for fresh and grain yield, rather they showed trend of increases under NT practices. Results from this trial indicate that NT practice for both *su* and *sh2* cultivation may be possible to recommend to farmers.

***Keywords*:** No-tillage, Conventional tillage, *Sugary* sweet corn, *Shrunken-2* super sweet corn

Reduced soil erosion, energy conservation, and high profitability would be advantages expected from reduced tillage and no-tillage (NT) practices for corn production. NT corn production is appropriate for highly erodible land, but concern among producers about potential yield reductions has limited its adoption in many areas. Many factors can limit corn yields, but cool and wet soil conditions, high accumulation of crop residue, and pooly drained soils are of great concern to many NT corn producers. Producer acceptance of NT is slow, due to lack of knowledge of the economics as well as other benefits of conservation tillage, Producers concern decrease of crop yields and inadequacy of weed control. Regardless of the environmental benefits, producers will not widely adopt NT practices unless these practices are economically sustainable.

Generally, corn production from NT practices has been compared favorably with production resulting from CT practice. Corn yields from NT have been reported as similar to or exceeding yields from CT on well-drained soils when optimum rates of fertilizer N are used (Blevins *et al.*, 1983; Meisinger *et al.*, 1985). At suboptimal fertilizer N rates, yields were generally greater in CT as compared with NT practice. NT management frequently required higher fertilizer N rates to obtain maximum yields, however, maximum NT yields were greater than maximum CT yields (Evanylo, 1990; Meisinger *et al.*, 1985). The NT systems resulted in greater economic returns, compared with a CT system, and lower production costs in all years (Smart & Bradford, 1999).

Corn yield and grain N content are often higher in NT because NT crops are more efficient at removing soil-N than CT crops (Angle *et al.*, 1993). In contrast, Olson & Kurtz (1982) found more N deficiency symptoms in corn with NT than with CT. Furthermore, tillage practices cause soil disturbance, which contribute to a decline in available soil N (McCarthy *et al.*, 1995), probably due to sufficient precipitation. The lack of soil mixing for extended periods of time associated with continuous NT has resulted in stratification of relatively immobile nutrient such as K (Ketchenson, 1980; Mackay *et al.*, 1987). K concentrations were higher in the surface 5 or 10 cm and lower below 10 cm than those of CT.

NT practice decreases N availability for crops due to potentially greater losses and immobilization (Fox & Bandel, 1986). Corn N requirement under NT is greater with respect to N requirement under CT (Meisinger *et al.*, 1985). Surface urea applications under NT have a low efficiency, due to potential NH_3 volatilization losses during urea hydrolization (Fox & Piekielek, 1993; Joo *et al.*, 1992; Watson *et al.*, 1994). Therefore, it is necessary to develop fertilization management suitable for maximizing fertilizer N recovery through decreasing N losses. Fertilization at six-leaf stage is more efficient than the application at planting, particularly under NT (Fox *et al.*, 1986; Wells *et al.*, 1992).

On poorly drained soils, especially during years of normal or above-normal precipitation, corn yields have generally

†Corresponding author: (Phone) 02-2260-3310 (E-mail) mhoonlee@dgu.ac.kr <Received November 22, 2002>

been less in NT than CT management when continuous corn was grown, regardless of rate of fertilizer N (Dick & Van Doren, 1985). NT corn production could be viable management strategy in drier climate with irrigation (Sims *et al.*, 1998) They suggested that tillage might be necessary to maintain optimum production levels when soil temperatures are cool. When spring soil temperatures are warm, NT strategies can be used for optimum production levels. In a long-term periods of tillage experiment in Ohio, NT corn initially yielded less than the moldboard plow treatment on a poorly drained fine textured soil, but similar yields were recorded during the later years (Dick *et al.*, 1991). They reported that on a well-drained soil, NT proved to be consistently superior to moldboard plowing with yield differences increasing with increasing years.

Poor weed control is often the limiting factor in the adoption of NT crop production systems (Gebhardt *et al.*, 1985; Koskinen & McWhorter, 1986). The selection of effective herbicides and the appropriate timing of application are important factors in controlling perennial weeds. Corn producers are concerned that insect levels might increase in NT corn. Berry & Ghidiu (1989) reported increased insect levels under NT in the U. S., although they speculated that corn plant size and stage of development relative to the time of insect emergence influence insect population more than tillage did. The NT treatment resulted in delayed silk emergence of 2 to 4 days compared with the spring plow and the fall plow treatment (Vyn & Raimbault, 1993). Al-Darby & Lowery (1984) also found that silk emergence with NT was delayed compared with fall plow.

Most of the NT studies were carried out on field corn and no researches were reported on sweet corn. In Korea, main production area of corn is mountainous slope land, therefore, benefits of NT practice in this land would be higher than those of plain area. The objective of this research was to evaluate the effect of NT practice compared with CT and to investigate the responses of different hybrids on yield and major characters.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Station of the Dongguk University in 2001. *Sugary* sweet corn and *shrunken-2* super sweet corn hybrids were planted under NT and CT practices. The experimental design was a split-plot within a randomized complete block with three replications. The main-plots were tillage systems and sub-plots were each hybrids. Hybrids of *sugary* sweet corn were GCB70 (Golden Cross Bantam70), Geumdanok, Sprint, and Danok3. GCB70 and Sprint were imported hybrids. GCB70 has been widely grown in domestic production of *sugary* sweet corn. Geumdanok and Danok3 were developed at the National Crop Experiment Station. Danok3 which has been released to farmers recently is a promising good hybrid to compete with GCB70. Hybrids of *shrunken-2* super sweet corn were BSS9472, Cambella90, GSS9299, Jubilee, KS-Y-65, and Chodangok1. All the hybrids except Chodangok1 were introduced from the USA. Among the imported hybrids, Cambella90 has been cultivated in domestic super sweet corn production and has been popular to the consumers. It has been growing recently in a large scale in some area of Gangwon and Gyeongbuk Provinces.

Herbicide round-up was applied to NT plot to kill perennial and annual weeds at three weeks before planting. Herbicide alachlor and simazine were applied to all plots after planting. The rates of fertilizers N-P_2O_5-K_2O were 180-100-100 kg/ha. The ratio of basal and sidedressing application of nitrogen and potassium was 70:30. The sidedressing was applied after final thinning. Phosphate was applied at basal application. Fertilizer was applied at the surface of the soil for NT system. Planting rows were spaced 60 cm apart and the distance between plant was 25 cm. Plot size was two rows with 5 m in length. Planting was formed with small garden spade for NT systems. Nylon string, marked up every 25 cm, was used to keep correct planting distance. Three seeds were planted per hill and thinned to two plants after data collection for emergence rate. Final thinning to one plant per hill was done at tassel initiation stages.

Plant heights were measured three times to investigate the growth responses under NT system. Fresh ears of each plot were harvested at 25 days after silk appearance. Fresh yield, ear characters such as ear length, number of kernel rows, and number of kernels per row were measured using 10 ears per plot. Grain yield was corrected to 15 % moisture contents.

RESULTS AND DISCUSSION

Sugary sweet corn

Emergence rates under NT were lower than those under CT in all hybrids (Table 1). Mean emergence rate under NT was 10% lower than that of CT. This low emergence rate might be due to irregular soil surface condition and shallow planting depth under NT. Emergence rate of NT ranged 58% to 88%, indicating that emergence problem would be solved by planting more seeds per hill. There were no differences between CT and NT for days to tasseling and silking. Plant heights at 30 days after planting and tassel initiation stage showed no differences between CT and NT. Plant heights of four hybrids under NT were taller than those under CT. This result shows that growth at late stages was more vigorous

Table 1. Emergence rate, days to flowering, plant and ear height of *sugary* sweet corn hybrids.

Tillage practice[1)]	Hybrid	Emergence rate	Days to tasseling	Days to silking	PH-1[2)]	PH-2[3)]	PH[4)]	EH[5)]
		%	---------days---------			------------cm-------------		
CT	GCB70	76.4	49.0	51.3	26	104	195	47
	Geumdanok	83.8	47.0	47.0	36	112	185	57
	Sprint	88.4	49.0	49.3	28	110	192	53
	Danok3	95.8	48.3	51.3	36	121	202	57
	Mean	86.1	48.3	49.8	32	112	193	53
NT	GCB70	57.9	48.0	51.0	27	103	197	43
	Geumdanok	78.7	47.3	48.0	28	109	188	48
	Sprint	77.3	48.7	50.3	28	109	198	60
	Danok3	88.4	47.3	50.0	35	122	213	63
	Mean	75.6	47.8	49.8	30	111	199	54
F-test	T	*	NS	NS	NS	NS	NS	NS
	H	**	*	**	**	**	**	**
	T × H	NS	NS	NS	*	NS	NS	NS

1)Tillage practice: CT= Conventional tillage, NT= No-tillage.
2)PH-1 : Plant height at 30 days after planting.
3)PH-2 : Plant height at tassel initiation stage.
4)PH : Plant height.
5)EH : Ear height.

Table 2. Ear characters and yields of *sugary* sweet corn hybrids.

Tillage practice[1)]	Hybrid	Ear length	No. of kernel rows	No. of kernels per row	100-kernel weight	Fresh yield	Grain yield
		cm	--------no.--------		g	------t/ha-----	
CT	GCB70	14.4	12.9	23.5	18.2	19.71	3.56
	Geumdanok	13.7	14.6	25.7	19.3	24.15	4.09
	Sprint	12.3	16.2	17.6	19.2	20.22	2.98
	Danok3	15.0	13.8	27.4	15.4	22.71	3.53
	Mean	13.8	14.4	23.5	18.0	21.70	3.54
NT	GCB70	14.8	12.5	24.7	19.0	21.40	3.56
	Geumdanok	13.0	14.3	25.1	18.6	23.60	4.21
	Sprint	12.9	16.1	17.6	18.3	20.62	2.99
	Danok3	15.5	14.0	26.5	15.9	22.69	3.65
	Mean	14.0	14.2	23.5	18.1	22.08	3.60
F-test	T	NS	NS	NS	NS	NS	NS
	H	**	**	**	**	**	**
	T × H	NS	NS	NS	NS	NS	NS

1)Tillage practice: CT= Conventional tillage, NT= No-tillage.

under NT due to high moisture content. Sims *et al.* (1998) reported NT corn production would be more desirable in drier condition. Drought was severe during the growing period even though sprinkler irrigation was done. Ear characters such as ear length, number of kernel rows, number of kernels per row, and 100-kernel weight were not significantly different between CT and NT (Table 2). All of these ear characters were significantly different between hybrids.

Fresh yield which is an important trait for commercial value of sweet corn production showed no significant difference between CT and NT. This result implies that NT would be possible production management of sweet corn for reduction of soil erosion, and energy conservation. GCB70, which is the most popular hybrids for domestic sweet corn production, was 8.5% higher under NT compared with CT for fresh yield. This suggests that further research under different

Table 3. Emergence rate, days to flowering, plant, and ear height of *shrunken-2* super sweet corn hybrids.

Tillage practice[1)]	Hybrid	Emergence rate	Days to tasseling	Days to silking	PH-1[2)]	PH-2[3)]	PH[4)]	EH[5)]
		%	--------days---------		---------------cm--------------			
CT	BSS9472	81.5	52.3	55.0	25	92	202	55
	Cambella90	57.4	52.0	53.7	31	104	200	62
	GSS9299	80.3	53.0	55.0	23	92	193	53
	Jubilee	66.6	55.3	57.0	20	86	225	65
	KS-Y-65	61.6	53.3	55.7	26	96	215	60
	Chodangok1	51.8	49.0	50.3	24	99	173	45
	Mean	66.5	52.5	54.5	25	95	201	57
NT	BSS9472	73.6	51.3	53.0	26	97	200	52
	Cambella90	75.9	52.0	52.3	34	108	210	50
	GSS9299	86.6	51.3	52.7	28	103	193	53
	Jubilee	56.5	53.0	54.7	26	93	235	70
	KS-Y-65	58.1	52.0	53.3	26	100	228	68
	Chodangok1	52.8	48.7	50.0	28	106	187	52
	Mean	67.2	51.4	52.7	28	101	209	58
F-test	T	NS	*	*	NS	NS	NS	NS
	H	**	**	**	**	**	**	**
	T × H	NS	**	NS	NS	NS	NS	NS

1)Tillage practice: CT= Conventional tillage, NT= No-tillage.
2)PH-1 : Plant height at 30 days after planting.
3)PH-2 : Plant height at tassel initiation statge.
4)PH : Plant height.
5)EH : Ear height.

Table 4. Ear characters, fresh and grain yields of *shrunken-2* super sweet corn hybrids.

Tillage practice[1)]	Hybrid	Ear length	No. of kernel rows	No. of kernels per row	100-kernel weight	Fresh yield	Grain yield
		cm	--------no.-------		g	------t/ha-----	
CT	BSS9472	15.3	15.3	29.5	9.7	23.87	3.23
	Cambella90	15.0	17.6	29.7	10.3	27.95	3.01
	GSS9299	15.5	17.3	32.1	11.2	27.02	3.51
	Jubilee	15.0	16.4	27.4	11.8	29.07	2.76
	KS-Y-65	16.2	16.6	29.9	10.1	32.27	3.35
	Chodangok1	13.8	13.3	25.1	10.2	20.09	2.23
	Mean	15.2	16.1	29.0	10.6	26.71	3.02
NT	BSS9472	15.2	16.1	29.7	11.1	25.09	3.18
	Cambella90	15.8	17.1	29.5	11.2	30.58	3.14
	GSS9299	16.3	17.5	33.9	10.0	29.51	3.58
	Jubilee	15.8	17.2	29.7	12.0	30.91	3.13
	KS-Y-65	16.6	15.9	31.7	11.7	32.91	3.67
	Chodangok1	13.3	13.3	25.3	10.8	21.07	2.47
	Mean	15.5	16.2	30.0	11.2	28.35	3.19
F-test	T	NS	NS	NS	NS	NS	NS
	H	**	**	**	*	**	**
	T × H	NS	NS	NS	*	NS	NS

1)Tillage practice: CT= Conventional tillage, NT= No-tillage.

Table 5. Correlation coefficients among plant, and ear characters, and yields of *su* and *sh2*.

	EM	TA	SI	PH-1	PH-2	PH	EH	EL	ROW	KNL	WT	FRESH	GRAIN
Emergence rate (EM)		-0.03	-0.16	0.66**	0.81**	0.21	0.70**	-0.02	0.44*	0.11	-0.57**	0.26	-0.06
Days to tasseling (TA)	0.30		0.64**	-0.57**	-0.35	0.06	-0.20	-0.28	0.20	-0.66**	0.07	-0.93**	-0.82**
Days to silking (SI)	0.30	0.96**		-0.26	-0.03	0.62*	-0.15	0.49*	-0.40	-0.03	-0.48*	-0.64**	-0.54**
Plant height at 30DAP[1)](PH-1)	0.03	-0.35*	-0.46**		0.85**	0.28	0.69**	0.44*	0.02	0.59**	-0.58**	0.71**	0.33
Plant height at TIS[2)](PH-2)	-0.14	-0.67**	-0.77**	0.88**		0.59**	0.79**	0.41*	0.16	0.42*	-0.82**	0.49*	0.07
Plant height (PH)	-0.09	0.73**	0.65**	-0.09	-0.37*		0.47*	0.68**	-0.19	0.22	-0.81**	-0.14	-0.32
Ear height (EH)	-0.29**	0.63**	0.62**	-0.19	-0.38*	0.88**		0.09	0.54**	-0.04	-0.52**	0.26	-0.20
Ear length (EL)	0.45**	0.59**	0.53**	0.12	-0.12	0.62**	0.48**		-0.77**	0.77**	-0.68**	0.20	0.26
Kernel row (ROW)	0.48**	0.69**	0.61**	0.23	-0.11	0.49**	0.43**	0.76**		-0.73**	0.22	-0.10	-0.48*
Kernel per row (KNL)	0.65**	0.40*	0.38*	0.15	-0.02	0.29	0.26	0.86**	0.78**		-0.50*	0.69**	0.77**
100-Kernel weight (WT)	-0.23	0.38*	0.22	-0.19	-0.26	0.64**	0.54**	0.16	0.21	0.00		-0.18	0.02
Fresh yield (FRESH)	0.14	0.68**	0.57**	0.17	-0.07	0.80**	0.68**	0.89**	0.77**	0.66**	0.39*		0.80**
Grain yield (GRAIN)	0.58**	0.46**	0.46**	0.11	-0.08	0.44**	0.36*	0.91**	0.71**	0.95**	0.07	0.72**	

1)DAP, days after planting.
2)TIS, tassel initiation stage.
*Above diagonal: *su*.
Below diagonal: *sh2*.

environmental condition would be necessary to introduce the NT management. It has been reported that NT would be more desirable in dry climate than wet climate. Drought is common during growing season in domestic sweet corn production, especially at germination and seedling stages. Irrigation is not practical method to solve the drought problem in slope land of mountainous region because sweet corn cultivation is small in scale. Grain yield was measured for the purpose of dry seed production estimation under NT management. This grain yield response would be useful for the estimation of F_1 seed production of sweet corn hybrid. It would be possible to introduce NT method for sweet corn production because no reduction of both fresh and grain yields were observed under NT.

Highly significant positive correlations between emergence rate and plant heights at early stages were observed indicating that good emergence is important for vigorous seedling growth (Table 5). Days to tasseling and silking were negatively correlated with fresh and grain yield. This results were different from the general positive correlation of field corn.

Shrunken-2 super sweet corn

Emergence rate, days to flowering, plant heights, and ear height are showed in Table 3. There was no difference between CT and NT for emergence rate. This result was different from that of *sugary* sweet corn. The *shrunken-2* seed has been reported for lower germination rate because of low starch content compared with *sugary* sweet corn. Among the six hybrids tested, three hybrids showed higher emergence rate under NT than under CT. This trend implies that *sh2* hybrids seed would be more advantageous for emergence under NT condition. Mean days to tasseling and silking under NT were delayed 1 to 2 days compared with CT. This observation was similar to the report (Sims *et al.* 1998). Plant heights at 30 days after planting and tassel initiation stages under NT were not significant compared with CT. However, mean plant heights under NT were 3 to 6 cm taller than those under CT. This vigorous growth might be due to the higher emergence rate. This trend continued to the final stages.

Ear length, number of kernel rows, number of kernels per row, and 100-kernel weight are shown in Table 4. These ear characters under NT were not significantly different compared with CT. A little higher values were observed for all ear characters indicating advantages of NT. Fresh yield was not significantly different between CT and NT. However, mean fresh yield under NT was 6.1% higher compared with CT and yield increase under NT were observed in all hybrids tested in this trial. From this trend, it would be possible to introduce NT cultivation for *sh2* production. In particular, hybrid Cambella90 which is popularly grown in domestic *sh2* production recently, increased 9.4% of fresh yield under NT. Grain yield showed similar trend to fresh yield in five hybrids among six hybrids. This grain yield data would support the advantages of NT management. From this trial, introduction of NT management for *sh2* production would be considered as a practical and economical method.

Days to tasseling and silking were positively correlated with plant height, ear height, ear length, number of kernel rows, number of kernels per row, fresh yield, and grain yield. Fresh and grain yields were positively correlated plant height, ear height and ear characters except a few cases. These correlations suggests that late maturity hybrids would be more desirable for *sh2* production.

ACKNOWLEDGEMENTS

This work was supported by the Dongguk University Research Fund.

REFERENCES

Al-Darby, A. M., and B. Lowery. 1984. Effects of conservation tillage on corn growth. Pap. 84-1033. ASAE, St. Joseph. MI.

Angle, J. S., C. M. Gross, R. L. Hill, and M. S. McIntosh. 1993. Soil nitrate concentrations under corn as affected by tillage, manure, and fertilizer applications. *J. Environ. Qual.* 22 : 141-147.

Berry, E. C., and G. M. Ghidiu. 1989. Effect of conservation tillage on European corn borer (Lepidoptera: Pyralidae) populations. *Environ. Entomol.* 18 : 917-920.

Blevins, R. L., G. W. Thomas, M. S. Smith, W. W. Frye, and P. L. Cornelius. 1983. Changes in soil properties after 10 years continuous non-tilled and conventionally tilled corn. *Soil Tillage Res.* 3 : 135-146.

Dick, W. A., and D. M. Van Doren, Jr. 1985. Continuous tillage and rotation combinations effects on corn, soybean, and oat yields. *Agron. J.* 77 : 459-465.

Dick, W. A., E. L. McCoy, W. M. Edwards, and R. Lal. 1991. Continuous application of no-tillage to Ohio soils. *Agron. J.* 83 : 65-73.

Evanylo, G. K. 1990. Dry corn response to tillage and nitrogen fertilization. I. Growth-yield-N relationships. *Commun. Soil Sci. Plant Anal.* 21 :137-151.

Fox, R. H., J. M. Kern, and W. P. Piekielek. 1986. Nitrogen fertilizer source, and method and time of application effects on no-till maize yields and nitrogen uptakes. *Agron. J.* 78 : 741-746.

Fox, R. H., and V. A. Bandel. 1986. Nitrogen utilization with no-tillage. p.117-225. In M. A. Sprague and G. B. Triplett (ed.) No-tillage and surface-tillage agriculture: The tillage revolution. John Wiley & Sons. New York.

Fox, R. H., and W. P. Piekielek. 1993. Management and urease inhibitor effects on nitrogen use efficiency in no-till corn. *J. Prod. Agric.* 6 : 195-200.

Gebhardt, M. R., T. C. Daniel, E. E. Schweizer, and R. R. Allmaras. 1985. Conservation tillage. Science (Washington, DC) 230 : 625-630.

Joo, Y. K., N. E. Christians, G. T. Spear, and J. M. Bremner. 1992. Evaluation of urease inhibitors as urea amendments for use on Kentucky bluegrass turf. *Crop Sci.* 32 : 1397-1401.

Ketchenson, W. J. 1980. Effect of tillage on fertilizer requirements for corn on a silt loam soil. *Agron. J.* 72 : 540-542.

Koskinen, W. C., and C. G. McWhorter. 1986. Weed control in conservation tillage. *J. Soil Water Conserv.* 41 : 365-370.

Mackay, A. D., E. J. Kladivko, S. A. Barber, and D. R. Griffith. 1987. Phosphorous and potassium uptake by corn in conservation tillage systems. *Soil Sci. Soc. Am. J.* 51 : 970-974.

McCarthy, G. W., J. J. Meisinger, and F. M. M. Jenniskens. 1995. Relationship between total-N, biomass-N and active-N under different tillage and fertilizer treatments. *Soil Biol. Biochem.* 27(10) : 1245-1250.

Meisinger, J. J., V. A. Bandel, G. Stanford, and J. O. Legg. 1985. Nitrogen utilization of maize under minimal tillage and moldboard plow tillage: . Four-year results using labeled N fertilizer on an Atlantic costal plain soil. *Agron. J.* 77 : 602-611.

Olson, R. A., and L. T. Kurtz. 1982. Crop nitrogen requirements, utilization and fertilization. p.567-599. In F. J. Stevenson *et al.*(ed.) Nitrogen in agricultural soils. Agron. Monogr. 22. ASA, CSSA, and SSSA, Madisom, WI.

Sims, A. L., S. S. James, R. A. Olson, and J. F. Power. 1998. Irrigated corn yield and nitrogen accumulation response in a comparison of no-till and conventional till: Tillage and surface-residue variables. *Agron. J.* 90 : 630-637.

Smart, J. R., and J. M. Bradford. 1999. Conservation tillage corn production for a semiarid, subtropical environment. *Agron. J.* 91 : 116-121.

Vyn, T. J., and B. A. Raimnault. 1993. Longer-term effect of five tillage systems on corn response and soil structure. *Agron. J.* 85 :1074-1079.

Watson, C. J., H. Miller, P. Poland, D. J. Kilpatrick, M. D. B. Allen, M. K. Garrett, and C. B. Christianson. 1994. Soil properties and the ability of the urease inhibitor N-(n-butyl) thiophosphoric triamide(nBTPT) to reduce ammonia volatilization from surface-applied urea. *Soil Biol. Biochem.* 9 : 1165-1169.

Wells, K. L., W. O. Thom. and H. B. Rice. 1992. Response of no-till corn to nitrogen source, rate, and time of application. *K. Prod. Agric.* 5 : 607-610.