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Conservation Tillage Systems for Spring Corn in the Semihumid to Arid Areas of China

Cai Dianxiong, Wang Xiaobin, Zhang Zhitian, Gao Xuke and Zhang Jingqing*

ABSTRACT

The field experiments were conducted in the dry farming experimental site located in Shouyang, Shanxi province in the semi-humid to arid area. The paper discusses the effects of conservation tillage systems (reduced tillage or no-till and mulching) on wind erosion control, water conservation, corn seedling emergence, yield, and water use efficiency (WUE). The field experiments involved two sets of conservation tillage systems for spring corn in Shouyang and other similar dryland areas: (1) using subsoiling between rows or no-till with the whole corn stalk mulching after harvest in fall, and seeding in the next spring with one pass seed and fertilizer application by no-till planter, in combination with weed control by herbicides; (2) using deep plowing with incorporated straw and fertilizers after harvest in the fall, next year harrowing in spring and rolling before sowing, then one pass seeding by machinery or by animal. The two sets of conservation tillage systems have shown promise to reduce water loss, soil erosion, energy, and increase corn yield and improve water use efficiency.

INTRODUCTION

Conservation farming is not a new phenomenon for China. For last 20 years, conservation tillage practices (including reduced tillage and no-till) have been practiced as a result of the low mechanization level. Research on conservation tillage in China has only recently started. Facing severe problems with land degradation, especially wind and water erosion involving over 80% of farmland in dry farming areas of northern China, research on conservation tillage is being given more consideration for preventing the decline in land productivity. Since the 1980's studies on conservation tillage in combination with machinery and agronomy have been conducted in the southeast and middle part areas of Shanxi early or late, according to the farmland conditions in the semihumid to arid area of northern China. The recent study results on different tillage methods for spring corn in Shouyang, Shanxi will be discussed.

MATERIAL AND METHODS

Shouyang Dryland Farming Experimental Station is in Shouyang County, Shanxi Province, located in the semi-humid to arid, continental monsoon climatic zone (112°4' 113°26' East longitude, 37°32' 38°6′ North latitude). The average annual open pan water evaporation varies from 1600 to 1800 mm, which is 3 times as much as the total annual rainfall of 520 mm. There are 4 distinct seasons with big seasonal temperature differences in the areas. The frost-free period is about 130 days. The area of spring corn, one crop per year, accounts for over 50% of the total area of food crops. The elevation of the area is around 1066-1159 m above sea level. Severe water loss and soil erosion, as well as soil denudation by natural climatic factors (such as precipitation and monsoon) causes the formation of an eroded landscape in the loess hills.

The experiments on corn were conducted on a sandy clay cinnamon soil. The organic matter, total N, available N (NH_4^++NO_3^-), and Olsen's P content of the soil were 23.8 g kg^{-1}, 0.956 g kg^{-1}, 56.1 mg kg^{-1}, and 1.8 mg kg^{-1}, respectively. Treatments with four replications were included as follows.

1) **CT (conventional tillage):** plowing and harrowing in fall; plowing and applying fertilizers in the next spring, then harrowing and seeding by animal (or machinery), weed control by hand
2) **NT1 (no-till with standing corn stalk):** keeping the corn stalk standing after harvest in fall, and using one pass seed and fertilizer application with a no-till planter in spring, in combination with weed control by herbicides
3) **NT2 (no-till with the whole corn stalk mulching):** keeping the whole corn stalk mulching on the fields after harvest in fall; and using one pass seed and fertilizer application with a no-till planter in spring, in combination with weed control by herbicides
4) **MT1 (minimum tillage i.e. deep plowing with fertilizers and corn stalk incorporated):** using deep plowing with incorporated straw and chemical fertilizers in fall; harrowing in early spring and rolling before sowing, then one pass seeding by machinery or by animal
5) **MT2 (minimum tillage i.e. subsoiling with the whole corn stalk mulching):** taking subsoiling between rows (at 60 cm interval) and keeping the whole corn stalk mulching after harvest in fall; and using one pass seed and fertilizer application with a no-till planter in spring, in combination with weed control by herbicides
6) **Mulch-before:** mulching before seedling emergence (after sowing) based on the treatment (4)

*D.X. Cai, X.B.Wang, Z.T. Zhang, X. Gao and J.Q. Zhang, Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences, 12 Zhongguancun Nandajie, Beijing 100081 PR China. *Corresponding author: dxcai@caas.ac.cn

7) **Mulch-after:** mulching after seedling emergence based on the treatment (4)

The area of each plot was 387 m^2. The no-till planter was designed by China Agricultural University. The corn-seeding rate (cv. Chidan 14) was 30 kg ha^{-1}.

The 0-200 cm soil was sampled before sowing and after harvest, using a gravimetric method with oven drying for soil water measurement, and at the same time using cutting rings with a volume of 100 cm^3 for bulk density measurement. The 10-cm soil temperature was calculated by averaging the daily 8:30, 12:00 and 18:00 temperature measured using soil thermometer. The seedling emergence and growth population were determined by counting plant numbers from two 3-m-long rows of each plot, and the mean plant height was measured from 6 plants in the rows. The topsoil loss by wind erosion was determined by measuring the increase in the height of each cylinder with a 9.5-cm diameter and an 11.5-cm height for a 8-h period.

RESULTS AND DISCUSSION

Soil Physical Conditions of the Seed Bed

Soil Water Content Before Sowing

Soil water contents (0-60 cm) before sowing increased 6-15 mm with NT and MT methods compared with CT (Table 1), except in 1994 when more soil water resulted from the last wet winter fallow (89.4 mm) and the wet spring season (41.7 mm). Therefore, conservation tillage practices are favorable to ease soil drought and ensure seedling emergence of spring crop, especially, under severe dry conditions.

Soil Bulk Density after Sowing

Compared with CT, the bulk densities were higher with NT. During the whole year, there was little change in the bulk densities (0-10 cm) under NT treatments (Fig. 1). After plowing in fall, the bulk density declined by 0.32, 0.35 and

Table 1 Effects of tillage methods on soil water (0-60 cm) before sowing

Treatment	1993		1994		1995	
	mm	-CK*	mm	-CK*	mm	-CK*
CT	99	-	147	-	115	-
NT 1	107	8	145	-2	128	13
NT 2	109	10	150	3	126	11
MT 1	114	15	152	5	126	11
MT 2	105	6	147	0	130	15

Note:
CT=conventional tillage;
NT1=no-till with standing corn stalk;
NT2=no-till with the whole corn stalk mulching;
MT1=minimum tillage i.e. plowing with fertilizer and corn stalk incorporated;
MT2=minimum tillage i.e. subsoiling with the whole corn stalk mulching
*Difference from conventional

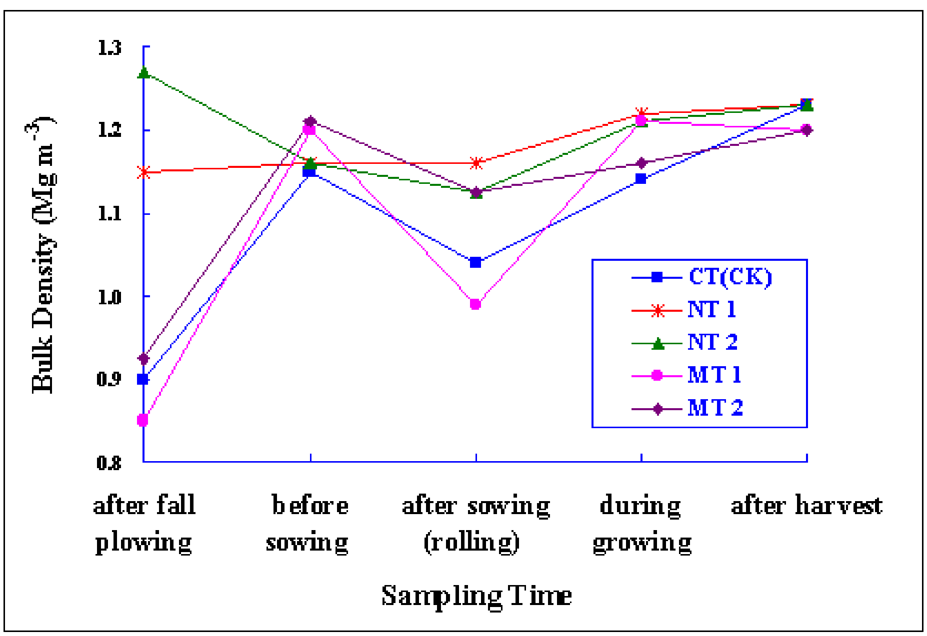

Figure 1. Changes in soil bulk densities in 0-10 cm layer in the whole year under different tillage treatments.

0.26 Mg m^{-3} with CT, MT 1 (plowing with stalk incorporated), and MT 2 (subsoiling), respectively. The bulk densities after sowing declined to 1.04 and 0.99Mg m^{-3} with CT and MT 1, respectively. The bulk densities with NT and MT 2 were about 1.14 Mg m^{-3}, which is suitable for spring corn seedling emergence. Rolling after sowing was needed with CT and MT 1 to increase the surface bulk density for seedling emergence.

Soil Temperature at Seedling Period

The soil temperature was influenced by different surface treatments. The surface temperature was 2-6º lower with mulching after sowing than with CT (Fig. 2). The surface temperature with MT was slightly lower than CT but higher than the treatment with mulching after sowing. The lower soil temperature during seedling period with mulching and MT was associated with the higher bulk densities and the increased soil water, which caused the increased heat capacity and slower changes in soil temperature.

Seedling Emergence and Growth

Spring corn seedling emergence was 2-3 days earlier and increased 17%-23% with conservation tillage practices compared with CT in the spring of 1993 that was proceeded by a dry winter fallow. The seedling emergence was the best with MT1 (plowing with straw incorporated), then with MT2 (subsoiling), and also better with NT compared with CT (Fig. 3). The seedling emergence was not influenced by tillage methods in the year with a wet spring season (1994). The plants with MT1 and with mulching after seedling emergence grew most quickly (Table 2). During the period from June 3 to July 1, the plant with MT1 was 6-11 cm higher than with CT. However, the plant growth with mulching after sowing was slower, its height measured on July 1 was 18 cm lower compared with CT, apparently influenced by the lower soil temperature. There was not much difference among other treatments.

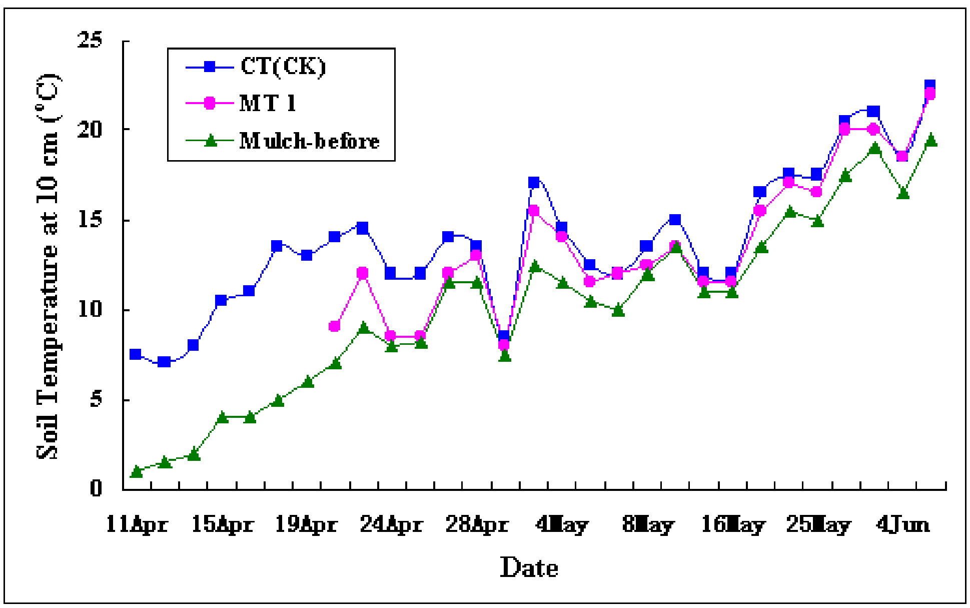

Figure 2. Changes in daily average temperature at 10-cm layer during the period of sowing to seedling emergence under different tillage treatments.

Table 2. The effect of tillage methods on the height (cm) of spring corn.

Treatments	June 3	June 10	June 16	June 21	June 26	July 1
CT	20	33	47	64	81	99
NT 1	22	36	52	67	84	103
NT 2	21	31	46	62	80	97
MT 1	27	38	57	75	94	110
MT 2	18	25	41	59	73	94
Mulch-before	22	34	49	67	71	81
Mulch-after	26	41	55	72	89	105

Note: Mulch-before = mulching before seedling emergence (after sowing);
Mulch after = mulching after seedling emergence

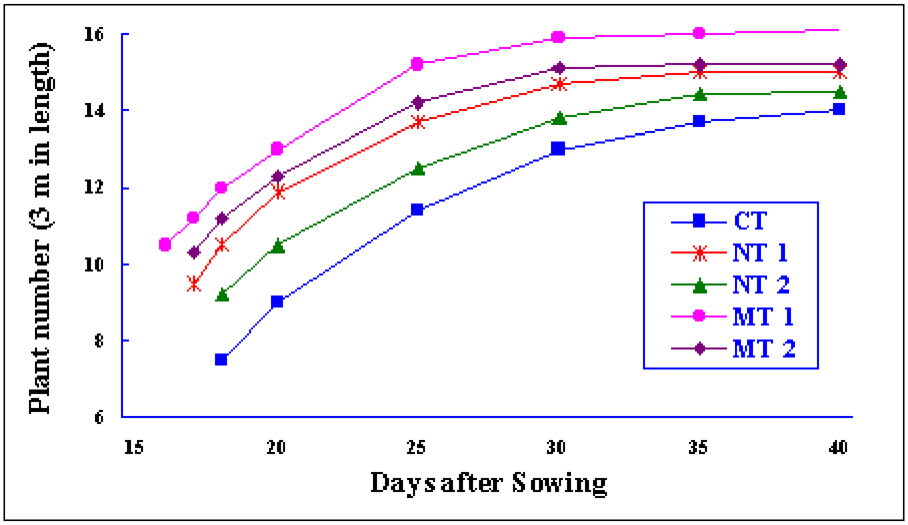

Figure 3. The effect of tillage methods on the speed of seedling emergence (1993).

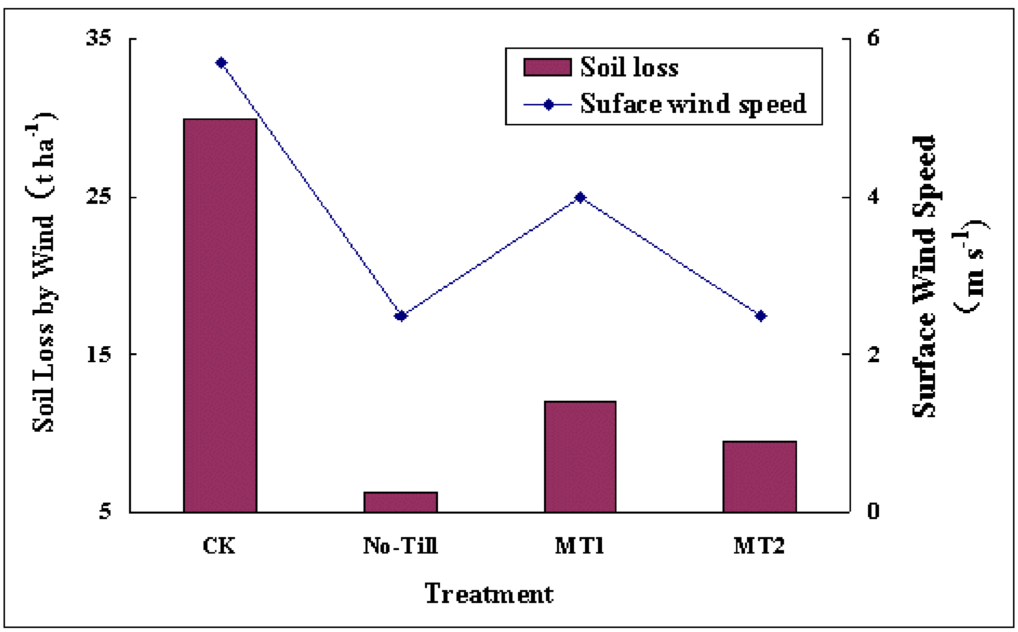

Figure 4. The effects of tillage methods on wind erosion control.

Impact on Wind Erosion

The 8-hour soil loss by wind erosion was measured when the wind speed was 8.4 m s^{-1} at 1 m above ground surface, showing the effects in reducing wind erosion with conservation was reduced by 60%, 68% and 79% with MT1, MT2 and NT, respectively, and the wind speed on the surface reduced by 29%, 56tillage. The soil loss was 29.7 t ha^{-1} with CT treatment (Fig. 4). As compared with CT, the soil loss % and 56% with MT1, MT2 and NT, respectively. This indicated that conservation tillage practices are good for protecting the topsoil from wind erosion, due to the increased residual cover on the surface.

Spring Corn Yield and WUE

The higher yields were obtained with conservation tillage practices compared with CT, except one case of yield reduction with the treatment of mulching after sowing, which was caused by the lower soil temperature at seeding. The highest yields were obtained with MT1 (plowing with straw incorporated) and treatment 7 (mulching after seedling emergence). MT1 increased yield by 27% and 35% in 1993 (although suffering from a hailstorm) and 1994, respectively; treatment 7 increased yield by 55% and 9% in 1993 and 1994, respectively (Table 3). The yield was also higher with NT 2 and MT 2 than with CT treatment. WUE increased with conservation tillage, for example, MT1 increased WUE by 36% and 29% in 1993 and in 1994 respectively.

Table 3. Effects of tillage methods on spring corn yield and WUE.

Treatments	1993 Yield (kg ha^{-1})	1993 increase %	1993 WUE (kg mm^{-1} ha^{-1})	1994 Yield (kg ha^{-1})	1994 increase %	1994 WUE (kg mm^{-1}ha^{-1})
CT	2612	-	6.3	5166	-	10.8
NT 1	2993	14.6	7.5	5181	0.3	11.9
NT 2	3188	22.1	8.3	5465	5.8	11.9
MT 1	3303	26.5	8.6	6966	34.8	14.3
MT 2	3092	18.4	8.3	5462	5.7	12.2
Mulch-before	2298	-12.0	6.3	4890	-5.3	11.9
Mulch-after	4059	55.4	11.0	5634	9.1	12.2

CONCLUSIONS

The nutrient level in most of the soil is low due to extensive cultivation, low input fertilizer, undeveloped husbandry production, insufficient organic manure source, and little use of crop straw.

Conservation tillage practices increased the 0-60 cm soil water before sowing, thus are favorable to ease soil drought and ensure seedling emergence of spring crop, especially, under the severe dry conditions.

The bulk density with no-till and reduced tillage were relatively higher, which is suitable for seedling emergence of spring corn. Rolling after sowing was needed with fall plowing treatments to create a suitable bulk density for seedling emergence.

Conservation tillage practices are good for protecting the topsoil from wind erosion due to the increased residue cover on the surface.

The field experimental results suggested benefits and further development of two conservation tillage systems for spring corn in Shouyang, China and other similar dryland areas.

1) **Using subsoiling between rows or no-till with the whole corn stalk mulching after harvest in fall,** and seeding in the next spring with a one pass seed and fertilizer application by a no-till planter, in combination with weed control by herbicides;
2) **Using deep plowing with incorporated straw and fertilizers after harvest in fall,** next year harrowing in the spring and rolling before sowing, then one pass seeding by machinery or by animal.

The two sets of conservation tillage systems have shown promise to reduce water and soil erosion, save energy, increase corn yield, and improve water use efficiency.