EFFECT OF CONSERVATION TILLAGE IN A CORN-OAT ROTATION SYSTEM ON CORN AND FORAGE OAT YIELD IN THE NORTH-CENTRAL REGION OF MEXICO

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ABSTRACT

The objective of this study was to assess the effect of different tillage methods in an irrigated corn-oat rotation system on corn grain, stubble, and forage oat yield. Seven tillage methods were evaluated: 1) traditional plow and disk (P+D), 2) disturbing the upper 0-4 in layer (D), 3) without disturbing the upper 0-4 in layer (ND), 4) zero tillage with 0% soil cover (ZT+0%SC), 5) zero tillage with 33% soil cover (ZT+33%SC), 6) zero tillage with 66% soil cover (ZT+66%SC), and 7) zero tillage with 100% soil cover (ZT+100%SC). In each year from 1996 to 2001, corn was sowed on the spring while forage oat was growth during the fall-winter season. A statistical analysis for the six-year period for grain corn, stubble, and forage oat yield was performed. Corn grain yield results showed statistical differences among treatments ($p \leq 0.05$), where ZT+66%SC was the best treatment, surpassing by 90% the corn yield registered with P+D. The statistical analysis for corn stubble yield showed not differences ($p \geq 0.05$) among treatments, however, with ZT+66%SC corn stubble production was increased 9.35 ton acre^{-1} compared with that of P+D, indicating that farmers can use 5.45 ton acre^{-1} to cover at least 33% of the soil surface. Forage oat yield within the seven treatments were not statistically different ($p \geq 0.05$), but all ZT treatments did not plow the soil. Conclusions for this study were that corn and forage oat can be growth without plowing the soil, increasing corn production and keeping stable that of forage oat.

INTRODUCTION

"The truth is that nobody has ever exposed a scientific reason to till." This phrase was mentioned for Edward H. Faulkner in the decade of the 1940s, and he largely was criticized for his contemporaries (Faulkner, 1974). Nevertheless, currently it is given him the reason by questioning the efficiency of plowing the soil to produce crops. Techniques such as conservation tillage have been developed with excellent results in several regions around the world, but as it happened with plowing and disking, it should not be accepted without local scientific evidences.

With his research results, Faulkner showed that erosion, soil impoverishment, and yield reduction are the results of inadequate soil management by farmers. He challenged the technological advancement at his time about how to produce crops, declaring that plow is and has been the main enemy of soils. He assured that by leaving crop residues on the soil surface, instead of burring them at the bottom of the soil profile removed by plow, and by weathering effects, the necessary soil organic matter for the next crop would be produced. For more than a century, scientists and farmers have accepted the use of plow and disk without any reserve.

Plow's adoption has been without any discrimination for all soil types, climates, and crops. Technical guides recommended by research, teaching, and extension institutions present the use of

plow and disk as the only option of soil tillage before sowing. In Mexico, conservation tillage has been promoted to farmers in the last 30 years with unsuccessful results, therefore the actual area at national level with conservation tillage does not surpass 10,000 acres, which is minimum compared with that of other Latin-American countries such as Brazil, where in recent years, conservation tillage has been implemented in 34 million acres (Claverán, 2000).

Soil erosion is one of the main problems that threaten the sustainability of agriculture, so that development of production systems with a sustainable scope should be a priority to satisfy production and quality demands of consumers (Osuna, 2000).

Conservation tillage is one of the most viable options to achieve the sustainability of natural resources such as soil and water, and crop yields (Angeles and Rendón, 1994 and Valdes et al., 1994). With conservation tillage, soil is protected of water and wind erosion, lost of nutriments is reduced, more soil water is available to plants, and soil organic matter, infiltration, and flora and fauna are increased (Figueroa 1975, Figueroa 1982 and 1983, Jasso 1985, Barron 1987 and Osuna 1987).

Among the main constraints to adopt conservation tillage in the semiarid zones in Mexico's north-central region, are: low diffusion among farmers, need of specialized machinery, use of herbicide, and above all that, the utilization of stubble to feed animals (Salazar et al., 1994). The use of crop residues as soil mulch is a key factor to succeed in conservation tillage, given that greater the quantity of residues left as soil mulch, greater will be the soil protection against erosion. The use of crop residues, especially corn stubble, to feed animals is a strong constraint in the north-central zone of Mexico, therefore development of agricultural systems with conservation tillage should contemplates diversification and increase of forage production (Cabrera 1988).

Finally, the conservation tillage concept which involves the combination of zero tillage with 30% of crop residues as soil mulch should be modified according with different agricultural systems, soils, climate and crops to avoid the same mistake made with plowing and disking as a unique option of soil till. (Sanchez 1975 and Ramirez 1982). The objective of this study was to assess the effect of different tillage methods in an irrigated corn-oat rotation system on corn grain, stubble, and forage oat yield.

MATERIALS AND METHODS

From 1996 to 2001, an irrigated corn-forage oat rotation system was conducted in the Experimental Station San Luis, in San Luis Potosi, Mexico. The site has a clay soil texture, a tempered dry climate, an annual average temperature of 61.16 ^{o}F, a frost free period from April to September, and an annual average rainfall of 7.77 inches (CGSNEGI, 1995). Seven tillage methods were evaluated: 1) traditional plow and disk (P+D), 2) disturbing the upper 0-4 inches layer (D), 3) without disturbing the upper 0-4 inches layer (ND), 4) zero tillage with 0% soil cover (ZT+0%SC), 5) zero tillage with 33% soil cover (ZT+33%SC), 6) zero tillage with 66% soil cover (ZT+66%SC), and 7) zero tillage with 100% soil cover (ZT+100%SC). A randomized block design with two repetitions was employed. Corn was seeding in the spring while oat was in the fall of each year. Genotype for corn was the hybrid H-311 with 24,282 plants per acre and the genotype for oat was the variety Cuauhtemoc with a density of 53.54 lb acre^{-1}. It was employed a zero tillage planter with wavy disk al front to cut the stubble. For fertilization and pet's control, local INIFAP's recommendations were followed. Before sowing, weeds in the zero tillage treatments were controlled with Glifosfato (0.214 gal acre^{-1}) and after planting, weeds were eliminated with herbicide (0.214 gal acre^{-1}), which was applied with protected bell type sprayers so the main crop was not damaged. Each crop was

irrigated when a deflection of 40% of the available soil moisture was registered. To make easy the conduction of water, beds of 1.7 m were built, and two lines of plants were sowed. Corn was sown in rows separated 0.33 inches among them and 0.078 inches among plants. After harvesting the corn, each year, 5.45 ton acre^{-1} of stubble was chopped on the top of the beds and furrows were reconstructed once a year. Four rows of oat were planted in each bed. Corn and oat forage yield was evaluated by samplings 103.34 ft^2 plots and the average of five years was analyzed. During the growing season of 2001, soil water content was monitored in the stratums of 0-38.1 inches and 38.1-76.2 inches. Results were statistically analyzed according with the experimental design employed by using the Statistical Analyses System (SAS Institute, 1995).

RESULTS AND DISCUSSION

Corn and oat yields are presented in Table 1. There was not statistical difference among tillage treatments ($p \geq 0.05$). However, a trend to increase the productivity of forage oat in 16% with ZT+0%SC compared to that of P+D was observed. These results were an indicator that soil structure destruction by plowing and disking the soil were not a limited factor in the sprout, emergence, establishment, growth, and yield of forage oat. Since the plow was introduced, the affirmation that plowing and disking the soil is beneficial for all crops has been made without local scientific evidences.

Table 1. Forage oat, corn grain, and stubble yiels (ton acre^{-1}) in an irrigated corn-forage oat rotation with different soil tillage. San Luis Potosi, Mexico.

Treatments	Forage oat (DM)	Corn grain (14% M)	Corn stubble (DM)	Total forage (DM)
	----------ton acre^{-1}----------			
Plow and disk.	16.13a	9.82c	19.16a	35.29a
Disturbing the upper 0-10 cm layer.	9.89a	12.63bc	20.68a	30.57a
Without disturbing the upper 0-10 cm layer.	16.42a	16.36ab	28.26a	44.69a
Zero tillage with 0% soil cover.	18.73a	18.37a	26.36a	45.08a
Zero tillage with 33% soil cover.	14.72a	17.47ab	28.60a	43.31a
Zero tillage with 66% soil cover.	13.31a	18.72a	28.51a	30.71a
Zero tillage with 100% soil cover.	10.61a	17.63a	27.98a	38.59a

Means followed by the same letter are not significantly different at the 0.05 level of probability according to the Tuckey test.
DM = Dry matter.
M = Seed moisture

There was a yield reduction of 39 and 34% with D and ZT+100%SC in comparison with P+D. In the case of D, this reduction was explained by a compacted layer, detected at 8 inches depth, indicating that when soil was just disking, a compact layer was developed, impeding an adequate oat root development. Regarding ZT+100%SC, the yield reduction was due to a greater competence for nutriments by soil microorganisms responsible of breaking down the stubble left on the soil surface.

In corn grain yield, a statistical difference among treatments was obtained ($p \leq 0.05$), where the best treatment was ZT+66%SC with 18.72 ton acre^{-1}, representing an increase of 90% in relation with that of P+D. In all the treatments, except P+D and D, there was a reduction of two irrigations during the corn growing season because of the stubble much effect. Soil water content was higher in those treatments compared to that of P+D. The main reason in the different response of corn and oat to the

tillage method evaluated was the higher temperatures registered during the spring and summer months than that in the fall and winter where oat was growth. During the growing season of corn, the stubble decreased evaporation, increasing soil moisture, and causing better corn yield. The higher soil moisture registered in ZT treatments than that of P+D was the reason to get superior corn and stubble yields.

Production of higher yields of forage is a challenge in the north-central region of Mexico to implement correctly conservation tillage by farmers before expecting to leave crop residues on the soil surface. Because farmers use to feed animals with stubble, only a part of the total stubble production can be used as mulch. There was not statistical differences ($p \geq 0.05$) among treatments in stubble yield, however there was a trend to increase 50% with ZT+33%SC and ZT+66%SC compared with that of P+D. This difference of 9.39 ton acre^{-1} opens the possibility to leave a stubble mulch of 5.45 ton acre^{-1}, which will cover 50% of soil surface without reducing the quantity of stubble that can be used as forage.

It is important to point out the forage oat, corn grain, and stubble yields obtained with ND, because with this treatment soil profile was not inverted, reducing production costs. With this treatment, a root-cutter type implant was used. This method can be used as an intermediate step between traditional and conservation tillage and it is largely recommendable in soils with compaction and drainage problems. In this study, soil mulch was not left on the surface, so there is a question to be answered in future researchers about the effect of stubble mulch with this tillage method on corn grain and forage oat yields.

It was evident that forage availability was increased 20% with ZT+33%SC and ZT+66%SC in comparison with that of P+D. The kindness of leaving crop residues in the soil surface is justified for the irrigation water which is saved during the cycle of corn, as well as the increment in the organic matter and conservation of the structure of soils.

CONCLUSIONS

Conclusions for this study were that corn and forage oat can be growth without plowing the soil, increasing corn production and keeping stable that of forage oat.

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