Pak. J. Bot., 47(4): 1249-1258, 2015.

EFFECTS OF TILLAGE METHODS, CORN RESIDUE MULCH AND N FERTILIZER LEVELS ON THE WHEAT CROP PRODUCTIVITY UNDER THE RAIN FED CONDITION OF LOESS PLATEAU CHINA

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Abstract

A 2 years study was conducted to assess the effects of different tillage methods (Chisel plough tillage, Zero-tillage, Rotary tillage and Mould board plough tillage), two mulch levels (M0 i.e. No corn residue mulch and M1 i.e. Corn residue mulch) and 5 N fertilizer levels (0, 80, 160, 240 and 320 kg N/ha) on the wheat crop productivity under the rain fed condition of Loess Plateau, China. Factorial experiment with three replications, having strip, split-split arrangement, with tillage methods in the main plots, mulch levels in sub- plots and N-fertilizer levels in the sub-sub plots was used for this study. Due to variations in rainfalls, during the year, 2010-11, maximum grain yields i.e. 6.58 t/ha and 6.72 t/ha were recorded in case of Zero tillage planting method and similarly in case of 80 kg N/ha, while during the cropping year 2011-12 equal grain yields were recorded in case of all tillage methods, however maximum grain yield (7.46 t /ha) was recorded in case of 320 kg N/ha, N fertilizer level. On two years average basis, maximum grain yields i.e. 6.75 t/ha and 6.80 t/ha were recorded in case of Zero tillage planting method and similarly in case of 80 kg N/ha as compared with the other tillage methods or N fertilizer levels. Use of mulch reduced > 40% weeds infestation. Economic analysis shows that Zero tillage and minimum use of N fertilizer according to the projected rainfalls along with the use of mulch are both economic and environmental friendly.

Key words: Tillage methods, Mulch, N fertilizer, Rain fed condition, Wheat, Loess plateau.

Introduction

With the exponential growth in human population and decreasing access to the arable lands, food demand and environmental deterioration are becoming the biggest global issues (Tilman *et al*., 2001; Perry *et al*., 2009). As 56% of total area of China consists of dry lands, so crops production in this country is also facing many problems. The main problems of these areas include, scarcity of water, severe weather conditions, low soil fertility and topography issues. In addition to these issues, intensive land cultivation, complete removal of crop residues or burning of residues has further degraded the soils (Tang, 2004). According to some reports, burning of crop residues has been increased since the last decade (Wang *et al*., 1999).

Loess Plateau China is one of the highest eroded areas of the world. There are many reasons for its erosion, but traditional agriculture is also considered as one of the leading man-made factor responsible for this problem. Traditional crops production in this region involves intensive cultivation and crop residues are generally used as forage or fuel. Mould board plough is commonly used for tillage operations, which is followed by harrowing, rolling, smoothing and hoeing etc (Wang *et al*., 2007).

Intensive cultivation has resulted in the increased risk of wind and water erosions as well as in the increased risk of soil compaction (Gao *et al*., 1991; Cai *et al*., 2002). It has decreased the soil fertility, soil organic matter and soil stability (Cai *et al*., 1994; 1995). In addition to it intensive tillage operations need up to 60-70% more energy and labor costs as compared with the reduced tillage operations (Wang *et al*., 2003).

No-tillage (NT) and sub soiling have been reported to be better as compared with the other tillage practices (Li *et al*., 2007; He *et al*., 2007, 2009). Lal, (1989) reported that No tillage reduces the loss of soil moisture, reduces soil erosion and also reduces the cost of production, but Cassel *et al*. (1995) reported that NT causes soil compaction. On the same way Evans *et al*. (1996) reported that annual sub soiling had a very little effect on water conservation. It has been reported that conservation tillage can control the soil erosion (Gan *et al*., 2008) and It can be helpful in improving the crops yields, farmers incomes and as well as soil properties (Pikul & Aase., 1999; Li & Gong, 2002; Fabrizzi *et al*., 2005), but some researchers (Tan *et al*., 2002 and Taa *et al*., 2004) have reported less wheat crop yields from conservation tillage than conventional tillage. Similarly Franzluebbers, (2002) reported that conservation tillage along with stubble mulch can serve as a barrier against runoff, which will be beneficial in the more infiltration of moisture (Shaver *et al*., 2002). Erenstein, (2002) reported that crop residues can be helpful in controlling the weeds growth, while Bhagat & Verma (1991) reported that mulches can increase the nitrogen use efficiency by reducing their volatilization.

To study the performance of conservation tillage, China government started a lot of projects, and promising results were observed. In spite of these achievements, traditional cultivation with residue burning or removal is still a common practice. A lot of efforts are still needed to further investigate the conservation tillage practices as compared with the intensive tillage methods which are commonly used for crops production.

The objectives of this two–year field experiment was to find out the effects of different tillage methods, N fertilizer levels and corn residue mulch on the wheat crop productivity under the rain fed conditions of Loess Plateau, China. The investigations will be helpful in improving the wheat crop yields in this area and as well as in other areas of the world having same climatic and soil problems.

Materials and Methods

Experimental site: Field experiments were conducted for two consecutive years (2010-12) at the experimental area of Northwest A&F University, Shaanxi Province, northwestern China (latitude 34˚ 20˚, N and longitude of 108˚ 04˚E and elevation of 466.7 m above sea level) on the Eum-Orthrosols (Chinese soil Taxonomy) soil , with the mean bulk density of about 1.29 g cm^3. The soil in the top 40 cm had SOC about 14.26 gram/kg, total N: 0.74 gram/kg and pH 7.85. The field was uniform in fertility. This area is under the corn-wheat rotation system. Both years (2010-11 and 2011-12), wheat crop was planted after the harvesting of corn crop. Fertilizer was applied to the corn crop according to the local recommendations of the area while both years (2010-11 and 2011-12) different doses of N fertilizers were applied to the wheat crop according to the experimental design. The total rainfall during the crop growing season (October-June) was 231.6 mm and 242.7 mm during 2010-11 and 2011-12 respectively.

Experimental design and treatments: The experiment was planted by using the factorial arrangements with three replications, with strip split-split arrangements having tillage methods in the main plots, mulch levels in the sub plots and nitrogen fertilizer rates/levels in the sub-sub plots. Total area of the experimental plot was equally divided into four main tillage treatments and the area of each tillage treatment was further sub-divided into sub–plots and finally the sub plots were further divided into sub-sub plots and each sub-sub plot had an area of 3 m × 25 m. The treatments were randomized within each sub-plot.

The experiment included four tillage methods i.e. T1 (Chisel plough tillage), T2 (Zero tillage), T3 (Rotary tillage) and T4 (Mould board plough tillage). Two levels of corn mulch were used i.e. Mo (No corn residue mulch) and M1 (corn residue mulch) and five rates of N fertilizer i.e. 0 kg N/ha (N0), 80 kg N/ha (N1), 160 kg N/ha (N2), 240 kg N/ha (N3) and 320 kg N/ha (N4). For T1 (Chisel plough tillage), after the application of fertilizers, Chisel plough having 30-35 cm deep and 40 cm apart tines, was used for one time. Later on Rotavator (up to 0-5 cm depth) was used just for the proper mixing of fertilizers and seed sowing. For T2 (Zero tillage), due to the non availability of proper Zero tillage drill, Rotavator was used up to 0-5 cm soil depth, just for fertilizers mixing and proper wheat planting. For the T3 (Rotary tillage), seed bed was prepared by using the Rotavator to the depth of 15-20 cm, while for T4 (Mould board plough tillage), Mould board plough or M.B plough was used up to the depth 0f 25-30 cm, followed by Rotavator for final seed bed preparation. Urea having N ≥ 46%, was used as the source of the nitrogen and N fertilizer doses were applied according to the experimental design. Both years, before the sowing of wheat crop, Calcium Phosphate $Ca_2(PO_4)_2$ having 16% phosphorus was equally applied to all the treatments @ 750 kg/ha.

Arrangements of treatments was kept same during the both years of study and both years, previously harvested crops were used as the source of corn mulch. Both years when the wheat crops were at the 3-4 leaf stage, corn mulch was applied @ 750 grams m^{-2}. For this purpose instead of chopping the corn plants, whole corn dried plants were flattened between the wheat crop rows and this corn mulch remained in the field for the whole wheat crop growing season. The field was flat in surface with uniform topography. This area is rain fed and wheat-corn rotation system is the main cropping system. So both years no irrigation was applied to both crops. Corn crop was planted after the harvesting of wheat crop by using the same tillage methods and no changes were made in case of any tillage treatment which was used for the planting of wheat crop. Wheat crop was harvested by using the combine harvester. Both years after the harvesting of wheat crops, corn crops were planted by using the corn planter and both Phosphorous (P) & Nitrogen (N) fertilizers were applied to this corn crop at the rate of 750 kg/ha and 375 kg /ha respectively.

Winter wheat (C.V Shaan mai-139) was planted respectively on 17 October 2010 and 18 October 2011 by using the wheat drill having line to line distance of about 16 cm apart. The seed had 13% moisture contents and 85% germination. During the cropping season 2010-11 seed rate was used @ 190-200 kg/ha while during the cropping season 2011-12, seed rate was used @ 205-210 kg/ha. Experimental treatments were separated from each other by making the boundaries. Both years, Carfentrazone-Ethyl ($C_{15}H_{14}Cl_2F_3N_3O_3$), a commonly used herbicide in the area was used to control the weeds at the required time. At physiological maturity on June 8, 2011 and on June 10, 2012, samples for grain yields and other yield related parameters were randomly selected from each treatment. Samples for grain yields were manually harvested by using the 1 m^2 Quadrate. Finally wheat crop was harvested by using the combine harvester.

Measurements: Data regarding rainfalls and temperature was taken from the Met Office. Germination data from each treatment was recorded after the completion of wheat crop germination. For this purpose data was collected from three randomly selected points by using the $1m^2$ quadrates. Similarly weeds population, their fresh weight and dry weight data were recorded from all the treatments at the crop revival stage. Weed population was counted by using the 1 m^2 Quadrates. However Quadrate having an area of 0.25 m × 0.50 m was used for the collection of weed samples. After recording the fresh weights of weed, samples were dried in oven @ 80˚C, till constant weight. Both years before the harvesting of wheat crops data was recorded regarding plant heights, spike lengths and other related parameters. 1 m^2 Quadrates were used for the collection of samples regarding crop biomass weight and grain yields. Before the recording of dry biomass weight, samples were kept for drying in green house sheds. Tillers of each sample were counted. After the recording of dry biomass yield, samples were finally crushed by using the small plot thresher machine and data was recorded for the grain yields and the remaining yield components.

Data was also analyzed regarding cost/ benefit ratio for the production of wheat crop under the different tillage treatments, application of corn residue mulch and as well as regarding the use of different levels of N fertilizer. Cost of production for different tested tillage methods and inputs (seed, fertilizer, herbicide, and labor charges etc) along with net output value was calculated based upon local market prices.

Statistics: Annual data collected for each parameter over the whole 2-years period were subjected to Analysis of variance (ANOVA), by using the factorial experiment with strip-split-split arrangement having tillage methods in the main plots, mulch in the sub plots and N- fertilizer rates in the sub-sub plots. The SAS analytical software package GLM (8.01) was used for the statistical analyses. Means were declared statistically significant by using the DUNCAN test (DNMRT) at the 0.05 probability level at $p<(0.05)$.

Results

Weather condition: Total monthly precipitations (including snow fall in winter months), along with 10 years average rainfall data of the area during the wheat crops growing periods are presented in Fig. 1. Total rain fall (October 2011 to June 2012) during the cropping season 2011-12 was 242.7mm, which was about 11.1 mm more as compared to the cropping season 2010-11, which had total rainfall of about 231.6 mm (Fig. 1). Rainfall data shows that more rains were concentrated in the early months (October & November) of cropping season 2011-12, as compared to the same month's rain falls during the cropping season 2010-11. However during the cropping season 2010-11, more rain fall (89.2 mm) was recorded during the month of May as compared to the cropping season 2011-12 with the rain fall of 68.4 mm during the same month.

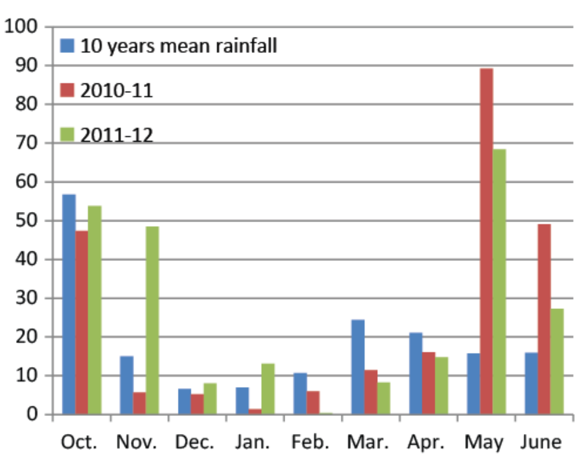

Fig. 1. Distribution of rainfall (m.m) during the wheat crop growing seasons (2010-11 & 2011-12), along with 10 years average wheat crop growing season rainfall at the experimental area.

Wheat crop productivity: Data regarding crop germination, plant heights, number of tillers, spike lengths, 1000 grain weights, biological yields and grain yields during the both planting years (2010-12) and their interactions under the different tillage methods, mulch levels and N fertilizers levels are given in Tables (1, 2, 3, 4 & 6).

During the cropping year 2010-11 maximum grain yield (6.58 t/ha) was recorded in case of Zero tillage (T2), followed by Mould board plough tillage (T4) having grain yield of 6.33 t/ha, while minimum grain yield (6.03 t/ha) was recorded in case of Rotary tillage (T3) (Table 1), however during the cropping year 2011-12, equal grain yields were recorded in all kinds of tillage methods (Table 2). During both years, application of corn residue mulch could not increase the yields as compared to the non mulched treatments (Tables 1 and 2). However during both cropping years variations were observed in grain yields by the application of different nitrogen fertilizer levels (Tables 1 and 2). During 2010-11, N1 (80 kg N/ha) fertilizer level gave the maximum grain yield (6.72 t/ha), than all other nitrogen fertilizer levels treatments, while during the year 2011-12, maximum grain yield (7.46 t/ha), was recorded in case of N4 (320 kg N/ha) fertilizer level (Tables 1 and 2).

Two years (2010-12) mean data shows that maximum average grain yield was recorded in case of 80 kg N/ha, N fertilizer level (Table 4). During both years (2010-11 and 2011-12), differences in grain yields in case of interactions between tillage methods x mulch kinds were recorded highly significant (Data not shown). as a result of which during the cropping year 2010-11, application of corn residue mulch increased the grain yields about 267 kg/ha in Zero tillage (T2), and 347 kg/ha in Rotary tillage (T3), while no differences in grain yields were recorded in case of Chisel plough tillage method. (T1). However in case of Mould board plough tillage method (T4), application of corn residue mulch decreased the grain yield up to 438 kg/ha, while during the year 2011-12, in case of interactions between tillage methods x mulch kinds, use of corn residue mulch increased the grain yields up to about 60 kg/ha, in case of Chisel plough tillage method (T1), while increase in grain yield was about 350 kg/ha in case of Rotary tillage planting method (T3). However applications of corn residue mulch reduced the grain yields in case of Zero tillage (T2) and Mould board plough tillage (T4) methods. The reductions in grain yields in these tillage methods were about 225 kg/ha and 448 kg/ha respectively (Data not shown). During the year 2010-11, highly significant differences in grain yields were recorded in case of tillage methods × N fertilizer levels interactions and these trends in grain yields were recorded as T2 > T4 > T1> T3 (Data not shown).

Similarly two years (2010-12) mean data indicates significant effects of tillage methods on wheat crop grain yields and some other yield components (Table 4). Statistically at par grain yields were recorded in Zero tillage (T2), Mould board plough (T4) and Rotary tillage (T3) planting methods but maximum wheat grain yield was recorded in case of Zero tillage (T2) planting method, which was 4.6% more than the minimum grain yield recorded in case of Chisel plough tillage method (T1) (Table 4).

Table 1. Means of wheat plants germination, weed infestation, yield and some yield components during the cropping year 2010-11.

	Tillage methods				Mulch levels		Nitrogen fertilizer levels				
	T1	**T2**	**T3**	**T4**	**M0**	**M1**	**N0**	**N1**	**N2**	**N3**	**N4**
Ger/m^2	280b	316a	305a	286b	296a	298a	298a	307a	299a	290a	290a
Weed/ m^2	203a	219a	142b	123b	169a	124b	290a	187b	162bc	123c	98d
Weed FWT	1.70a	1.18bc	1.35ab	0.92c	1.43a	1.14b	1.21ab	1.61a	1.22ab	1.01b	1.37ab
Weed DWT	0.43a	0.27bc	0.33b	0.22c	0.35a	0.27b	0.29a	0.38a	0.29a	0.29a	0.31a
Tillers/m2	468.6b	505.4a	474.0b	491.4ab	487.9a	482.1a	480.4bc	518.6a	488.2b	455.3c	482.3c
P.H	64.1b	66.6a	66.4a	66.9a	65.9a	66.1a	67.2a	66.3a	65.8bc	64.9c	66.0b
S.L	7.5b	7.7b	7.6b	7.9a	7.6a	7.7a	7.4b	7.6b	7.7ab	7.8a	7.8a
1000 g.wt(g)	39.6a	39.6a	39.4a	38.2b	38.3b	40.1a	39.4a	39.1ab	39.6a	39.2ab	38.8b
B.Y	11.90bc	12.80a	11.73c	12.51ab	12.27a	12.27a	11.88b	12.91a	12.34ab	11.84b	12.20ab
G..Y	6.15b	6.58a	6.03b	6.33ab	6.25a	6.30a	6.06b	6.72a	6.16b	6.13b	6.27b
H.I%	50.8a	51.4a	51.4a	50.7a	50.9a	51.3a	51.1a	51.3a	50.0b	51.8a	51.4a

T1, Chisel plough tillage; T2, Zero tillage; T3, Rotary tillage; T4, M.P tillage; Mo, No corn residue mulch; M1, corn residue mulch; N1, 0 kg N/ha; N2, 80 kg N/ha; N3, 160 kg N/ha; N4, 240 kg N/ha and N5, 320 kg N/ha; Ger/m^2, Wheat plants /m^2 : Weed FWT, Weed fresh weight t/ha; Weed DWT, Weed dry weight t/ha; P.H, Plant height (cm); S.L, Spike length (cm); 1000g.wt(g), 1000 grain weight (grams); B.Y, Biological yield t/ha; G.Y, Grain yield t/ha; HI%, Harvest Index %; Significant at p≤0.05; Values with the same letters with in the rows/group are not significantly different

Table 2. Means of wheat plants germination, weed infestation, yield and yield components during the cropping year 2011-12.

	Tillage methods				Mulch levels		Nitrogen fertilizer levels				
	T1	**T2**	**T3**	**T4**	**M0**	**M1**	**N0**	**N1**	**N2**	**N3**	**N4**
Ger/m^2	436a	430ab	418b	431ab	419b	438a	425a	429a	429a	446a	428a
Weed/ m^2	270a	195b	206b	174b	283a	139b	234a	207ab	193b	211ab	207ab
WFWT	2.68a	2.15b	2.64a	2.12b	3.63a	1.16b	1.08c	2.46b	2.50b	2.91ab	3.04a
WDWT	0.47a	0.38bc	0.44ab	0.33c	0.62a	0.19b	0.21c	0.43b	0.42b	0.46ab	0.52a
Tillers/m^2	554.9a	547.1a	548.5a	546.9a	546.0a	552.7a	520.0b	552.0c	551.8a	553.7a	569.3a
P.H (cm)	80.1a	79.6a	77.7c	78.6b	79.0a	79.0a	75.5b	79.9a	79.6a	80.4a	79.6a
S.L (cm)	8.3a	8.2ab	8.1b	8.1b	8.2a	8.1b	7.8c	8.1b	8.3a	8.4a	8.3a
1000g.wt(g)	39.7a	40.1a	40.5a	39.7a	39.9a	40.0a	40.7a	40.1ab	39.7ab	39.5ab	40.0a
B.Y	13.48a	13.74a	13.83a	14.05a	13.77a	13.78a	12.19b	13.86a	13.94a	14.29a	14.58a
G.Y	6.82a	6.91a	7.06a	7.08a	7.0a	6.94a	6.07d	6.92c	7.09bc	7.30ab	7.46a
H.I%	50.6ab	50.3b	51.1a	50.7ab	50.9a	51.3a	49.8c	50.3bc	50.9ab	51.1ab	51.2a

T1, Chisel plough tillage; T2, Zero tillage; T3, Rotary tillage; T4, M.P tillage; Mo, No corn residue mulch; M1, corn residue mulch; N1, 0 kg N/ha; N2, 80 kg N/ha; N3, 160 kg N/ha; N4, 240 kg N/ha and N5, 320 kg N/ha; Ger/m^2, Wheat plants /m^2; Weed FWT, Weed fresh weight t/ha; Weed DWT, Weed dry weight t/ha; P.H, Plant height (cm); S.L, Spike length (cm); 1000g.wt(g), 1000 grain weight (grams); B.Y, Biological yield t/ha; G.Y, Grain yield t/ha; HI%, Harvest Index %; Significant at p≤0.05; Values with the same letters with in the rows/group are not significantly different

Table 3. Average means of wheat plants germination, weed number, weed fresh weight and weed dry weight during the two (2010-12) cropping seasons.

	Wheat plants germination/m^2	No of weed/m^2	Weed FWT	Weed DWT
Tillage				
T1	358.3 b	338.4a	2.20a	0.45a
T2	373.0a	157.6bc	1.66b	0.33bc
T3	361.1b	174.1b	2.00a	0.38b
T4	358.3b	148.6c	1.52b	0.28c
Years				
2010-11	296.9b	148.4b	1.30b	0.31b
2011-12	428.6a	211.0a	2.40a	0.41a
Mulch				
M0	357.4b	227.7a	2.54a	0.49a
M1	368.2a	131.6b	1.15b	0.23ab
Fertilizer				
N0	361.5a	202.9a	1.17c	0.35b
N1	368.2a	196.6a	2.03ab	0.39a
N2	367.3a	177.4ab	1.87b	0.38ab
N3	358.2a	166.9b	1.96ab	0.38ab
N4	358.7a	154.7b	2.20a	0.38ab

T1, Chisel plough tillage; T2, Zero tillage; T3, Rotary tillage; T4, M.P tillage; Mo, No corn residue mulch; M1, corn residue mulch; N1, 0 kg N/ha; N2, 80 kg N/ha; N3, 160 kg N/ha; N4, 240 kg N/ha and N5, 320 kg N/ha; Weed FWT, Weed fresh weight t/ha; Weed DWT, Weed dry weight t hm^{-2}; Significant at p≤0.05; Values with the same letters with in the column are not significantly different

Table 4. Average means of, grain yield and different yield components during the two (2010-12) cropping seasons.

Treatments	Tillers/m^2	P.H	S.L	1000g.wt (g)	B.Y	G.Y	HI%
Tillage							
T1	511.8a	72.1b	7.89ab	39.6a	12.69b	6.44b	50.7b
T2	526.0a	73.1a	7.90ab	39.8a	13.27a	6.75a	50.9ab
T3	511.2a	72.0b	7.83b	40.0a	12.78b	6.54ab	51.3a
T4	520.7a	72.7a	7.99a	38.9b	13.55a	6.74a	50.7b
Years							
2010-11	485.1b	66.0b	7.64b	39.2b	12.25b	6.26b	51.08a
2011-12	549.3a	79.0a	8.17a	40.0a	13.77a	6.70a	50.70b
Mulch							
M0	517.2a	72.4a	7.93a	39.2b	12.99a	6.61a	50.8a
M1	517.8a	72.6a	7.88a	40.0a	13.04a	6.63a	50.9a
Fertilizers							
N0	500.5b	71.2b	7.61c	40.0a	12.04b	6.06b	50.4c
N1	536.8a	73.1a	7.84b	39.6ab	13.44a	6.80a	50.8bc
N2	520.0ab	72.7a	7.98ab	39.7ab	13.14a	6.62a	50.5c
N3	504.5b	72.6a	8.06a	39.3b	13.07a	6.72a	51.5a
N4	525.8a	72.8a	8.05a	39.4b	13.39a	6.87a	51.3ab

Table 5. Two years (2010-12) estimated average output and input (on hectare basis) values of winter wheat crop planted under the different kinds of tillage methods, mulch kinds and N fertilizer levels.

Treatment	OV	IV	O/I ratio	E.B1	BFD 2
Tillage					
T1	12898.0b	2691b	4.79:1c	10207.9c	-260.7c
T2	13493.6a	1938d	6.96:1a	11555.6a	+1087.0a
T3	13088.6ab	2388c	5.48:1b	10700.6b	+232.0b
T4	13473.6a	3005a	4.48:1d	10468.6bc	-
Years					
2010-11	12501.5b	2503a	4.99:1b	9998.5b	-
2011-12	13937.7a	2498b	5.58:1a	11439.7a	1441.2
Mulch					
M0	13223.6a	2356b	5.61:1a	10867.7a	-
M1	13252.4a	2644a	5.01:1b	10608.4a	-259.3
Fertilizers					
N0	12132.0b	1836e	6.61:1a	10296.0b	-1146.0b
N1	13607.0a	2165d	6.28:1b	11442.0a	-
N2	13246.2a	2501c	5.30:1c	10745.2b	-696.8b
N3	13436.8a	2822b	4.76:1d	10614.8b	-827.2b
N4	13729.9a	3144a	4.37:1e	10585.9b	-856.1b

T1,Chisel plough tillage; T2, Zero tillage; T3, Rotary tillage; T4, M. P tillage; M0, No corn residue mulch; M1,Corn residue mulch; N0, 0 kg N/ha; N1, 80 kg N/ha; N2, 160 kg N/ha; N3,240 kg N/ha and N4, 320 kg N/ha; OV: Output value (Yuan/ha); IV: input value (Yuan/ha); O/I: Output/input; EB1: Economic benefit (Yuan/ha); BFD2: Benefit difference (Yuan/ha)., Significant at $p \leq 0.05$., Values with the same letters are not significantly different; Economic benefit1 = output value- cost value (grain price = 2 Yuan kg-1; the Yuan is the Chinese currency unit). Difference from T4 (M.P tillage), No mulch and recommended fertilizer level. + show benefit/saving while – shows loss/ over expenditure etc

Significant differences in both dry biomass and grain yields during the cropping year 2011-12 as compared with the planting year 2010-11, may be due to the availability of more rains in the start of cropping year, 2011-12 as compared to the year, 2010-11 (Fig. 1).

In case of tillage methods × mulch kinds interactions (Table 6), application of corn residue mulch increased the grain yields, which were about 2.16%, 0.32%, and 5.7% in case of T1, T2 and T3 tillage methods respectively while in case of Mould board plough (T4) tillage method application of corn residue mulch decreased the grain yields up to about 6.4% (Data not shown).

In case of tillage methods × year's interactions (Table 6) performance of different tillage methods differed significantly during the both years of study. As a result of which as compared to the cropping year, 2010-11, during the cropping year 2011-12, 12.6%, 5.0%, 17.2%, and 10.8% more grain yields were recorded in case of Chisel plough tillage (T1), Zero tillage (T2), Rotary tillage (T3) and Mould board plough tillage (T4) methods respectively (Data not shown). In case of planting years × N fertilizer levels interactions, significant differences in grain yields were recorded during the cropping year 2011-12, as compared to the cropping year 2010-11 (Table 6). As a result of which 3.7%, 15%, 19.1%, 18.9% respectively more grain yields were recorded in case of N1, N2, N3 and N4, nitrogen fertilizer levels during the year 2011-12 as compared to the year 2010-11 respectively (Data not shown).

Table 6. Analysis of variance (mean square) of different studied parameters during the two (2010-12) cropping years.

Source	D.F	Wheat plants/m^2	Tillers/m^2	P.H	S.L	1000 g, wt (g)	B.Y	G.Y	HI%
Tillage	3	2902.9*	3339.5NS	17.3***	0.3NS	12.9***	6593271.9***	122260.7**	4.7NS
Year	1	1041220.3**	235573.5***	10150.0***	16.8***	17.1***	13496603.4***	29504910.6***	9.2*
Mulch	1	6955.3**	25.7NS	0.9NS	0.1NS	48.4***	132977.5NS	20786.1NS	0.2NS
Fertilizer	4	1071.4NS	10357.4***	25.8***	1.1***	4.0NS	1470235.5***	4549170.3***	11.6***
Tillage x Mulch	3	1044.2N.S	13445.1***	38.7***	0.7***	0.4NS	6780289.1***	1690508.3***	3.0NS
Tillage x Fertilizer	12	1396.6NS	3437.7NS	8.8***	0.2NS	2.1NS	1443071.8 NS	302485.9NS	5.6***
Tillage x Years	3	7183.9**	6404.4*	71.6***	0.8***	5.7*	3443481.8NS	1276931.9*	3.9NS
Year s x Mulch	1	4332.0*	2151.1NS	1.3NS	0.8**	40.1***	66692.7NS	418751.6NS	11.3**
Year x Fertilizer	4	541.5NS	10721.7***	83.8***	0.1NS	2.9NS	10758689.1***	3983648.6***	7.7***
Mulch x Fertilizer	4	1286.5NS	1392.9NS	4.8NS	0.2NS	3.4NS	975872.1NS	461889.2NS	8.6***
Tillage x Year x Mulch	3	689.7NS	3575.5NS	22.3***	0.3*	1.3NS	1162751.4NS	190005.0NS	6.2*
Tillage x Year x fertilizer	12	1179.7NS	1839.7NS	4.4NS	0.3*	2.5NS	12108232.1NS	369168.7NS	4.8***
Tillage x Mulch x fertilizer	12	837.2NS	4215.9*	6.2*	0.2NS	1.5NS	1785389.2NS	420989.7NS	4.6***
Tillage x Mulch x Year x fertilizer	16	1516.1*	3953.4*	2.0NS	0.1NS	2.5NS	2029198.1 NS	782603.9***	5.3***

* Significant at 0.05 probability levels, ** Significant at 0.01 probability levels, *** Significantat0.001probability

Weed infestation: During both years, different weed types were found in the wheat crops. A few of them were *Phalaris minor*, *Chenopodiun album*, *Avena fatua*, *Tellaria media cryill*, *Veronicag restis*, *Galiumaparine*, *Loium multiflorium*. But both years the most common weeds in the crops were *Veronicag restis* and *Chorisporatenella*. Data regarding weed infestation in the different tillage kinds, corn residue mulch and nitrogen fertilizers levels during the both years are given in Tables 1 and 2.

Two years (2010-12) mean data shows that, all factors i.e., tillage methods, mulch kinds and N fertilizer levels significantly affected the weed population (Table 3). Minimum number of weed (148.6 m^{-2}) was recorded in case of Mould board plough (T4) tillage method, while maximum number of weed (238 m^{-2}) were recorded in case of Chisel plough tillage method (T1) (Table 3). Less weeds infestation was recorded in the treatments where corn residue mulch was applied. Data shows that weed populations and their growths were very high in case of non mulched treatments. However more weed population was recorded during the planting year, 2011-12 as compared with the planting year, 2010-11 (Table 3). More fresh weights of weed were recorded in case of Chisel plough tillage method (T1) and Rotary tillage method (T3), as compared to the Zero tillage (T2) and Mould board plough (T4) tillage methods. Minimum fresh weights (1.52 t /ha) of weed was recorded with the Mould board plough tillage method (T4) (Table 3). More than 42% of weed population was reduced by the use of corn residue mulch as compared with the non mulched treatments. Similarly more than 50% of fresh weights and dry weights of these weed were reduced by the use of corn residue mulch as compared to the non residue mulched treatments (Table 3). Corn residue mulch suppressed the weed growth by reducing the availability of light to the weeds, which ultimately suppressed their growths. Due to more rains during the planting year 2011-12, more fresh weights of weed was recorded during the planting year, 2011-12 as compared to the planting year, 2010-11 (Table 3). In case of N fertilizer levels, maximum fresh weights of weed were recorded in case of application of maximum N fertilizer level (N4), as compared with the minimum weed fresh weights in case of N0, N fertilizer level (Table 3). Significant reduction in weed dry weights were recorded by using the different treatments, and in case of tillage methods, maximum weed dry weights were recorded in case of Chisel plough tillage method (T1) and in case of mulches, less weed dry weights were recorded with the treatments having corn residue mulch as compared with the non mulched treatments. Likewise maximum weed dry weights were recorded in case of treatments having maximum N fertilizer level (N4).

Economic benefits: The economic benefits by using the different treatments are given in Table 5. The input costs include the estimated costs of different tillage operations, fertilizers costs, herbicides costs, seed costs, mulch application and harvesting charges etc. Output relates to the total income in the form of grain yields in Chinese currency units i.e. RMB. Maximum economic benefit was recorded in case of Zero tillage (T2) planting method as compared with other three tillage methods. Although application of corn residue mulch cost more money in the form of mulch application charges etc, as compared to the non-mulched treatments. Economic benefit analysis also shows that the application of higher rates of N fertilizer could not help in getting the better grains yields.

Discussion

Wheat crop productivity: Variations in grain yields by the use of different tillage methods and nitrogen fertilizers levels during the different years were mainly due to the variations in the rainfalls timings and concentrations (Fig. 1). Because during the cropping year (2011-12), more rains were concentrated in the early period of wheat crop growth as compared to the year 2010-11, due to which higher levels of N fertilizer gave the maximum productivity during this year (Tables 1 and 2).The results are similar to the findings of Garabet *et al*. (1998). Who reported that wheat yield and its response to N fertilizer mainly depends on the availability of soil water. Similarly Alcoz *et al*. (1993) and Westerman *et al*. (1994) reported great variations in the response of wheat crop under rainfed conditions. These variations were mainly due to the N fertilizer rates, accumulation of mineral N in the soil profiles, application time and N source etc. Regarding fertilizer application rates, overall two years (2010-12) average data shows that maximum average grain yield was recorded in the nitrogen fertilizer rate of 80 kg N/ha (Table 4). Almost same results regarding the effects of N fertilizer on wheat crop yields in this area have also been previously reported by Cai *et al*. (2005).

Both years (2010-11 and 2011-12) variations in grain yields were recorded in case of tillage methods × mulch kind's interactions. These variations might be due to different reasons as Doring *et al*. (2005) and Gao & Li, (2005) reported that there are complex ways i.e. mulch application time, mulch quantity etc due to which mulching affects crop yields. Similarly overall two years (2010-12) data indicated significant affects of tillage methods on wheat crop mean grain yields and some other yield components (Table 4). Same trend in wheat crop grain yields due to different tillage methods have also been previously reported by He Jin *et al*. (2009). Significant differences in both dry biomass and grain yields during the different cropping years may be due to the variations in rains (Fig. 1). Campbell *et al*. (1993) also reported that crop yield response depends mainly on the availability of soil moisture under semi arid conditions. Variations in the wheat crop grain yields during the different years, in this area have also been previously reported by Cai *et al*. (2005). They reported that the variations in the grain yields during the different years were mainly due to the variations in rain fall patterns of that year. The response of different tillage methods for dry biomass and grain yields especially in the Zero tillage (T2) and Mould board plough tillage method (T4) might be due to the availability of more moisture and less evpaotransptration in Zero tillage (T2), and on the other hand more availability of soil mineral nitrogen in Mould board plough tillage method (T4). These kinds of results have also been reported by Cantero-Martinez *et al*. (2003).There might be many reasons for the variations in crop yields in case of tillage methods x mulch kinds interactions (Table 6), but few of them may be, the variations in soil temperature as reported by Gao & Li, (2005) and similarly may be the N immobilization as reported by Acharya *et al*. (2005). Differences in crop yields in case of tillage methods x planting year's interactions (Table 6) might be mainly due to weather conditions during the crop growing season, especially for the no-till or reduced tillage systems have been previously reported (Johnson & Lowery, 1985; Griffith *et al*., 1986 & Hussain *et al*., 1999). They reported the variable effects of weather conditions on the maize crop yields under the different cropping years. In case of planting year's × N fertilizer levels interactions, the effects on grain yields may be mainly due to the variations in the availability of soil moisture. It might be also because, nitrogen (N) application quantity increases the WUE up to a certain limit i.e. ranging from 150-250 kg N/ha per crop because soil nitrogen availability is influenced by many factors such as soil type, tillage method, crop, residue, rotation and climate condition etc (Hatfield *et al*., 2001).

Weed infestation: Data (2010-12) shows that, all factors i.e. tillage methods, mulch kinds and N fertilizer levels significantly affected the weed population (Table 3). Less weed infestation was recorded in the treatments where mulch was applied. The same findings have also been reported by Rehman *et al*. (2005).Variations in the rainfalls during the different years was mainly due to the variations in the rainfalls timings (Fig. 1). Corn residue mulch suppressed the weeds growth by reducing the availability of light to weed, which ultimately resulted in growth suppression. According to Erenstien, (2002), mulches can be helpful in controlling the weed growth by their allelopathic effects or by smothering them. Light interception on soil surface is affected by crop residues, which reduces the photosynthesis process, ultimately resulting in reduced weed growth (Kamara *et al*., 2000). Similarly Bilalis *et al*. (2003) reported that wheat straw mulch had a significant effect on weed emergence and their dry mass. Variations in weed fresh weights due to the different fertilizers levels during the different cropping years might be due to the variations in rainfalls. These trends of weed establishment in relation to fertilizer levels are also similar to the findings of Rehman *et al*. (2005).

Economic benefits: Maximum economic benefit was recorded in case of Zero tillage planting method (T2) as compared with the other three tillage methods. Similar results regarding economic benefits have been also reported by Su *et al*; (2006) and He, Jin *et al*. (2007). However as compared with the no mulch, application of corn residue mulch costs more money in the form of application charges etc but the application of mulch reduced the weeds infestation and it improved soil organic carbon (Data not shown) and some other studied parameters i.e., 1000 grain weight etc. This shows that the application of corn mulch will have better effects on crops yields and on soil health with the passage of time. This trend has been also reported by the simulation study of Zhang *et al*. (2007). They reported that the use of No-tillage (conservation tillage) and mulch can be helpful in maintaining the water balance and sustainable wheat production in the rain fed environment of Loess Plateau china. Economic benefit analysis also shows that the application of higher rate of N fertilizer cannot be helpful in getting the better grains yield, but is a economic loss of farmers and is also harmful for the environment.

Study shows that as in Loess Plateau China, rainfall is mainly concentrated during the months of July, August and September. So wheat crop yield in this dry land condition is severely affected by the variable and low rainfall during the wheat growing period. So to increase the available water in the soil profile is very important for successful crop production. Our study shows that the timings of precipitation had much influence as compared with the tillage practices. So as a result of more rains during the early period of cropping year 2011-12 as compared to the same period of the year 2010-11, due to the better utilization of fertilizers, more grain yields were recorded during the year 2011-12 as compared to the year 2010-11. This also shows that rainfall timings and distribution is more important than that of total rainfall. The same results have also been reported by Cantero-Martinez *et al*. (2007) under the Mediterranean rainfed conditions. Our results regarding crop grain yields under the Zero tillage planting method are in line with the Halvorson *et al*. (2000). They reported differences in wheat crop yields between CT and NT in particular environmental conditions. According to them, in dry years there were more yields in the NT than CT; while in wet years opposite trends in yields were recorded. In our study use of corn residue mulch could not increase the crop yield, but it significantly reduced the weeds infestation. Corn mulch could not increase the crop yield; its one reason may be that we used whole crop residues instead of chopping them. Other benefits of mulch are that its use can also reduce the runoff of rain water and can protect the soil from the direct impacts of rain drops and can reduce the water evaporation from the soil surface (Hillel, 1998).

From the economic point of view, as Zero tillage mean less expenses for the farmer's because it needs less farm operations, so it can reduce the cost of production as compared with the intensive tillage operations and it can also reduce the risk of crop failure during the drier years. This kind of tillage has environmental benefits because it can improve the soil quality.

Conclusion

As water is the most limiting factor for better crops production in the dry land condition of Loess Plateau China. On the basis of this two years study in this area, it can be concluded that the planting of wheat crop with Zero tillage technology gave the maximum grain yields with maximum economic returns. Its output/input ratio was also higher than the other tillage methods. However variations in wheat crop grain yields, due to the different tillage methods were observed during the different cropping years. During the year 2010-11, Zero tillage gave better grain yields than the other tillage methods, but during the year 2011-12 equal grain yields were recorded in case of all the tested tillage methods.

Similarly although variations in grain yields were recorded due to the different N fertilizer levels during the both years, but on two years average basis maximum grain yield was recorded in case of 80 kg N/ha. Due to the variations in the rainfall patterns during the year 2010-11, 80 kg N/ha gave the maximum grain yield, while during the year 2011-12, maximum grain yield was recorded in case of 320 kg N/ha.

Application of corn residue mulch did not help in increasing the crop yield but it helped significantly in reducing the weeds infestation and it also improved soil organic carbon as compared with the non mulched treatments (Data not shown). So it is clear from the study that the adaptation of Zero tillage technology, use of corn residue mulch and the application of suitable nitrogen fertilizer according to the projected environmental conditions is the best strategy to get the maximum wheat crop production. As intensive tillage is the common practice for soil preparation in this region, which accelerates soil erosion so these practices can not only help to reduce the production costs but can also be helpful in reducing the soil erosion. These practices are also environmental friendly because they need less fuel for soil preparations. Use of corn residue mulch has also many benefits because their use reduces the weeds infestation, which can be helpful in reducing the use of herbicides and also the burning of crop residues is a big threat to the environment because it increases the quantity of carbon dioxide in the atmosphere.

Acknowledgments

The study was supported by the National Natural Science Foundation of China (31071375 and 31171506).

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(Received for publication 25 June 2013)