Original Article **Asian J Agri Biol, 2014, 2(2):96-104.**

EFFECT OF TILLAGE AND INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON YIELD AND WATER USE EFFICIENCY OF WHEAT UNDER SUB-HUMID CONDITIONS

Shaheen*, N. Sabir and M. Zafar

Department of Soil and Environmental Sciences. The University of Poonch, Rawalakot, Azad Jammu & Kashmir-Pakistan

ABSTRACT

Conventional practices of farming in mountainous and hilly topographic features of Rawalakot Azad Kashmir-Pakistan accelerate runoff and erosion. To study effect of tillage and integrated nutrient management practices field study was conducted in 2009. Layout of experiment was split plot with four main plots of shallow (0-15 cm) and deep tillage (15-30 cm) with residues (wheat straw; 4 Mg ha^{-1}) and without residues incorporation. Four tillage levels were: S (Shallow tillage), SR (Shallow tillage with residues; wheat straw @ 4 Mg ha^{-1}), D (Deep tillage) and DR (Deep tillage with residues; wheat straw @ 4 Mg ha^{-1}). Sub plots were having three fertilizer levels viz. F0 (control), F1 (Recommended rate of inorganic fertilizers at per hectare rate; 120 Kg N-90 Kg P_2O_5-60 Kg K_2O) and F3 (application of farm yard manure (FYM @ 7692 kg ha^{-1}) + 60 Kg N- 90 Kg P_2O_5-60 Kg K_2O ha^{-1}). Significantly ($p \leq 0.05$) higher wheat grain yield of 2.9 kg ha^{-1} was obtained under D while wheat straw yield was statistically similar under all tillage practices. Fertilizer's level F2 and F3 increased grain yield and straw yield compare to F0 but between F2 and F3 statistically no difference was observed. Statistically higher Water Use efficiency (WUE) was obtained for D (4.56 kg ha^{-1} mm^{-1}) and lower with S (2.79 kg ha^{-1} mm^{-1}). Among fertilizers levels F2 gave higher WUE (4.24 kg ha^{-1} mm^{-1}) which is similar to F1 (3.78 kg ha^{-1} mm^{-1}).

Keywords: Farm yard manure, residues incorporation, Tillage practices, water storage, wheat

INTRODUCTION

In sub-humid to humid mountainous region sustainable crop production demands that soil should be in good biological, physical and chemical condition. A mountainous land form causes more rain water losses as run-off and less infiltration. There is a need of extensive experimentation on soil water conservation practices that could increase infiltration and productivity to encourage farmers of these areas for adoption of these measures. Due to global change in rainfall pattern the humid areas having uncertain conditions of rainfall, winter rains are becoming less during wheat germination period. For efficient utilization of rain water focus on more infiltration and less runoff is required. Research on tillage system is necessary in sub-humid region of Rawalakot (Latitude 33° 51' to 33° 85' N and longitude 73° 48' to 73° 80' E) Azad Kashmir-Pakistan to lessen land degradation and to get potential crop yields as average yield production of wheat is 1 Mg ha^{-1} to 1.5 Mg ha^{-1}.

Soil water is important factor that is influenced by tillage practices because of changes produced in infiltration and surface run-off (Zhai *et al*., 1990). Implementation of tillage practices and incorporation of crop residues varies according to climatic conditions and soil types. Deep tillage (30 cm) disrupts water impeding layers down in soil profile, conserve rainwater and increase grain yield and water use efficiency (Shaheen *et al*., 2010a). Tillage and residue management variations form a complex association of soil and surface condition and influence on crop yield. For example, crop residues incorporation has been observed to increase yield and in some studies decreases yield. As on the plus side, residues have protected soil from rain drop crusting (Blevins *et al*., 1983) and have conserved soil and water (Doran *et al*., 1984). Crop residues incorporation improves soil condition and enhances crop productivity. Residues management affects on soil moisture storage, bulk density, build up soil structure and reduce raindrop impact (Rasmussen and Collins, 1991). Residues may be incorporated or left on the soil surface as mulch. Few studies showed lower wheat yield during first 2 to 3 years of straw incorporation due to wide C:N ratio of

*Corresponding author: e-mail: aqeela.shaheen@gmail.com

added straw, but in later years straw incorporation did not affect adversely (Mandal *et al*., 2004). Swan *et al*. (1994) reported poor crop yield with crop residues because of poor weed control, excessively wet and cold soils (Irena, 2011), and poor seed placement and stand. During winter wheat, as low temperature prevails and slow decomposition of residues takes place, so short term studies shows contrasting results and reasons for contrasting results are also related to factors such as existing soil organic carbon, climatic conditions, physico-chemical conditions of soils and crop management practices (Wilhelm *et al*., 2004).

With adoption of water conservation practices, fertility build up is equally important. In sub-humid to humid conditions losses of inorganic fertilizers with leaching can be minimized by application of integrated nutrients from both inorganic and organic source. Integrated nutrient management is a rational strategy (Palm *et al*., 1997) that reduces losses by converting inorganic N into organic form (Kramer *et al*., 2002), increases the efficiency of the fertilizers and reduces the environmental problems that may arise due to use of inorganic source. Farm yard manure has the potential to improve soil physical conditions (El-Shakweer *et al*., 1998) and provision of nutrients (Schjonning *et al*., 1994). Unlike inorganic fertilizers, nutrients from organic source release slowly and have long residual effects (Sharma and Mittra, 1991). Many studies conducted on integrated nutrient management showed variable results due to the climatic, soil type quality effects on the performance of the organic component of the system (Palm *et al*., 2001).

Objectives of study were to determine (i) Effect of straw incorporation and tillage depths on grain yield and water use efficiency. (ii) Effect of integrated nutrient management practices on yield and water use efficiency.

MATERIALS AND METHODS

Field experiment was carried out in 2009 on clay loam soil at experimental research fields of Rawalakot university and wheat was used as test crop. Soil characteristics of experimental sites are given in Table 1. The experiment was conducted as a split plot arranged in randomized complete block design with three replications. The treatments of main plots consist of: shallow tillage (0-15 cm; S), Shallow tillage with wheat straw incorporation at the rate of 4 Mg ha^{-1} (SS), Deep tillage (0-30 cm; D) and deep tillage with wheat straw incorporation at the rate of 4 Mg ha^{-1} (DS). The sub-plots were having three fertilizers levels viz. Control (no application of fertilizers; F0), recommended rate of fertilizer application (at per hectare rate of 120 kg N, 60 Kg P_2O_5 and 90 Kg K_2O; F1) and integrated application of inorganic and organic fertilizers (at per hectare rate of 7692 kg Farm yard manure (it provided 60 kg ha^{-1} N), 60 Kg N, 60 Kg P_2O_5 and 90 Kg K_2O; F2). Urea was applied as source of nitrogen and Diammonium phosphate as a source of phosphorus and sulphate of potash as a source of potassium. All inorganic fertilizers were broadcasted at the time of sowing and nitrogen was applied as split dose, half at the time of sowing and half after germination. The Farm yard manure (FYM) was collected from neighboring house's pens and its analysis showed total nitrogen percent was 0.78%. FYM was mixed thoroughly and spread evenly and incorporated into the experimental plots at the time of sowing.

Wheat straw in specified treatments according to layout plan was incorporated and properly mixed up to 15 cm depth at the time of sowing. The sub-plot size of experimental field was 3.6 m^2. The rainfall data during growing season of wheat is given in Figure 1. Monthly minimum and maximum temperature distribution during growing season of wheat is given in Figure 2.

Soil water contents and bulk density was measured at the time of sowing and after harvest of crop by gravimetric and core method respectively up to depth of 30 cm. The water contents were converted into volumetric water contents by multiplying with bulk density. Threshing was done manually and yield data was recorded at 12 % water contents after harvesting middle rows of each plot. Water use efficiency was calculated as: economic yield / amount of water applied. Where amount of water applied= water at sowing – water at harvesting + growing season precipitation Schlegel *et al*., 2002. Leaf area was measured with leaf area meter at the flowering stage. Harvest index was calculated as the ratio of grain yield to above ground biomass. Partial factor productivity (Pfp) was calculated (Cassman *et al*., 1996) as ratio of economic yield to all nutrients applied and stated as:

$Pfp = Y/Nr$

Where, Y is the yield in kg ha^{-1} and Nr is the amount of fertilizer nutrients (N+P +K) in kg ha^{-1}.

Analysis of variance was performed by using MSTAT C software, whenever treatment differences were found significant based on F-test, critical differences were calculated at the 5% level of probability by using least significant difference (LSD) test.

Table 1. Soil properties of experimental site

Soil characteristics	0-15 cm	15-30 cm
pH $_{1:1}$	7.38	7.67
EC $_{1:1}$ (dSm^{-1})	0.99	0.64
Organic matter (%)	1.03	----
Bulk density	1.12	1.17
Sand (%)	39.12	----
Silt (%)	30.02	----
Clay (%)	30.86	----
Textural class	Clay loam	----
Average annual precipitation	1481 mm; 33 % rainfall is received in winter (Dec. to March)	
Mean soil temperature	Winter 15 ◦C	
Parent material	Residuium-colluvium from shales	

Table 2. Effect of tillage practices and fertilizers levels on wheat yield harvest index, leaf area and partial factor productivity

	Wheat grain yield (Mg ha^{-1})	Wheat straw yield (Mg ha^{-1})	Harvest Index	Leaf area (cm^2)	Partial factor productivity (Pfp) (kg grain yield / kg N+P+K applied)
Tillage practices					
S	1.79 C	3.99 NS	0.33 NS	26 C	7.53 B
SR	2.08 BC	3.76	0.37	29 BC	9.01 B
D	2.86 A	5.10	0.34	34 AB	11.97 A
DR	2.21 B	4.23	0.34	36 A	8.95 B
LSD value	0.41	--	--	5.47	2.67
Fertilizers levels					
F0	1.64 B	2.68 B	0.37 NS	27 B	------
F1	2.39 A	4.88 A	0.33	32 A	8.86 NS
F2	2.68 A	5.28 A	0.33	34 A	9.88
LSD value	0.53	0.79	--	3.76	--

S= Shallow tillage, 0-15 cm depth, SR= Shallow tillage with incorporation of wheat straw, D= deep tillage, 0-30 cm depth, DR= Deep tillage with incorporation of wheat straw. F0= control, F1= recommended rate of fertilizer application, F2= Farm yard manure application at the rate of 7.6 Mg ha^{-1} with inorganic fertilizer application

Columns sharing same letters are statistically non-significant $P \leq 0.05$; NS= non-significant

Table 3. ANOVA for the effect of tillage practices and fertilizers levels on yield, harvest index, leaf area and partial factor productivity

	Mean Squares					
	df	Grain yield	Straw yield	Harvest index	Leaf area	Partial factor productivity
Replications	2	0.16	0.48	0.001	29.19	0.73
Tillage (T)	3	1.83 **	3.09 ns	0.002 ns	195 *	21 *
Error	6	0.13	1.77	0.004	22.51	3.56
Fertilizers (F)	2	3.38 **	23.52 **	0.006 ns	183 **	6.23 ns
T X F	6	0.40 ns	1.61 ns	0.007 ns	9.65 ns	6.19 ns
Error	16	0.39	0.83	0.008	18.86	6.99
Total	35					

*; ** significant at $p \leq 0.01$ and $P \leq 0.05$ respectively
ns: non-significant

Table 4. Effect of tillage practices and fertilizers levels on bulk density, water contents and water use efficiency (kg ha^{-1} mm^{-1}).

	Bulk Density Mg m^{-3}		Water contents mm		Water use efficiency kg ha^{-1} mm^{-1}
Tillage practices (T)	0-15 cm	15-30 cm	0-15 cm	15-30cm	
S	1.12 C	1.07 B	24.8 B	21.15 A	2.79 B
SR	1.16 BC	1.08 B	34.4 A	26.70 AB	3.31 B
D	1.22 AB	1.17 A	34.3 A	29.3 A	4.56 A
DR	1.24 A	1.10 AB	29.6 AB	26.05 AB	3.45 B
Fertilizers levels (F)					
F0	1.22 A	1.14 A	29.4 A	24.6 A	2.57 B
F1	1.19 AB	1.11 AB	31.2 A	25.7 A	3.78 A
F2	1.14 B	1.08 B	31.8 A	27.2 A	4.24 A
LSD value					
T	0.06	0.08	6.88	5.69	
F	0.06	0.03	5.04	4.18	0.84
TxF	Ns	ns	ns	ns	ns

S= Shallow tillage, 0-15 cm depth, SR= shallow tillage with incorporation of wheat straw, D= deep tillage, 0-30 cm depth, DR= Deep tillage with incorporation of wheat straw. F0= control, F1= recommended rate of fertilizer application, F2= Farm yard manure application at the rate of 7.6 Mg ha^{-1} with inorganic fertilizer application
Columns sharing same letters are statistically non-significant $P \leq 0.05$; ns= non-significant

Mean Squares						
	df	Bulk Density (0-15 cm)	Bulk Density (15-30 cm)	Water contents (0-15 cm)	Water contents 15-30 cm	Water use efficiency
Replications	2	0.001	0.015	0.001	29.19	0.73
Tillage (T)	3	0.028**	0.018*	0.002 ns	195 *	21 *
Error	6	0.0026	0.004	0.004	22.51	3.56
Fertilizers (F)	2	0.021*	0.009*	0.006 ns	183 **	6.23 ns
T X F	6	0.002 ns	0.001	0.007 ns	9.65 ns	6.19 ns
Error	16	0.005	0.002	0.008	18.86	6.99
Total	35					

Table 5. ANOVA for the effect of tillage practices and fertilizers levels on bulk density, water contents and water use efficiency

*; ** significant at $p \leq 0.01$ and $P \leq 0.05$ respectively

ns: non-significant

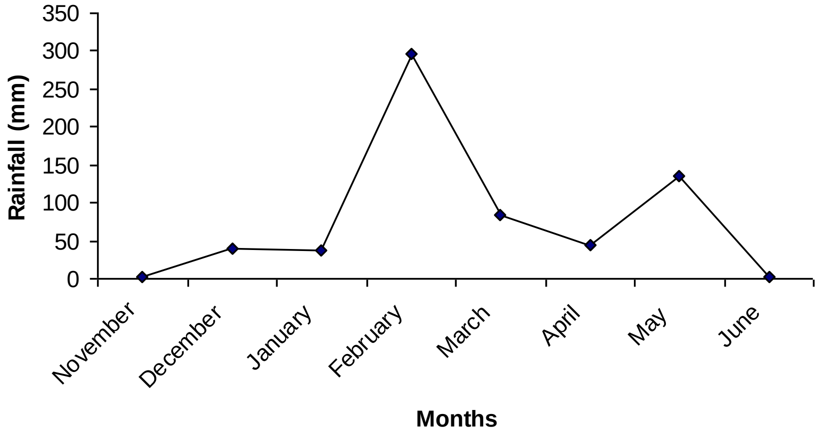

Fig. 1 Rainfall during growing season of wheat 2009-2010.

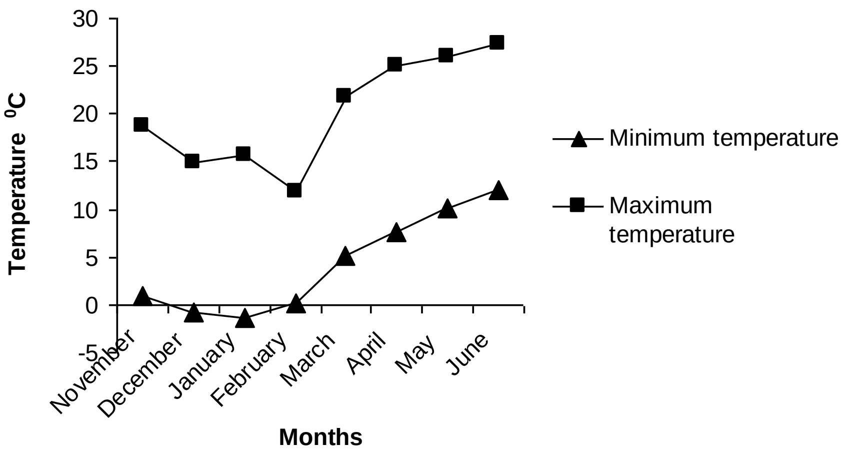

Fig. 2 Monthly minimum and maximum temperature during growing season of wheat 2009-2010

RESULTS AND DISCUSSION

Tillage practices and fertilizers levels (Table 2) have showed statistically ($p \leq 0.05$) significant effect on grain yield. Among tillage treatments D gave higher yield (2.86 Mg ha^{-1}) while the lowest yield (1.79 Mg ha^{-1}) in S. Among fertilizers levels, F1 and F2 gave statistically similar grain yield relative to control (F0). Higher straw yield was observed under D that is statistically non-significant with DR, SR and S. Among fertilizers levels same trend of increase in straw yield was studied as in grain yield. Interactive effects of tillage and fertilizers are non-significant for all parameters (Table 3). Both tillage practices and fertilizers levels showed statistically ($p \leq 0.05$) similar harvest index values.

Crop residues management with different tillage practices and integrated nutrient application does not show same results for all soil types and climate but it varies. In this study residue incorporation with shallow and deep tillage (Table 2) did not show significant impact that may be due to lower temperature (Cook and Haguland., 1991) or application of residues at the time of sowing and nutrient contents of residues that have not been converted into readily available form. Few studies has shown decreased grain yield of wheat due to poor germination with crop residues incorporation (Hejazi *et al*., 2010). Higher yield under D compare to S (Table 2) may be attributed to more infiltration of water and higher proliferation of roots due to breaking of hard layer up to 30 cm depth (Shaheen *et al*., 2010a). Data of grain yield (Table 2) suggests that integrated nutrient management was about as efficient as inorganic fertilizer source. The combined use of FYM with inorganic fertilizers improve soil permeability to air and water, water stable aggregates, checks N losses by forming organic mineral complexes and uptake of nutrients witch in turn increase plant growth and yield (Satyanarayana *et al*., 2002). In long-term studies (Bayu *et al*., 2006; Yadav, 2001) application of 5 Mg FYM ha^{-1} in combination with 50 % of the recommended inorganic fertilizer rate has increased grain yield comparable to 100 % of the inorganic recommended rate of fertilizer. The results propose that by application of 50 % the recommended fertilizers with FYM can save cost on inorganic fertilizers. Wilhelm and Wortmann (2004) found that tillage methods had no effect on crop yield.

Leaf area response for both tillage and fertilizers practices (Table 2) is statistically non-significant. D and DR showed higher leaf area than S and SR. Both F1 and F2 showed higher leaf area than F0. Interaction of fertilizers and tillage practice was found non-significant (Table. 3). Higher leaf area under D and DR may be attributed to higher uptake of both nutrients and water under these treatments and shows higher growth under these treatments.

Higher values of Pfp (11.97) were obtained under D while S, SR and DR showed statistically similar values (Table 2). Fertilizers levels showed more or less similar values while interaction of fertilizers and tillage (Table. 3) practices was non-significant statistically.

There are many measures of productivity (Dawe and Dobberman, 1999) one example is the partial factor productivity (PFP) of fertilizer, which is the average productivity, measured by grain output divided by quantities of fertilizer. This is relatively easy to measure, but its interpretation is not clear. Some studies have calculated trends in the partial factor productivity of fertilizer (PFP-F) over time. Invariably, these calculations show sharply declining trends, and they are cited as a cause for concern.

Partial factor productivity (Pfp) is a useful measure of nutrient use efficiency as it provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system (Yadav, 2003). Decline in partial factor productivity for tillage with residues application may be attributed to nutrients immobilization in short term experimental trial. Non-significant effect of fertilizers levels (Table 2) may be due to slow release of nutrients from integrated nutrient application in one growth season of crop. According to Cassman *et al*. (1996), Pfp can be increased by increasing the efficiency with which applied nutrients are taken up by the crop and utilized to produce grain.

Data of water contents at the time of harvest in given in Table 4. Statistically non-significant water contents for depth of 0-15 cm were calculated for SR, D and DR tillage treatments but significantly higher than S. Water contents at depth of 15-30 cm was calculated higher for D at the time of harvest. Fertilizers levels showed statistically non-significant difference but overall non-significant higher water contents were observed under F2. Effect of tillage practices shows (Table 4) higher bulk density values with DR and lower with S for depth of 0-15 cm. Similar trend was found for 15-30 cm depth. However, among fertilizers levels lower bulk density values are obtained with F2 and higher with F0 for both soil depths. Table 4 shows that statistically higher WUE values were obtained for D (4.56 kg ha^{-1} mm^{-1}) and lower with S (2.79 kg ha^{-1} mm^{-1}). Among fertilizers levels, F2 gave 4.24 kg ha^{-1} mm^{-1} WUE which is statistically higher than F0 (2.57 kg ha^{-1} mm^{-1}) and similar to F1 (3.78 kg ha^{-1} mm^{-1}). Interaction of TxF (Table 5) for water contents, bulk density and WUE was statistically non-significant.

Higher water contents and WUE under deep tillage may be due to disruption of hard layers or naturally occurring dense pans that develops due to ploughing at same depths year after year (Campbell *et al*., 1994). Similarly crop residue management, especially in sub-humid and semiarid regions, is to improve soil water conservation (Steiner, 1994) due to reduced runoff of surface water and improved soil surface condition that allows more time for and permits greater water infiltration. Improved water conservation with suitable tillage practices is an important factor in humid regions where the short-term drought can severely limit crop yields on soils that have low water-holding capacities. In short-term studies combined use of organic and mineral fertilizers gave comparable amount of water used by the crop and similar water use efficiency values (Shaheen *et al*., 2010b). Apart from increasing yield, fertilizers reduce the rate of evaporation by rapid growth of canopy that shades the soil surface (Cooper *et al*., 1987) so water contents under F_1 and F_2 were similar statistically. Residue management practices affect soil physical properties such as soil moisture content and bulk density. In some studies however, researchers failed to obtain a significant difference in soil water content between conservation tillage and conventional tillage (Hill *et al*., 1985; Nuttall *et al*., 1986). Such results occur because of extended dry periods or because of very low residue rates. Soil water contents affected by tillage practices because of changes produced in infiltration, surface runoff, evaporation and protection from rainfall impact (Zhai *et al*., 1990; Triplett *et al*., 1968). The effect of residue management on soil bulk density is variable as some workers reported no effect (Skidmore *et al*., 1986; Hill, 1990), whereas others found lower soil BD in a conservation tillage-residue management system (Edwards *et al*., 1992) and residue incorporation (Sidhu and Sur, 1993). Several authors found greater bulk density under conservation tillage than conventional tillage (Hammel, 1989; Ferreras *et al*., 2000). Water-use efficiency depends upon physiological processes in plants, and these processes are affected by soil fertility. Any practice that leads to an increase in soil water in the root zone may have a positive impact on WUE, due to increased water availability and nutrient uptake (Hatfield *et al*., 2001). As during moisture-stress conditions the shortage of assimilates and the reduced availability of nutrients cause reduction of grain growth and duration of grain filling (Ren *et al*., 2003) which results lower WUE.

CONCLUSIONS

The higher yield was obtained with deep tillage than shallow tillage and it is attributed to breaking of hard pans that develops with year to year ploughing of same soil depth (0-15 cm). Crop residues incorporation with shallow and deep tillage practices did not give higher yield as deep tillage without residues incorporation but showed higher yield than shallow tillage. Farm yard manure application as integrated approach with inorganic fertilizers gave comparable yield, pfp as inorganic fertilizers application.

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