Effects of Tillage System, Previous Crops and N-P rate on Agronomic Parameters of Wheat at Shambo in Horro Highlands, Ethiopia

By

Tolera Abera, Daba Feyisa, Hasan Yusuf and Wakene Negassa

Oromiya Agricultural Research Institute, Bako Agricultural Research Center

P.O. Box 26, Email: akthirpha@yahoo.com, *Bako, Oromiya, Ethiopia*

Abstracts

In the Horro highlands, wheat planting with conventional tillage and previous crops by application of N-P fertilizer is more common for smallholder farmers. In this area, the consequences of conventional and minimum tillage with different previous crops and rate of N-P fertilizer on wheat yields have not previously been tested. A trial was conducted to compare the effects of tillage system, previous crops and N-P fertilizer rate on wheat yield. Two-tillage system (minimum and conventional tillage), three-previous crops (Niger seed, faba bean and barley) and two N-P rates (75 and 100% of the recommended fertilizer rate) were tested with continuous wheat for both tillage systems in three replications. Tillage system, previous crops and N-P fertilizer rate significantly produced higher wheat grain yields and straw biomass. Significant change of soil pH was observed due to combined use different factors compared to soil pH before treatment application. Minimum tillage gave better grain yield and straw biomass of wheat. Wheat following Niger seed gave better grain yield and straw biomass followed by faba bean and barley compared to continuous wheat. Higher grain yield and straw biomass of wheat were obtained from wheat produced on minimum tillage, following Niger seed and faba bean with recommended N-P fertilizer rate application. Niger seed and faba bean was the best precursor crop for wheat production in the region. Application of recommended rate of fertilizers following previous crop was necessary for wheat production. Thus integrated use these factors have the potential to increase wheat grain yield in Horro highlands.

Key words: Tillage system, cropping sequence, fertilizer rate

Introduction

Wheat is among the major widely produced cereal crops in highlands of Horro with conventional tillage system (Asfaw *et al.*, 1997). However, conservation tillage and crop rotation are considered to be the major means of sustaining agricultural productivity globally (Lal, 1989). Conservation or minimum tillage has received considerable attention because of its ability to conserve soil and water compared to conventional tillage practices (McFarland *et al.*, 1991); increase soil organic matter content (Douglas and Goss, 1982), aggregate stability (Heard et al., 1988), improved infiltration and increased soil water storage (Mielke *et al*., 1986). Wagger and Denton (1989) reported increased grain yield with conservation tillage. Greater economic return with reduced tillage compared to conventional tillage reported by McFarland *et al.* (1991). Gumbs and Lindsay (1993) found zero-tillage has potential for year round crop production especially when the rainfall regime is not high. However, Campbell et al. (2001) reported that the conversation to no tillage management might not always result in an increase in soil C or

N without adequate fertility. Hill (1990) indicated that no-tillage resulted in decreased pore space.

Previous crops may also increase the efficiency of cereal crop production. Rotational benefits to wheat from previous crops may include enhanced soil fertility, increased water use efficiency, as well as decreased yield and quality losses from weeds and soil-borne disease (Derksen *et al*., 2002; Krupinsky *et al*., 2002), increased wheat grain yield (Asefa *et al*., 2000; and Tolera and Mathewos, 2005). However, previous crops with N-P rate effects from different crops managed in minimum and conventional tillage systems have not been previously determined in the region. Therefore the objectives of this study were to evaluate minimum and conventional tillage with previous crops and N-P rate on sustainable production of wheat.

Materials and Methods

The experiment was conducted from (2001-2004) cropping seasons at Shambo in Horro Highland. It lies between $9^{o}34'$N latitude and $37^{o}06'$E longitude at an altitude of 2400 meter above sea level. Mean annual rainfall of 1,695 mm. It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 9, 17 and $13^{o}{}_{C}$, respectively. The experiment was laid out in 2x3x2 factorial arrangement in a randomized complete block design as tillage system (minimum and conventional) main plot, previous crops (Niger seed, faba bean and barley) as sub-plots and N-P rates (75 % and 100 % of the recommended rate) as sub sub-plots were tested with two continuous wheat planting. The treatment combinations were:

No.	Tillage system	Previous crop	N-P rate
$T_{1.}$	Minimum	Continuous	100 % RR
T_2.	Minimum	faba bean	75 % RR
T_3.	Minimum	Faba bean	100 % RR
$T_{4.}$	Minimum	Niger seed	75 % RR
T_5.	Minimum	Niger seed	100 % RR
T_6.	Minimum	Barley	75 % RR
T_7.	Minimum	Barley	100 % RR
$T_{8.}$	Conventional	Continuous	100 % RR
$T_{9.}$	Conventional	Faba bean	75 % RR
$T_{10.}$	Conventional	Faba bean	100 % RR
$T_{11.}$	Conventional	Niger seed	75 % RR
$T_{12.}$	Conventional	Niger seed	100 % RR
$T_{13.}$	Conventional	Barley	75 % RR
$T_{14.}$	Conventional	Barley	100 % RR

where as RR is recommended rate (100 kg Urea and DAP ha^{-1}) for wheat production in the area.

The conventional tillage was five times ploughing with oxen and local marasha. In minimum tillage the field was first treated with Round-up three weeks before planting to clear the field from weed. The previous crops were Niger seed (*Guizotia Abyssinca*) faba bean (*Vicia fabae)* variety CS-20-DK, and barley (*Hordeum vulgar)* variety, Shege. First year in 2001 cropping season the field was divided in to two and wheat variety (Kubsa) was planted with minimum and conventional tillage. The previous crops were planted in 2002 cropping season where as wheat variety (Kubsa) was planted following previous crops with different N-P rate for two consecutive years on two tillage systems. The plot size was 4 m x 4 m. The seed rate used was 150 kg ha^{-1} for wheat. Sowing dates were between mid Junes to early July. The N-P fertilizer rates as (DAP and Urea) sources were applied at planting.

For the control of weed, hand weeding was done twice once at 25 days after sowing and second 45 days after sowing. Pre-harvest (plant height, spike length) and post-harvest (above ground biomass, 1000 seed weight and grain yield) data were collected. All collected data were analysed using Statistical Analysis system SAS (SAS, 1996) and MSTATC (Freed *et al*., 1989). Mean separation was done using least significance difference (LSD) at 5 % probability level (Steel and Torrie, 1980). For partial budget and marginal rate of return analysis, wheat grain yield was valued at an average open market price of EB 222 per 100 kg for the last 10 years and herbicide cost was EB 210 ha^{-1}. Tillage cost was EB 80 ha^{-1}. Grain yield was down adjusted at 10 % (CIMMYT, 1988).

The soil samples were collected at the depth 0-20 cm with augur once before establishing the experiment in 2001 and second after harvesting of the previous crops in 2003. The collected soil samples were analyzed following standard procedures.

Results and Discussion

Plant height

Tillage system was non-significantly ($p>0.05$) affected plant height of wheat (Table 1). Previous crops significantly ($p<0.05$) affected plant height of wheat in 2004 and combined over years (Table 2). Similarly Kelley and Sweeney (2005) reported yield components of wheat were affected by previous crops. N-P fertilizer rate non-significantly affected mean plant height of wheat.

Straw biomass

Tillage system significantly ($p<0.05$) affected straw biomass of wheat in 2005 and combined over years (Table 1). Similarly result was reported by Kelley and Sweeney (2005). Higher combined mean straw biomass was harvested from minimum tillage system. Straw biomass advantage of 1114 kg ha^{-1} or 18 % was recorded from minimum tillage compared to conventional tillage system (Table 1). Previous crops significantly ($p<0.05$) affected straw biomass of wheat (Table 2). Result agrees with previous results reported by Tolera and Mathewos (2005); Kelley and Sweeney (2005). Amanuel et al. (2000) also reported that crop rotation had a significant effect on the yield components of wheat. Wheat following Niger seed produced 11 and 21 % compared to faba bean and barley (Table 2). This indicates Niger seed is the best precursor crop for sustainable wheat production. N-P fertilizer rate non-significantly ($p>0.05$) affected straw biomass of wheat (Table 3). Application recommended rate of fertilizer produced higher straw biomass of wheat as compared to 25 % less of the recommended rate. Use of recommended rate of fertilizer following different management practices gave straw biomass advantage of 259, 495 and 377 kg ha^{-1} compared to 25 % less of the recommended fertilizer rate (Table 3).

1000 seed weight

Tillage system, previous crops, N-P fertilizer rate and combined treatment effects non-significantly ($p>0.05$) affected 1000 seed weight of wheat (Table 1, 2 and 3).

Grain yield

Tillage system was significantly ($P<0.05$) affected grain yield of wheat except in 2004 (Table 1). Similarly Kelley and Sweeney (2005) reported wheat grain yield was affected by tillage system. Minimum tillage significantly produced higher grain yield of wheat compared to conventional tillage that might be due to the decomposition plant debris before planting with the application of round up three weeks before planting. Combined mean grain yield advantage of 351 kg ha^{-1} or 15.45 % was obtained from minimum tillage compared to conventional tillage system (Table 1). Wheat mean grain yield variation for tillage system was in smaller gap. Kelley and Sweeney (2005) reported tillage effects on grain yield generally were of a smaller magnitude. Therefore, production of wheat with minimum tillage was a viable agronomic management practices for the area.

Previous crops significantly ($p<0.05$) affected grain yield of wheat (Table 2). Similar result was reported by Kelley and Sweeney (2005). Wheat following Niger seed significantly produced higher grain yield compared to faba bean and barley (Table 2). This result agrees with the findings of others (Tilahun *et al.*, 2000) Tanner *et al. (*1999) and Amsal *et al.* (1997) reported wheat grain yield to be 22 to 54 % and 59 % more following a dicot crop as compared to a cereal crop. Kelley and Sweeney (2005) also reported grain yields of wheat following soybean were greater than wheat following grain sorghum. Mean grain yield of wheat following barley was equal or less than continuous planted under minimum and conventional tillage system. Amsal *et al.* (1997) found wheat following any cereal (tef, wheat or barley) exhibited depressed yield and yield component performance and stunted plants. N-P fertilizer rate was significantly ($p<0.05$) affected grain yield of wheat (Table 3), which was in agreement with Kelley and Sweeney (2005). Significantly higher grain yield of wheat was recorded from application of recommended fertilizer rate. Mean grain yield of wheat was better with application of recommended rate of fertilizer following different previous crops with minimum and conventional tillage system. Averaged across cropping season, mean grain yields were higher for the use of recommended rates of fertilizers following different crops under two tillage systems. Similarly Kelley and Sweeney (2005) grain yields were greatest in all cropping system for the higher rates of N fertilizer.

Economic analysis for tillage system indicated that the highest net benefit of EB 5908 ha^{-1} with marginal rate of return of 366 % and values to cost ratio of EB 11.82 profit per unit of investment for wheat were obtained from minimum tillage system (Table 4). The net benefit for conventional tillage system was EB 5542 ha^{-1} with values to cost ratio of EB 13.86 profit per unit investment for wheat production (Table 4). The values to cost ratio with both management levels accommodate the price production and provides profit to wheat producers of the area. With the average current prices of input of production use of both tillage systems were economically optimal and profitable. The result of this finding justifies that minimum tillage system enhanced the yield of wheat at Shambo in Horro highlands.

Soil properties

The soil pH in H_2O ranged from 5.2 (before planting) to 6.0 (Table 5). This implies that the soil reaction was moderately acidic to slightly acidic (FAO, 1990; Landon, 1991). The soil pH in H_2O after application of treatments ranged from 5.8 to 6.0 (Table 5). This indicates there is soil reaction (pH) change with previous crops and application of N-P fertilizer rate. Soil amendment with crop rotation and N-P fertilizer rate improve the pH of the soil which is in agreement with Asefa et. al. (2003). Minimum tillage exhibited relatively higher soil pH as compared to conventional tillage (Table 5). Similar result was reported by Asefa et. al. (2003). Total N ranged from 0.158 to 0.357 % (Table 5) found in medium range (FAO, 1990). Organic carbon contents of the soil ranged from 3.012 to 3.312 % (Table 5) found in medium range (FAO, 1990). The soil needs higher inputs to amend the soil for sustainable production of wheat. Available P was ranged from 4.72 to 10.10 (Table 5). Low available p was recorded. This situation can be attributed due to the low phosphorous fixing capacity of moderately acidic soil. The phosphorous content of the soil was found between faire to adequate range for Wheat production (FAO, 1990).

Conclusion

Mean grain yield and yield components of wheat significantly affected by tillage system, previous crops and N-P fertilizer rates. Higher mean grain yield of wheat was obtained from minimum tillage as compared to conventional tillage system. The economic analysis also confirms the use minimum tillage system for wheat production at Shambo is profitable. Higher mean grain yield of wheat was produced following Niger seed followed by faba bean as compared to barley and continuous wheat. Therefore, production of wheat following Niger seed and faba bean with recommended rate of fertilizer under minimum tillage was recommended for sustainable production of wheat at Shambo in Horro highlands.

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Table 1. Effects of tillage system on plant height, straw biomass, 1000 seed weight and grain yield of wheat in 2004, 2005 and combined over years.

Year	Tillage system	Plant height (cm)	Straw biomass (kg ha-1)	1000 seed weight (g)	Grain yield (kg ha-1)
2004	Minimum	80	2473	35	1759
	Conventional	81	2256	34	1565
	Mean	80.5	2365	34.5	1662
	CV (%)	5.71	28.92	19.13	23.88
	LSD (5%)	Ns	Ns	Ns	Ns
2005	Minimum	95	12339	40	4655
	Conventional	92	11450	40	4388
	Mean	93	11894	40	4521
	CV (%)	5.58	10	3.97	5.45
	LSD (5%)	Ns	822	Ns	170
Combined	Minimum	87	7406	38	3207
	Conventional	87	6853	37	2974
	Mean	87	7129	37	3090
	CV (%)	5.76	13.66	12.99	10.55
	LSD (5%)	Ns	462	Ns	155

Ns= non-significant

Table 2. Effects of cropping sequence on plant height, straw biomass, 1000 seed weight and grain yield of wheat in 2004, 2005 and combined over years.

Year	Previous crops	Plant height (cm)	Straw biomass (kg ha^{-1})	1000 seed weight (g)	Grain yield (kg ha^{-1})
2004	Faba bean	81	1922	32	1379
	Niger seed	87	4007	37	2864
	Barley	73	1165	35	742
	Wheat	76	1208	35	791
	Mean	81	2364	35	1662
	CV (%)	5.71	28.92	19.13	23.88
	LSD (5%)	3.91	579	Ns	336
2005	Faba bean	94	12176	40	4624
	Niger seed	94	11703	39	4568
	Barley	93	11805	40	4372
	Wheat	95	11425	32	4111
	Mean	94	11894	40	4522
	CV (%)	5.58	10	3.97	5.45
	LSD (5%)	Ns	Ns	Ns	208
Combined	Faba bean	88	7049	36	3002
	Niger seed	90	7855	38	3716
	Barley	83	6485	37	2553
	Wheat	86	6317	34	2451
	Mean	87	7130	37	3090
	CV (%)	5.76	13.66	12.99	10.55
	LSD (5%)	2.92	566	Ns	189

Ns= non-significant

Table 3. Effects of N-P rate on plant height, straw biomass, 1000 seed weight and grain yield of wheat in 2004, 2005 and combined over years and locations.

Year	N-P rate	Plant height (cm)	Straw biomass (kg ha^{-1})	1000 seed weight (g)	Grain yield (kg ha^{-1})
2004	75 % RR	81	2235	34	1592
	100 %	80	2494	35	1732
	Mean	81	2365	35	1662
	CV (%)	5.71	28.92	19.13	23.88
	LSD (5%)	Ns	Ns	Ns	Ns
2005	75 % RR	94	11647	40	4400
	100 %	93	12142	40	4643
	Mean	94	11895	40	4522
	CV (%)	5.58	10	3.97	5.45
	LSD (5%)	Ns	Ns	Ns	170
Combined	75 % RR	88	6941	37	2993
	100 %	87	7318	37	3188
	Mean	87	7130	37	3090
	CV (%)	5.76	13.66	12.99	10.55
	LSD (5%)	Ns	Ns	Ns	278

Ns= non-significant

Table 4. Partial budget and marginal rate of return (MRR) analyses for the effects of tillage system on the mean grain yield of Wheat at Shambo

Items	Tillage system	
	Conventional	Minimum
Average yield (kg ha^{-1}) wheat	2974	3207
Adjusted yield kg ha^{-1}) wheat	2676.6	2886.3
Gross field benefit of wheat	5942.05	6407.6
Total field benefit (EB ha^{-1})	59407.6	6407.6
Tillage cost (EB ha^{-1}) Herbicide Cost (EB ha^{-1})	400 0	80 420
Total costs that vary (EB ha^{-1})	400	500
Net benefit	5542.05	5907.6
Values to cost ratio	13.86	11.82
Marginal rate of return (MRR)		366 %

Note: Grain price= EB 2.22 kg^{-1}, Herbicide price= 210 ha^{-1} , Yield was down adjusted with 10% coefficient, d= dominated treatment, 1$ = 9.02 EB.

Table 5. Properties of soil in the study area before and after application of treatments at Horro highlands.

Treatment	pH	T.N	O.C	C:N	A.P	K	Ca	Mg	Sand	Silt	Clay	Class
	H_2O	(%)			(ppm)	Meq 100 gm $Soil^{-1}$			(%)			
1	5.9	0.343	3.312	10	6.24	3.95	9.78	1.81	29	42	29	Clay loam
2	5.8	0.158	3.292	21	5.80	5.06	9.88	1.40	31	42	27	Loam
3	5.9	0.350	3.212	9	5.76	3.43	10.18	1.56	23	42	35	Clay loam
4	6.0	0.350	3.292	9	4.54	4.29	10.13	1.81	19	42	39	Silt clay loam
5	5.9	0.330	3.112	9	4.66	3.79	9.43	1.56	31	40	29	Clay loam
6	5.9	0.357	3.192	9	5.18	4.06	9.53	1.73	27	40	33	Clay loam
7	5.9	0.343	3.272	10	4.64	2.99	9.68	1.48	23	42	35	Clay loam
8	5.8	0.336	3.052	9	5.24	4.06	10.38	2.23	19	40	41	Clay
9	5.9	0.273	3.052	11	4.84	4.49	9.53	1.98	21	38	41	Clay
10	5.8	0.328	3.172	10	5.66	3.98	9.43	1.89	33	36	31	Clay loam
11	5.9	0.339	3.0923	9	5.14	3.79	10.78	1.89	27	40	33	Clay loam
12	5.8	0.339	3.072	9	5.12	4.17	8.73	1.81	23	40	37	Clay loam
13	5.9	0.326	3.0423	9	10.10	4.42	9.68	1.98	23	42	35	Clay loam
14	5.8	0.321	3.012	9	4.72	4.41	8.88	1.81	27	40	33	Clay loam
Before treatment	5.2	0.343	3.272	10	5.0	0.74	2.41	2.14	22	36	42	Clay