

Tillage Effect on Soil Moisture Storage and Wheat Yield on the Vertisols of North Central Highlands of Ethiopia

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Abstract

Vertisols are one of the agriculturally important soils in Delanta Dawunt, north central highlands of Ethiopia, for peasant farmers as almost all the cereal, soil and forage crops are grown on them. However, waterlogging during the growing season impedes the performances of cereal crops. It is crucial to seek for cost effective means to mitigate waterlogging for increased production. Hence, a field experiment was conducted to observe effectiveness of tillage on draining excess soil water. To this effect treatments, i.e., 'flat seedbed, 'traditional drainage system' (Shurube), 'broadbed and furrow with 100 cm (BBF-100 cm)' and 'broadbed and furrow with 80cm'(BBF 80 cm) were arranged in a randomized complete block design with three replications on 6 m by 4 m plot. The study revealed that BBF-100 cm, BBF-80 cm and traditional drainage system significantly increased the grain yield of wheat by 51.4 %, 41.6 % and 11.2 % compared to the control, respectively. Therefore, this study recommends 'BBF-100 cm followed by BBF-80 cm to fight against seasonal waterlogging and to boost wheat production in the North central highlands of Ethiopia.

Key words: Broadbed and furrow with 100 cm, Broadbed and furrow with 80 cm, Flat seedbed; Traditional drainage System; Tillage, Vertisols; Wheat

Introduction

Ethiopia ranks third in Vertisols abundance in Africa after the Sudan and Chad (Berhanu, 1985). An estimated 7.6 million ha of Ethiopian Vertisols are located in the highlands above 1500 m a.s.l. and on higher elevations (> 2500 m a.s.l.) in temperate ecosystems (Berhanu, 1985; Jutzi and Mesfin, 1987; Lakew et al., 2005; Teklu et al., 2006). About 25% of those occurring in the highlands are believed to be cultivated (Berhanu, 2000, Abate et al., 1993). The highest coverage of Vertisols in the country is found in Oromiya region (47.6 %) followed by Amhara sharing (25.2 %) or 3.2 million ha of the total (ARDB, 2005). Among the 113 Woreda's in the Amhara Region, Vertisols are found only in 79 Woredas of which Delanta Dawunt Woreda is one (ARDB, 2005) wherein this research was conducted.

Wheat is the most important single crop in the area followed by lentil. It is also the first crop, which accounts 26.6 % and 5.6 % of the cultivated land in Meher and Belg cropping season in the study area, respectively. Seasonal water logging is one of the major agricultural problems during the main rainy season of the north central highlands of Ethiopia. As a result, early planting is prohibited with traditional

management system, which in its turn will reduce the length of the growing cycle. Apparently, seeking for a means to reverse the limitation is pragmatic. Amongst the technological options, broad bed furrow (BBF) had gain much attention for draining the excess water out of the field thereby production is increased (ARDB, 2005). Besides, local farmers traditionally grow relatively waterlogging resistant crop, *Enzosh Synde*, a 'local wheat variety' which also tolerates frost. Thus, this study was conducted to examine effect of the BBF system on the productivity of *Enzosh Synde* by entwining the BBF technology with the nature of a local water logging resistant wheat variety.

Materials and Methods

Study area

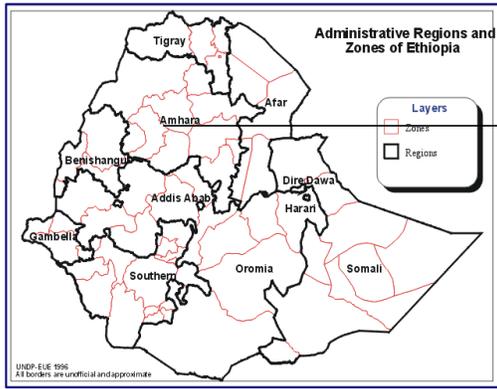
Delanta Dawunt woreda is located in North West part of *Wollo* and administrated under North *Wollo* administrative Zone (Fig.1). Currently, *Delanta Dawunt* has a population of 200,000 with a landmass of 1678.6 km². The altitude of the *Woreda* ranges between 1700 m a.s.l in river valleys to 3500 m a.s.l at Mountains. The experimental site was selected based on the criteria of area coverage of waterlogging problems, population density and proximity when the comparison made among other hamlets.

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The climatic data of the study area for the years 1995 to 2005 indicates that the mean annual rainfall of the area 776.7 mm of which 72.2 % is received during the main growing season (*Kiremet*) i.e. from June 20 to

September 10. July and August alone contribute more than 65.6 % to the annual rainfall (Fig.2). The periods from October to May and the first 20 days of June are virtually dry.



NORTH WOLLO BASE MAP



Figure 1. Location map of the study area

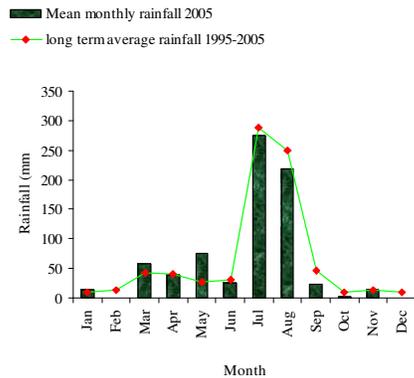


Figure 2. Rainfall distribution for the period of 1995-2005 of *Dalenta Dawunt*

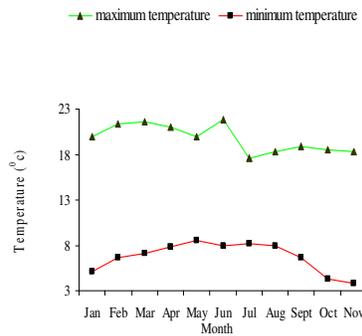


Figure 3. Monthly minimum and maximum temperature in 2005

The highland plateau areas have very cold temperature that ranges from 0°C to 20°C (Getaw et al, 2000). Asfaw and Amdemeskel (1998) reported that monthly average maximum temperature become high starting from December to May and then reduces significantly from September and October being the coldest months of the year. Besides, the minimum temperature recorded in this

experimental year varied from 3.8°C in November to 8.5°C in May (Fig. 3).

Soil types

Table 1, showed the pH of these Vertisols as slightly acid. The chemical fertility is very poor and characterized by low Total. N, available P and exchangeable K. The

clay content is generally quit high in distribution. The moisture storage of Vertisols ranged from 91.8 to 465.7 mm at field
Experimental lay out

The experiment was conducted in 2005 cropping season in a randomized complete block design (RCBD) with three replicates. The treatments were flat seedbed (FSB), traditional drainage system, “Shurube” (TDS), broadbed and furrow with 100 cm bed and 50 cm furrow width by 30 cm bed height (BBF-100) and BBF with 80 cm bed and 40 cm furrow width by 20 cm bed height (BBF-80). A partially water logging resistant local wheat variety was sown at the rate of 150 kg ha⁻¹. Diammonium phosphate fertilizer was applied at a rate of 100 kg ha⁻¹ at sowing whereas urea was top dressed at 35th day after sowing at the rate of 100 kg ha⁻¹.

Plant data collection and analysis

Dates during which 50% of the plant population reaches germination, tillering, stem elongation and anthesis and maturity were recorded. Plant height measurement was made using ruler in randomly selected five plots wherein samples were collected from seven quadrants. Plant density was measured at tillering; stem elongation and anthesis growth stages through direct counting. The length of spikes was measured using ruler. Weed infestation was studied by direct identification and counting within seven quadrants during tillering and stem elongation stages. Finally, data on wheat grains and dry matter were collected. Data collected were analysed using SAS (2002) and JMP-5.

Soil moisture content measurement

Soil moisture was measured in-situ using Time Domain Reflectometre (TDR) after installing access probe tubes to 100 cm depth in each plot so as to monitor water removal capability of each tillage practice. Then data were collected every other 10 days at depths of 0-20, 20-40-, 40-60, 60-80 and 80-100cm. Finally, JMP5 statistical software was used to analyze the data.

capacity and 43.8 to 289.3 mm at permanent wilting point percentage (Table 2).

Results and Discussions
Tillage effects on yield component and yield of wheat
Plant height

Figure 4 showed the mean plant height at different growth stages, it compared the four treatments and the highest plant height was recorded on BBF-100 plot and followed by BBF-80 whereas the shortest plant was observed from control plot in all growth stage.

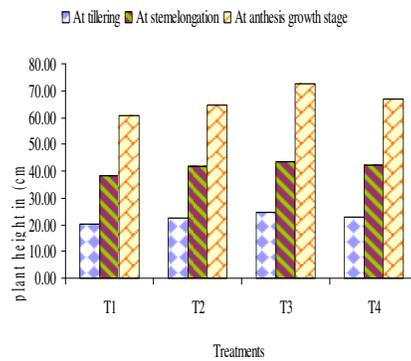


Figure 4. Tillage effect on plant height during the growing cycle

The difference due to treatments in the height of wheat resulted in a significant effect at all stages of the growing cycle. However, the highest treatment mean observed at tillering, stem elongation and anthesis on BBF-100. In the contrary the lowest treatment mean was obtained from FSB at all growth stages (Table 3).

Plant density

Figure 5, revealed plant density at different growth stages. More tillers were from plot BBF-100 followed by TDS and BBF-80 at 50 % tillering stage. Conversely, tillers from TDS plots were declined before reaching stem elongation and anthesis growth stages due to waterlogging.

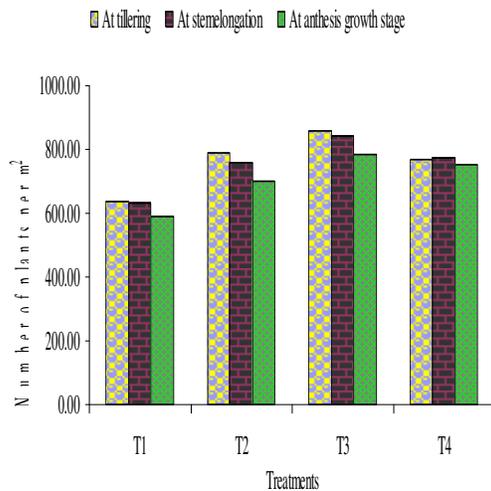


Figure 5. Cumulative plant densities at different growth stages

Although not significant, the highest density of wheat resulted in BBF-100 all growth stages when comparison was made amongst the treatment T2 and T4 but significant at ($p < 0.05$) level with control plot (Table 4).

Tillage effects on growth stages

The study revealed that BBF-80 and BBF-100 have instigated early germination but late maturity. In the contrary TDS caused shortening the duration to reach heading and maturity. Though BBF-100 was instrumental for causing the highest tiller number per quadrant and enhanced early germination, it extended the total length of the growing cycle due to delaying heading and maturity (Table 5). This is probably due to the largest amount water stored in the beds of the furrow (Table 2). As is shown in Table 5, tillage has significantly affected the length of days required for germination and to reach maturity but it insignificantly affected the length of days to reach heading. It was observed that about two and a half-months elapsed to reach heading.

Spike length

Though the ANOVA did prove the non-significant effect of tillage on the length of spike, the longest and shortest spike lengths were obtained from BBF-100 and FSB plots, respectively (Table 6).

Dry matter yield

The mean grain and straw yields of wheat was significantly affected ($p < 0.05$) by different tillage practices. When comparison was made among the treatments, significantly higher straw yield value was observed in BBF treatments (T3 & T4) and non-significantly higher straw yield was observed on traditional drainage system as compared to control. The difference due to treatments resulted in a significant effect on the straw weight during cropping season. The lowest weight of straw was resulted in control plot (Table 7). Several authors had reported increased yields of some crop grown on Vertisols due to the use of BBF as compared to flat seedbeds (Abiye et al., 1995; Srivastava et al., 1993; Teklu et al., 2006).

Grain yield

BBF with 100 cm beds gave the highest mean grain yield of wheat. Yield increased by 51.44 % as compared to the control plot (Table 7). The grain yield was also significantly increased in BBF 80 cm beds and traditional drainage system 41.6 % and 11.2 % as compared to control plot respectively. Although not significant, BBF T3 gave the highest 1000-grain weight g resulting 35.4 g as compared to the control. The treatment mean value indicates that the highest weight of straw, grain and 1000 grain was resulted in BBF T3 but the lowest weight of straw, grain and 1000 grain was recorded in the control plot (Table 7).

Tillage effect on soil water contents

Although not significant relation was observed among the treatment, the highest mean moisture content at the depths of 60-80 cm and 80-100 cm at anthesis growth stage as compared 0-20 cm depth in all tillage practices (Table 8). As is shown in Table 8, differences due to treatments on different soil layer resulted in a non significance ($p < 0.05$) on moisture content. Also in Table 2 the highest moisture content was obtained from FSB and BBF-100 whereas the lowest were in BBF-80 followed by TDS at 0-20 cm depth during

early rain in the season late July and August. The tillage practice did not have a significant effect on soil moisture within the depth of 0 to 100 cm during the rainy season (Table 8). In late July until end of August 45.1 % the mean soil moisture for 0-20 cm depth was comparatively higher than for 0-20 cm depth early September to late November 33.3 %. At the surface (0-20 cm depth) of the soil, the maximum moisture content was observed in late July and end of August and the least were in September to November.

Soil moisture characterization in different soil layer

Table 9, showed moisture storage variations in the study area at field capacity and permanent wilting points was ranging from 91.9 to 465.7 and 43.8 to 289.3 mm, respectively whereas the available moisture storage was varied from 48 to 176.4 mm.

Conclusion and recommendations

This study revealed that BBF-100 favored better plant height, density, spike length and eventually dry matter and grain yield formation than the other treatments. BBF-100 did increase the grain yield by 51.4 % as compared to the control plot. Promising results were found in BBF-80 in which the grain yield was also increased by 41.6% over the control. The impact of BBF-100 and BBF-80 has been proved by the cost benefit analysis. Cost to benefit ratio was computed for the four tillage practices and higher ratio was obtained from BBF-100 and BBF-80 plots. Hence, based on the agronomic effect and cost to benefit analysis, this study recommends the use of BBF-100 followed by BBF-80 in water logging prone areas of the central highlands of Ethiopia.

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Table 1. Physico-chemical characteristics of Vertisols in the study area

Depth (cm)	pH H ₂ O	OC %	N %	P ppm	K me/100g	CEC me/100g	Clay	Sand	Silt	Textural class name
							%	%	%	
0-20	6.7	0.86	0.08	2.5	1.1	37	68	25	7	Clay
20-40	6.5	0.87	0.07	1.7	1.6	40	73	23	4	Clay
40-60	6.5	0.83	0.08	1.4	1.5	37	72	23	5	Clay
60-80	6.5	0.88	0.08	1.5	1.1	36	72	23	5	Clay
80-100	6.4	0.72	0.07	1.5	0.9	37	71	23	6	Clay

Table 2. Moisture storage at different depth in the study area

Soil depth	Thickness (mm)	FC at 0.33 bar tension	PWP at 15 bar tension	AW (mm)	Moisture storage (mm)		
					FC	PWP	AW
0-20	200	45.9	21.9	48.1	91.8	43.8	48.1
20-40	200	46.5	29.9	33.2	184.9	103.6	81.3
40-60	200	53.0	36.2	33.8	290.9	175.9	115.0
60-80	200	48.7	26.9	43.4	388.3	229.9	158.4
80-100	200	38.7	29.7	17.9	465.7	289.3	176.4

Table 3. Tillage practices effect on wheat height

Treatment	Mean of plant height (cm)		
	Tillering	Stem elongation	Anthesis
T1	20.2c	38.1b	60.8b
T2	22.3b	41.9ab	64.7ab
T3	24.5a	43.6a	72.4a
T4	23.0ab	42.0ab	66.8ab
(p0.05)	*	*	*
CV %	7.61	5.89	7.38

NS= non-significant *= the difference is significant at (p<0.05) level

Levels not connected by same letter are significantly different

Table 4. Tillage effect on density of wheat

Treatment	Mean of plant density		
	Tillering	Stem elongation	Anthesis
T1	639.3b	633. b	591.0c
T2	789.67a	758.33a	698.3b
T3	860.33a	841a	783.0a
T4	769.33a	774.3a	752.3ab
(p0.05)	*	*	*
CV %	11.9	11.38	11.38

NS= non-significant *= the difference is significant at (p<0.05) level

Levels not connected by same letter are significantly different

Table 5. Tillage practices effect on agronomic parameter

Treatment	Mean of days to		
	Germination	Heading	Maturity
T1	5.7a	78.3a	121.67b
T2	5ab	70.7a	118.0b
T3	4bc	79.0a	129.33a
T4	3.7c	76.0a	122.33b
(p0.05)	*	NS	*
CV%	19.64	5.64	3.82

NS= non-significant *= the difference is significant at (p<0.05) level. Levels not connected by same letter are significantly different

Table 6. Tillage effect on the spike length yield of wheat

Treatment	Mean spike length (cm)
T1	6.40a
T2	6.77a
T3	7.83a
T4	7.27a
(p0.05)	NS
CV %	11.02

NS= non-significant *= the difference is significant at (p<0.05) level.
Levels not connected by same letter are significantly different

Table 7. Tillage effect on wheat dry matter and grain yield

Treatments	Straw yield kg/ha	Mean Grain yield t/ha	1000 grain wt (g)	% Increase over control	
				Straw yield %	Grain yield %
T1	2056.03c	1.25c	31.50a		
T2	2474.13bc	1.39b	33.17a	20.34	11.18
T3	3090.06a	1.89a	35.30a	50.3	51.44
T4	2797ab	1.77a	34.50a	36	41.6
(p0.05)	*	*	NS		
Cv %	16.41	17.63	6.60		

NS= non-significant *= the difference is significant at (p<0.05) level. Levels not connected by same letter are significantly different

Table 8. Tillage practice effect on soil water

Treatment	Depth of profile (cm)									
	0-20		20-40		40-60		60-80		80-100	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
T1	32.1a	13.79	34.4a	18.21	32.9a	19.17	47.1a	5.21	43.5a	7.03
T2	25.0a	16.15	34.1a	16.58	33.4a	17.76	45.9a	4.99	43.6a	6.92
T3	30.8a	17.82	35.6a	15.70	36.2a	15.91	46.8a	3.45	45.5a	5.91
T4	24.7a	17.41	33.4a	16.95	34.2a	16.15	45.2a	4.58	44.4a	5.69
(p0.05)	NS		NS		NS		NS		NS	
CV (%)	58.5		48.9		50.31		9.97		14.4	

NS= non-significant *= the difference is significant at (p<0.05) level

Table 9. Moisture storage at different depth in the study area

Soil depth	Thickness (mm)	FC at 0.33 Bar tension	PWP at 15 bar tension	AW (mm)	Storage (mm)		
					FC	PWP	AW
0-20	200	45.9	21.9	48.1	91.8	43.8	48.1
20-40	200	46.5	29.9	33.2	184.9	103.6	81.3
40-60	200	53.0	36.2	33.8	290.9	175.9	115.0
60-80	200	48.7	26.9	43.4	388.3	229.9	158.4
80-100	200	38.7	29.7	17.9	465.7	289.3	176.4