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Full Length Research Paper

Performance of *in-situ* rainwater conservation tillage techniques and inorganic fertilizer practices on sorghum production at Ethiopia Somali Region (Kurdha Metan district)

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One of the major crop production constraints in semi-arid areas is short growing period, short term rainfall with high run-off and moisture deficit. In such area, *in-situ* rainwater harvesting techniques are very crucial. In Gursum wereda (Kudha Metan district) which is one of the moisture stressed areas in Ethiopia Somali Region, this study was carried out to determine the effect of different tillage practices as *in-situ* rainwater harvesting technique, and inorganic fertilizer application on sorghum production. The experiment was conducted in two successive growing seasons from 2013 to 2014 using spilt-plot design in a RCBD. The tillage treatments on the main-plot were: Shilshalo (Sh); tied-ridge during planting time (TRB); tied-ridge after a month of planting (TRA); and Control (C), and two levels of fertilizer application on the sub-plot. The sorghum seed variety called "Ase", nationally recommended for semi-arid environment was used in the experiment. The yield and yield component data of sorghum was collected. At the end of crop harvest, soil samples were taken from the top 0-20 cm soil depth to analyze the effect of *in-situ* rainwater harvesting techniques on some soil chemical properties. The soil texture was also studied. Data were analyzed by using SAS software version 9.0. ANOVA at $p<0.05$. The results show that the highest value of available phosphorus (15.3 $mgKg^{-1}$) and the highest value of total nitrogen (1500 $mgKg^{-1}$) were conserved by tied-ridge during planting time with fertilizer compared to the control with fertilizer (12.6 $mgKg^{-1}$). However, tillage practices did not bring significant change on soil pH. Tied-ridge during planting time has brought statistically significant effect on the yield and yield components of sorghum. This treatment was also constrained by the fact that it was not much effective without fertilizer application at the study area. In general, tied-ridge with inorganic fertilizer application resulted in 210.64% more grain yield per hectare than the control treatment. Next to tied-ridge during planting time, tied-ridge after one month of planting time has also resulted relatively better performance compared to control treatment.

Key words: Fertilizer, rainwater harvesting, sorghum, tillage, yield component.

INTRODUCTION

Agriculture is the major economic activity for Sub-Saharan Africa countries, and it is strongly considered as the backbone of these countries' economic development and their people's wellbeing in the future (Giller et al., 2009). From the 41% of semi-arid region of Sub-Saharan Africa farming land, only about 2% of the arable lands are irrigated, that is, rain fed agriculture is the dominant crop production system to meet the food demand (Zougmoré et al., 2002). However, the unreliability in rainfall and

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recurrent droughts lead to subsequent production failures and puts great pressure on the food self-sufficiency of the region. The low soil water retention capacity or the high potential evapotranspiration rate is the major problem. In eastern and southern Africa where Ethiopia is located, about 35% of the sorghum production takes place in drought-prone areas with warm mean temperature and low mean monthly rainfall (Wortmann et al., 2006). Of all the environmental and socio-economic challenges people are facing, eastern lowlands of Ethiopia are vulnerable to this problem and there have been notable droughts in this part of the country throughout human history (Tadesse et al., 2008; UNEP, 2006; Gebre-Michael and Kifle, 2009).

There has been substantial growth in cereal crop cultivation, in terms of area cultivated, yields and production since 2000 GC. Much of the increase in these crops production in the past decade has been due to increases in areas cultivated. However, yields are below international standards, and overall production is highly susceptible to drought shocks (Alemayehu et al., 2012). Spring and summer rains in parts of Ethiopia have declined by 15-20% since the mid-1970s. This could dramatically increase the number of at-risk people in Ethiopia during the next 20 years at drier and warmer climate regime areas (Chris et al., 2012). Unfortunately, most dry spells occur during critical crop growth stages and lead to frequent crop failure. This urges the need of dry spell mitigation by improving water availability *in-situ* in semi-arid areas (Stephen, 2003).

The agro-pastoralist part in Ethiopia Somali region is cultivating cereal crops such as maize, sorghum and sometimes wheat. Sorghum is a major staple crop in this semi-arid region. In this area, not only moisture deficit, but also nutrient depletion, and soil erosion are the most prominent crop production limiting factor as other parts of semi-arid environments of Ethiopia (Morin, 1993; Holden and Shiferaw, 2002). In order to solve these problems, using rainwater harvesting techniques and supplementing it with soil fertility improvement options are essential coping mechanisms for improving food security in this semi-arid areas.

The effectiveness of micro-basin tillage to improve soil moisture has been studied in different parts of the semi-arid areas in highlands of Ethiopia (Gebreyesus, 2012; McHugh et al., 2007; Heluf, 2003). All of the works at the thematic areas were at the highlands. However, the same problem (scarcity of moisture) is happening in the lowlands of Somali region that has difference in soil, agro-ecology and production management practices. There was less attention given to identify suitable rainwater harvesting techniques to solve sorghum production problem. Hence this study was carried out on the selected farmer's farm lands at semiarid lowlands in Ethiopian Somali region.

The objective of this study was: (1) to determine the effect of tillage practices on sorghum yield and yield components, (2) to evaluate the effectiveness of different tied-ridging time on sorghum yield and yield components, (3) to assess the soil physicochemical properties and (4) to assess the effect of inorganic fertilizer application on sorghum yield and yield components.

MATERIALS AND METHODS

Description of the study area

The study area is located at the northern part of Upper Fafem Sub-Basin in Ethiopia Somali regional state. It is around 535 km and 25 km away from Addis Ababa and the regional capital city Jigjiga, respectively. It is bounded between the geographical coordinates of 912,270 - 1,058,809.8 UTM north and 877449.1 - 975,927.2 UTM East and 1020 - 2620 m.a.s.l. altitude ranges. The mean annual potential evapotranspiration (PET) of the district is around 1388 mm/year. The mean maximum and minimum temperatures are 14.73°C and 28.1°C, respectively. Generally, the sub-basin falls in the range of hot semiarid to cool sub humid Agro climatic zones. The area is characterized by double seasons: wet season and dry season (OWWDSE, 2012). The local sorghum variety (Ase) used in this study is one of the crops cultivated starting from July. Widely distributed soil in the area is Cambisols (42%), and is classified as Chromic and Vertic Cambisols. Various major land forms in the area include plains and hills, undulating land form and dissected by many runoff drains towards common outlet of Fafam River.

Treatments and experimental design

The experiment was conducted in the two successive growing seasons from 2013 to 2014 using spilt-plot design in completely randomized blocks (RCBD). The tillage treatments on the main-plot were Shilshalo (Sh), tied-ridging before planting (TRB), tied-ridging after one month of planting (TRA), and control (C). In the case of the tied-ridging, a depth of 0.30 m ridges was made by using oxen-drawn tools. The experiment was replicated three times at each trial season. Each tillage treatment was applied on the main-plot size of 20 m lengths × 9 m widths, whereas the fertilizer treatments were applied on the sub-plot size of 20 m lengths × 4.25 m widths. The spaces between sub-plots were 0.5 m. The distances between rows, tied-ridges, and ties were 0.75, 0.75 and 2 m, respectively according to Gebreyesus (2012). The entire experimental area was tilled twice using the traditional oxen-drawn plow before imposing any of the treatment.

The sorghum seed variety called “Ase”, nationally recommended for semi-arid environment was used. This variety is preferably planted at late season compared to the other sorghum varieties in the area, and the seed was obtained from farmer's hand. Planting was done on the ridge with manual row planting method for all plots with tied-ridge; however, for Shilshalo and control treatments, the seeds were broadcasted manually relatively in uniform rate. By hand thinning at 21 days after sowing, the desired plant spacing of 20 cm was obtained for sorghum plants planted in a row according to Gebreyesus (2012). Making ties for tied-ridges after planting treatment, and ridges for Shilshalo were undertaken after one moth of the planting day by using oxen-drawn plow.

The two fertilizer levels on the sub-plot were, 0-0 kg N-P ha^{-1} (without fertilizer, F1), and 41-20 kg N-P ha^{-1}(with fertilizer, F2). The source of nitrogen (N) was urea and DAP and that of phosphorus (P) was DAP fertilizer as 50-100 kg urea-DAP ha^{-1}. DAP was applied at planting in a band, whereas urea was side dressed after one month of planting.

Data collection and statistical analysis

The representative data were collected on plant height, leaf number, panicle length, grain yield, total dry weight and 1000-seed weight in each trial season. In each of the central three rows, randomly selected 10 plants' panicle length and plant height were measured just at harvesting time. Seed weight was determined for sample of 1000 air-dried seeds at 125 g kg^{-1} moisture content. Above ground biomass yield (straw + yield) was determined after cutting the plants just at the ground level and taking the fresh weights from each subplot at field by using digital balance.

Then allowed to oven-dry for 24 h at 65°C, and dry mass was recorded. The total dry mass was calculated by using the formula:

"Total Dry mass = (sub-sampled dry wt. /sub-sampled fresh wt.)*fresh wt. of the whole sample" as stated by (Chidumaya, 2009).

Three soil samples were taken from each subplot and bulked to get one representative sample at each trial year at the end of crop harvest. With three replications, a total of 24 soil samples were taken from the top 0-20 cm soil depth at each year. Then, total nitrogen, available phosphorus, soil pH, and soil texture were analyzed. Soil samples were air-dried, homogenized and made to pass through 2 mm sieve for chemical analysis. Soil pH was measured in water by using a glass–calomel combination electrode.

Available P was analyzed according to the standard methods. Total N was analyzed with Kjeldahl method (Ryan et al., 2001). For soil textural class analysis, the hygrometer was used. Statistical analysis was conducted for the two years (2013 and 2014) data; with the help of SAS software version 9.0. ANOVA was computed and mean differences were made by using least significant difference (LSD) at P≤0.05. The results were presented by using tables, figures and text.

RESULTS

Soil physicochemical property

Soil texture

Soil water conservation is dependent on soil textural. The courser soil particles have less water holding capacity. Subsequently there will be limited water availability in the root zone of the plant if the production is only rain fed. In arid and semi-arid areas where evapotranspiration is higher and crop production is constrained by moisture, soil textural class with better water retention capacity is very important.

Effect of rainwater harvesting tillage with fertilizer on soil chemical properties

The interaction effect of integrated *in-situ* rainwater harvesting tillage techniques and inorganic fertilizer application has shown incredible soil total nitrogen and available phosphorus variation between treatments. Accordingly, the highest value of total nitrogen (1500 $mgKg^{-1}$) was obtained from tied-ridge during planting time with fertilizer compared to the control with fertilizer (1010 $mgKg^{-1}$) (Figure 2). Similarly, the highest value of available phosphorus (15.3 $mgKg^{-1}$) was obtained from tied-ridge during planting time with fertilizer compared to the control with fertilizer (12.6 $mgKg^{-1}$) (Figure 3). Regarding the soil pH value, fertilized tied-ridge during planting has shown more alkaline soil pH (7.45) compared to the control.

Effect of rainwater harvesting tillage with fertilizer on yield components

The effect of different tillage practices and inorganic fertilizer application on sorghum yield and yield components is indicated in Figures 4 to 9. Almost all tillage treatments that received fertilizer have shown better performance on leaf number, panicle length, plant height, and total dry mass compared to those that did not receive fertilizer. Accordingly, the highest value on panicle length, plant height and total dry weight were recorded from tied-ridge-during planting with fertilizer, while the least was recorded from control (Figures 4 to 9).

Effect of rainwater harvesting tillage on sorghum yield and yield components

The effect of tillage practices on sorghum leaf number and plant height was not significantly higher compared to the control at $p<0.05$ in 2013, but they have shown a significant difference at 2014 trial year. Although there was no significant difference observed between tied-ridge during planting time and tied-ridge after one month of planting, there was statistically higher panicle length observed for these treatments at $p<0.05$ compared to control at both 2013 and 2014 trial season. Regarding total dry mass, tied-ridge during planting time and tied-ridge after one month of planting treatments have shown statistically higher result compared to that of the control at both 2013 and 2014 trial seasons. Tied-ridge during planting time, tied-ridge after one month of planting time and shilshalo have shown significantly better performance on 1000 seed weight compared to the control at $p<0.05$ (Table 3). Statistically significant difference was also observed between these three treatments at $p<0.05$.

The effect of tillage practices on the grain yield is presented in Table 2. At $p<0.05$, the grain yield has shown significant difference between treatments. Tied-ridge during planting has resulted in significantly higher grain yield compared to all other treatments.

Effect of fertilizer application on sorghum yield and yield components

Inorganic fertilizer application has resulted in statistically significant effect on the yield components such as leaf number, panicle length, plant height, total dry mass and 1000 seed weight compared to non-fertilized plots at $p<0.05$ at both 2013 and 2014 trial seasons (Table 3).

The pooled mean of the two years grain yield response for inorganic fertilizer application was significantly higher than non fertilized treatments at $p<0.05$ (Table 4).

Effect of tillage practices with fertilizer on sorghum grain yield

The most economical and usable part of the products is grain yield. All other yield components investigated do contribute to the improvement of grain yield. As indicated in Table 5, grain yield estimated on hectare basis has shown big difference between different tillage treatments.

DISCUSSION

Soil texture

The result of soil texture analysis of the study area revealed that 69.88% sand, 13.87% clay and 15.87% silt represent sandy loam soil textural class. The *in-situ* rainwater harvesting techniques tested here could have far better results if this soil texture is improved with organic fertilizer application and retaining more crop residues on farm lands during harvest time.

Effect of fertilizer and tillage treatments on soil chemical properties

With the same amount of urea and DAP applied on both of these treatments, tied-ridge during planting time has resulted in the highest value of total nitrogen and available phosphorus concentration in the soil. This shows that *in-situ* rainwater harvesting tillage techniques with tied-ridge during planting time has better performance to minimize the loss of fertilizer applied on the farm land.

Fertilizer application has resulted in higher soil pH on this treatment. This may be attributed to the water harvesting capacity of the ridges with ties formed earlier to harvest of more amount of water. Generally, the semi-arid areas are higher in basic cation concentration, and when it gets water, the cations may be dissolved with increases in basic compounds. In other words, the H ion has a capacity to displace some basic cations on the parent materials and enrich the soil with more basic cations to induce the pH increment. However, the shilshalo and control treatments with fertilizer application had shown lower soil pH. These treatments have lower potential to conserve more water *in-situ* and dissolve basic cations in the soil. With the fertilizer application, the soil pH had become more lowered to neutral pH level (Figure 1). This may be due to the nitrogen fertilizer application that contributes to the formation of anions which lower the soil pH level if there is are extra cations added to the soil to counter balance it (Aklilu, 2012). The rate of acidification can increase when there is higher amount of N input through fertilizer (Hazelton and Murphy, 2007).

Effect of rainwater harvesting tillage on yield and yield components

Although the results were not uniform in both trial years, the 1000 seed weight has shown statistically significant difference between all treatments at 2014, with better performance on tied-ridge during planting time (Table 1). This might be due to the effect of tied-ridge on retaining more water at plant root zone. The finding by Tewodrose et al. (2005) pointed out the effect of tied-ridge over other tillage practices as the mean soil water throughout the season was nearly 20% more with tied-ridging. Similarly, the tied-ridged tillage effects have shown a significantly higher yield on sorghum compared to zero tillage (Gebreyesus, 2012). Tied-ridge during planting time has shown the best result followed by tied-ridge-after one month of planting time and shilshalo. This is in line with the finding of Mahamed and Shirdon (2013), who have seen significantly higher 1000 seed weight of maize crop on tied-ridge planting compared to other tillage practices. From the given *in-situ* rainwater harvesting tillage techniques, tied-ridge during planting time has resulted significantly high grain yield (28.06 quintals/ha).

Effect of fertilizer application on yield and yield components

Inorganic fertilizer application has resulted in the improvement of yield and yield components at both 2013

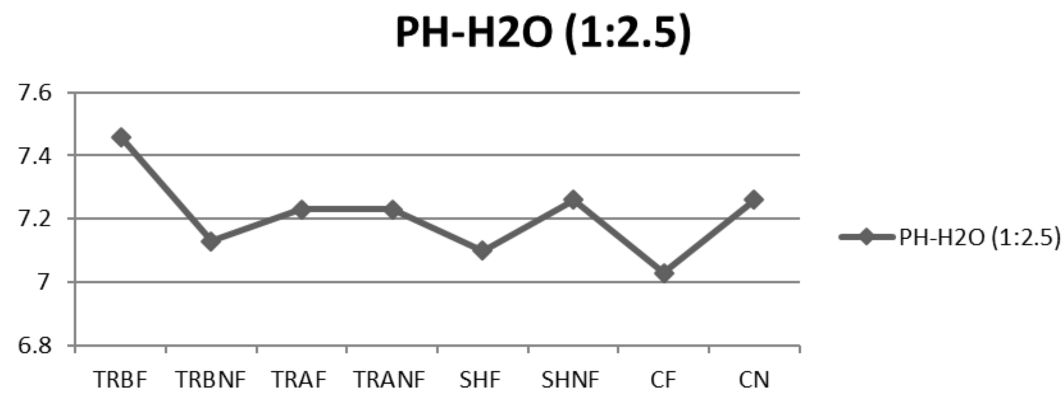

Figure 1. Effect of tillage practices and fertilizer application on soil pH. Where, TRBF is tied-ridge before planting with fertilizer; TRBNF is tied-ridge before planting with no fertilizer; TRAF is tied-ridge after a month of planting with fertilizer; TRANF is tied-ridge after a month of planting with no fertilizer; SHF is Shilshalo with fertilizer; SHNF is Shilshalo with no fertilizer application; CF is control with fertilizer; and CNF is control tillage treatment without fertilizer application.

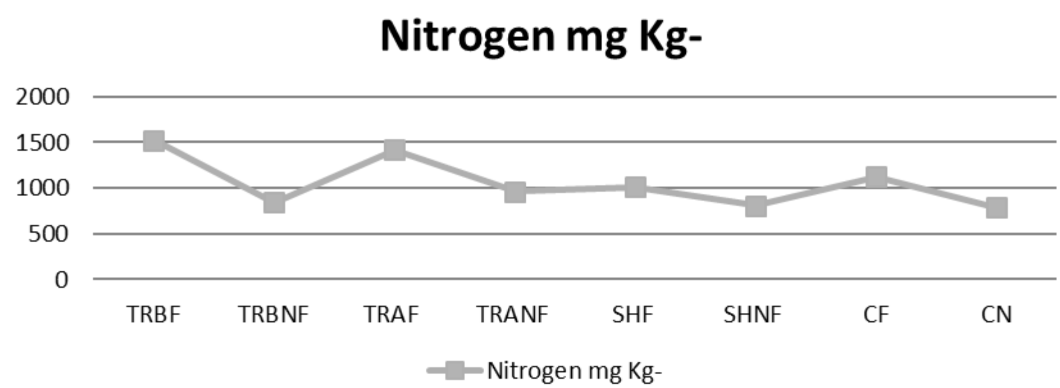

Figure 2. Effect of tillage practices and fertilizer application on soil total nitrogen.

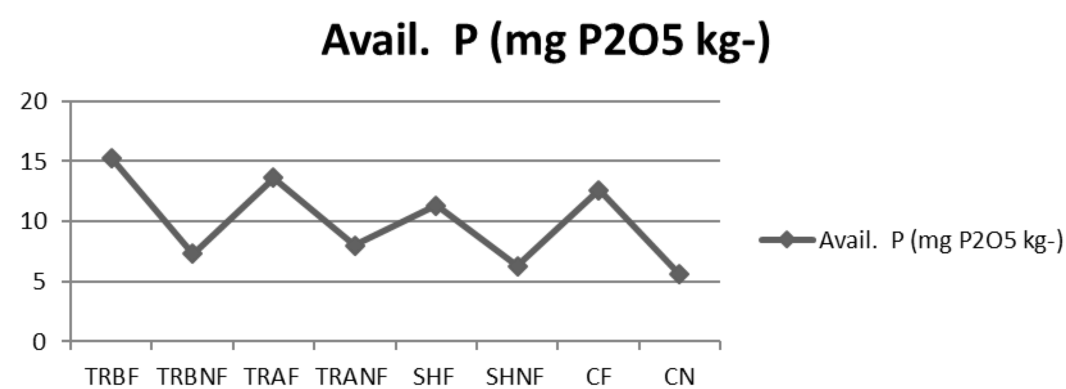

Figure 3. Effect of tillage practices and fertilizer application on available P.

and 2014 trial seasons. This may be due to the fact that the soil of the experimental site is significantly dependent on fertilizer application. The 1000 seed weight was significantly higher with nitrogen fertilizer application. This

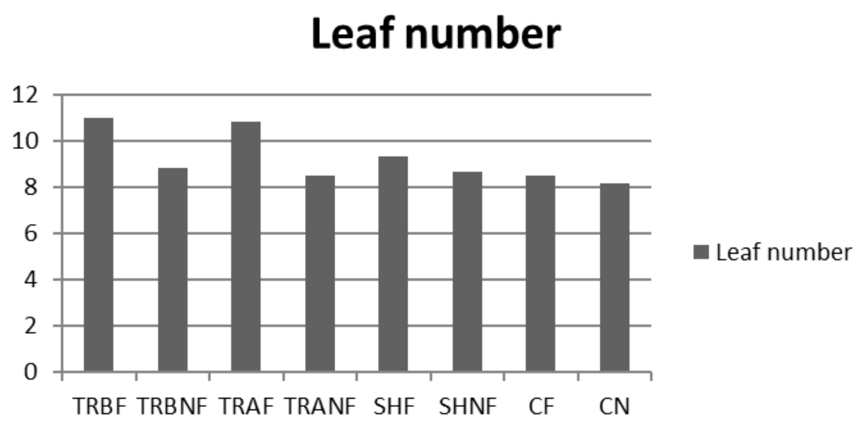

Figure 4. Interaction effect of tillage practices and fertilizer on leaf number.

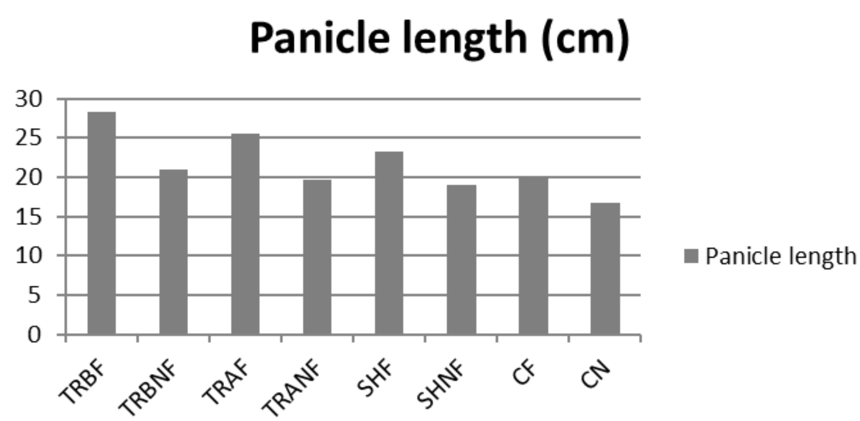

Figure 5. Interaction effect of tillage practices and fertilizer on panicle length.

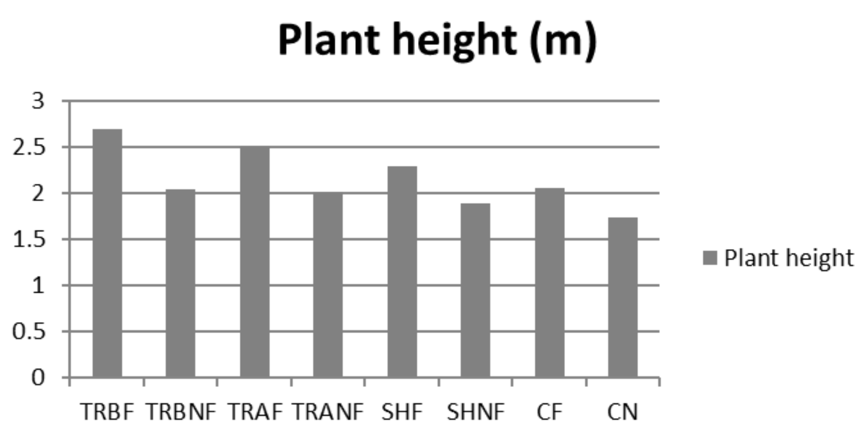

Figure 6. Interaction effect of tillage practices and fertilizer on plant height.

result contrasts the finding of Mahamed and Shirdon (2013) that the effect of various levels of nitrogen did not bring significant effect on 1000 seed weight of maize crop in Jigjiga area. The yield of sorghum produced with the application of Urea and DAP fertilizers was superior as compared to that produced on the same soil type without

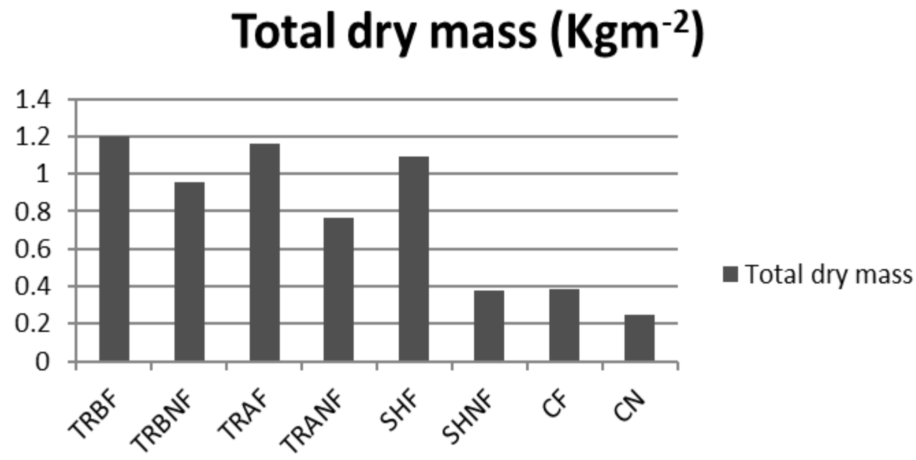

Figure 7. Interaction effect of tillage practices and fertilizer on total dry mass.

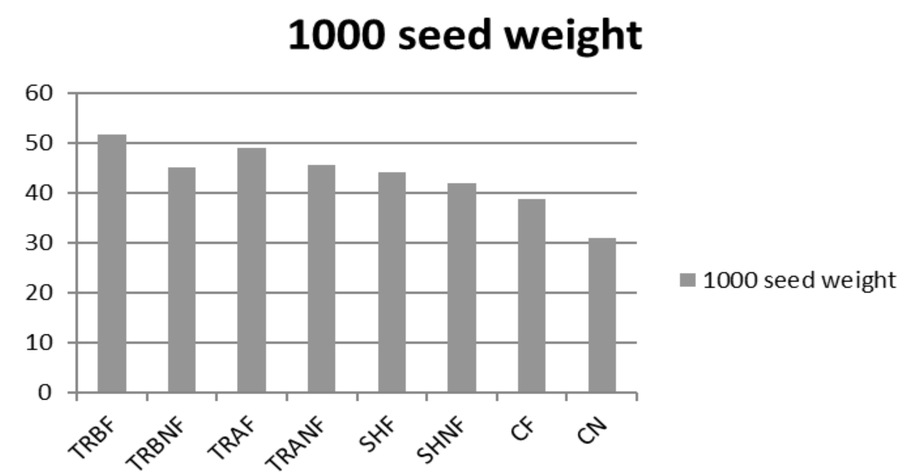

Figure 8. Interaction effect of tillage practices and fertilizer on 1000 seed weight.

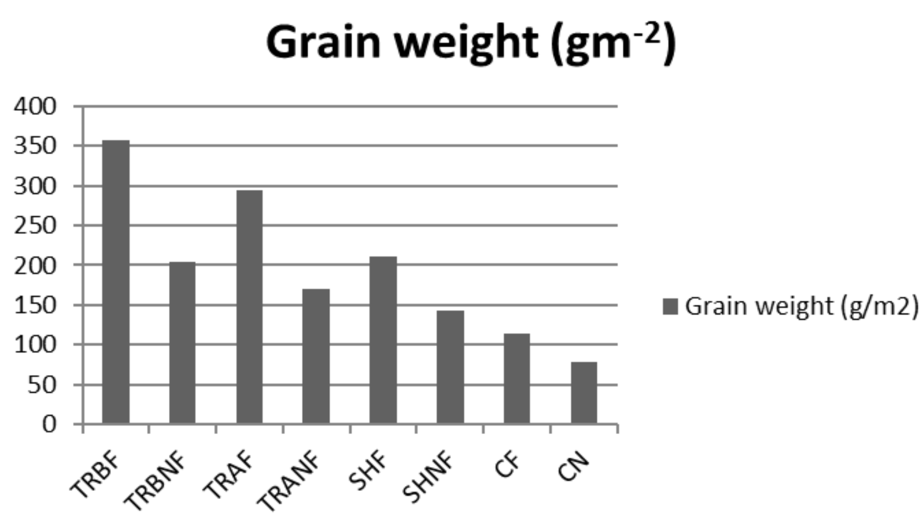

Figure 9. Interaction effect of tillage practices and fertilizer on grain weight.

Table 1. Effect of tillage practices on some yield components of sorghum.

Year	Parameter	TRB		TRA		Sh		C		CV (%)	LSD (0.05)
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
2013 GC	Leaf number	8.67[a]	1.5	8.33[a]	1.63	7.83[a]	1.16	7.50[a]	1.05	11.84	1.58
	Panicle length	24.16[a]	5.49	21.83[ab]	5.19	21.08[ab]	4.56	17.16[b]	3.43	15.09	5.25
	Plant height	1.85[a]	0.35	1.73[a]	0.42	1.70[a]	0.37	1.59[a]	0.29	12.43	0.35
	Total dry mass	0.96[a]	0.21	0.87[a]	0.24	0.65[b]	0.46	0.23[c]	0.09	19.35	0.21
	1000 seed wt.	33.91[a]	4.22	36.41[a]	4.54	34.05[a]	3.87	26.25[b]	6.43	11.71	6.32
2014 GC	Leaf number	11.16[a]	1.47	11.00[a]	1.41	10.16[ab]	1.16	9.16[b]	0.75	9.22	0.82
	Panicle length	25.16[a]	3.81	23.33[a]	2.58	21.16[b]	1.94	19.50[b]	1.97	7.76	1.49
	Plant height	2.88[a]	0.44	2.80[a]	0.23	2.48[b]	0.22	2.19[c]	0.22	7.50	0.16
	Total dry mass	1.19[a]	0.42	1.06[a]	0.33	0.82[a]	0.46	0.39[b]	0.09	37.02	0.27
	1000 seed wt.	62.90[a]	4.99	58.11[b]	3.74	52.03[c]	4.04	43.48d	4.85	6.01	2.81

NB: Panicle length is in cm, plant height is in m, total dry mass is in Kgm^{-2}, and 1000 seed weight is in g.

Table 2. Effect of tillage practices on sorghum grain yield and harvest index.

Parameter	TRB		TRA		Sh		C		CV (%)	LSD (0.05)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Grain yield (Quintal/ha)	28.06[a]	83.62	23.18[b]	68.35	17.64[c]	38.60	96.06[d]	23.66	32.53	14.00

Table 3. Effect of fertilizer on some yield components of sorghum.

Year	Yield components	With fertilizer		Without fertilizer		CV (%)	LSD (0.05)
		Mean	SD	Mean	SD		
2013 GC	Leaf number	9.00[a]	1.28	7.17[b]	0.58	11.84	0.83
	Panicle length	24.46[a]	4.11	17.66[b]	3.55	15.09	2.75
	Plant height	1.99[a]	0.19	1.45[b]	0.23	12.43	0.18
	Total dry mass	0.89[a]	0.38	0.47[b]	0.28	19.35	0.11
	1000 seed wt.	34.58[a]	3.62	30.74[b]	7.34	11.71	3.31
2014 GC	Leaf number	10.83[a]	1.74	9.91[b]	0.79	9.22	0.82
	Panicle length	24.08[a]	3.57	20.50[b]	1.83	7.76	1.49
	Plant height	2.78[a]	0.40	2.39[b]	0.27	7.50	0.16
	Total dry mass	1.03[a]	0.47	0.69[b]	0.38	37.02	0.27
	1000 seed wt.	57.10[a]	8.69	51.15[b]	7.47	6.01	2.81

Note: Panicle length is in cm, plant height is in m, total dry mass is in Kgm^{-2}, and 1000 seed weight is in g.

Table 4. Effect of fertilizer on grain yield and harvest.

Yield components	Fertilized		Not fertilizer		CV (%)	LSD (0.05)
	Mean	SD	Mean	SD		
Grain yield (Quintal/ha)	24.37a	95.45	14.86b	49.49	32.53	9.90

Table 5. Grain yield affected by tillage and inorganic fertilizer application estimated by hectare basis.

Treatment	Grain weight (Quintals ha^{-1})
Tied-ridge at planting with fertilizer	35.63
Tied-ridge at planting without fertilizer	20.48
Tied-ridge after a month of planting with fertilizer	29.40
Tied-ridge after a month of planting without fertilizer	16.97
Shilshalo with fertilizer	21.00
Shilshalo without fertilizer	14.28
Control with fertilizer	11.47
Control without fertilizer	7.75

fertilizer application (Heluf, 2003).

Effect of rainwater harvesting tillage with fertilizer on yield and yield components

The study by Mahamed and Shirdon (2013) on maize crop production in Jigjiga area indicated that there was higher performance with the use of ridges and nitrogen fertilizer application. According to the result, the higher value in leaf number, panicle length, plant height and total dry weight was recorded on tillage treatments that received fertilizer. Fertilized tied-ridge-during planting has shown better performance than other tillage treatments received fertilizer.

All tillage treatments with fertilizer have performed much better than their respective unfertilized treatments. This might be due to the fact that the soil fertility of the experimental site is poor and dependent on fertilizer application. Although the soil water status was improved through ridge formation at different time, without fertilizer application, the performance of yield and yield components were low. This result is in agreement with the finding by Gebreyesus (2012) that tied-ridge and fertilizer, and its interaction significantly influenced the yield and yield components of sorghum and resulted in up to 48% increment. In the current result, the yield of sorghum was affected by the interaction effect (Figures 4 to 9).The work of Heluf (2003) also supports this finding by the fact that the yield response to water conservation treatments was higher under fertilized than under unfertilized conditions.

Within the same *in-situ* rain water harvesting tillage techniques, there was big difference in grain yield ha^{-1} due to fertilizer application. Accordingly, tied-ridge at planting without fertilizer (164.34%), tied-ridge after a month of planting without fertilizer (119%), and Shilshalo without fertilizer (84.28%) showed more grain yield ha^{-1} compared to that of control without fertilizer. In a similar way, the tillage treatments with fertilizer application have shown even better performance than those without fertilizer application. For instance, tied-ridge at planting time with fertilizer resulted to 73.99% more grain yield, tied-ridge after a month of planting with fertilizer resulted to 73.25% more grain yield, Shilshalo with fertilizer resulted to 47.16% more grain yield and control with fertilizer resulted to 48% more grain yield when compared to the respective tillage treatments without fertilizer.

CONCLUSION AND RECOMMENDATIONS

As it can be suspected for effective *in-situ* rainwater conservation techniques, good soil structure and textural classes are determinant factors. The soil texture of the area studied was sandy loam, and it has low moisture retention capacity. This property of the soil may have its own effect on the performance of tillage techniques used. However, the tillage practices have shown variation on their effectiveness on conserving the soil total nitrogen and available phosphorus.

The interaction effects of the tillage treatments and inorganic fertilizer application has indicated as fertilized tied-ridge during planting has shown more alkaline soil pH than other treatments. On the other hand, this treatment has reduced the loss of total nitrogen and available phosphorus concentration from the soil in the highest value compared to other tillage treatments used.

Integrating tillage treatments with inorganic fertilizer resulted in better performance on the sorghum yield components compared to that of non fertilized tillage treatments.

Fertilized tillage treatments were also effective and they resulted significantly in higher sorghum grain yield. Therefore, the soil of the study area has shown more dependency on fertilizer application.

By taking the tillage treatments effect independently, on the production of sorghum, almost all yield and yield components have been positively affected more by tied-ridge formation during planting followed by tied-ridge formation after one month of planting. Tied-ridge during planting time with inorganic fertilizer resulted in 210.64% more grain yield than control treatment with fertilizer application.

As regards this study, the following recommendations were made:

- Tied-ridge during planting time is more effective than tied-ridge after a month of planting time, shilshalo, and conventional broadcasting tillage by improving the sorghum productivity. Therefore, this tillage technology should be scaled up in in semi-arid areas for crop production improvement.
- Since the soil of the study area did not show good response without fertilizer, the tillage treatment should be integrated with fertilizer application.
- The level of fertilizer treatment used in this research was only two (with fertilizer and without fertilizer). This should be seen at different levels of fertilizer treatment to identify the optimum rate of fertilizer application to that specific agro-ecology.
- The research has to be repeated in other dimensions by using organic fertilizer in place of urea and DAP in order to see the effectiveness of the selected tillage treatments on improving the soil moisture.

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