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Influence of In-situ Moisture Conservation Techniques and N rates on Agronomic Traits of Sorghum in Raya Valley, Northern Ethiopia

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ABSTRACT: *Soil erosion, low nitrogen availability and soil moisture stress during main season are among the major limitations to high crop production and sustainable land management in semiarid areas. In such area, in-situ moisture conservation techniques and right application of fertilizer are very important. The study was carried out to determine the appropriate in-situ moisture conservation technique and nitrogen rate for sorghum production in Raya Azebo (chercher) district of Tigray, Ethiopia in 2017 and 2018 cropping season on farmer field experiment. Adoption of soil moisture conservation techniques such as tie-ridges and mulching and appropriate use of fertilizer has shown improved soil moisture retention in a wide range of environments. The treatments includes four levels of moisture conservation techniques (planting on flat bed, closed end tied ridge , flat bed + grass mulch (3 cm thick), closed end tied ridge + grass mulch); and three rates of nitrogen viz., 11.5, 23, and 46 kg N ha-1 laid out in factorial arrangement of RCBD design. According pooled mean result plant height, panicle length and panicle weight were not significantly (p>0.05) affected by the main effect of nitrogen, but leaf area, biomass yield and harvesting index were significantly influenced by the two main effects. Moreover, thousand kernel weight and grain yield have interaction effect. The maximum grain yield (3633 kg ha-1) and thousands seed weight (39.12 gram) was obtained from closed end tied ridge interact with 46 kg N ha-1 could be recommended for study area and related agro-ecology.*

KEY WORDS: moisture conservation, nitrogen fertilizer, yield of sorghum

INTRODUCTION

The efficient use of water in agricultural systems is needed to improve crop production and resilience to environmental adversities that may be caused by climate change and extended droughts, especially in arid and semi-arid areas. Marginal and erratic rainfall aggravated by the loss of water by runoff and evaporation are the main causes of low crop production in these areas (Yosef and Asmamaw, 2015).

Sorghum (Sorghum bicolor L. Moench) is one of the drought tolerant crops grown in arid and semi-arid areas and is the fifth important cereal crop in the world surpassed by maize, wheat, rice and barley (Akram et al., 2007). Sorghum is indigenous to Ethiopia and thus has tremendous range of genetic variability. It is one of the major traditional crops grown mainly in the dry semi-arid areas of the country. Especially sorghum is the most important crop in the Kobbo-Alamata plain, Shewa Robit area, Chercher and Humera. It is used for making injera and preparing local drinks such as tela and areke. The crop is also consumed as boiled and roasted forms. The stalk is used as a fodder, construction material for housing and fencing. Sorghum is grown mainly as a rain fed crop in the semi-arid areas. In these areas sorghum production is being limited by water stress due to low and variable rainfall between season and with the seasons. Sorghum yields vary considerably between years and show a close dependence on rainfall. The other major sorghum production constraints in the semi-arid areas include low soil fertility, weeds particularly striga, and stalk borer infestation, poor seedling emergence, birds (Qulea), these production problems have also regional importance in both eastern and southern African countries although their relative importance vary between regions and agro ecologies (Moges, 2004). Moreover, different stresses often occur together, causing severe damage to the sorghum crops. In this case, use of effective moisture conservation practices is the most important issue in areas where availability of soil moisture is the most limiting factor for crop production in general. The in-situ and ex-situ rain water harvesting techniques have shown significant impact on improved soil moisture, runoff control and ground water recharge; and increased agricultural production which intern reduces risks and deliver positive impacts on the ecosystems (Binyam and Desale, 2015). In-situ rain water harvesting, also called soil and water conservation, involves the use of methods that increase the amount of water stored in the soil profile by trapping or holding the rain where it falls (Hatibu and Mahoo, 1999; Stott et al., 2001). In this application there is no separation between the collection area and the storage area, the water is collected and stored where it is going to be utilized (UNEP, 1997). In-situ rainwater harvesting involves small movements of rainwater as surface runoff, in order to concentrate the water where it is wanted most. It is basically a prevention of net runoff from a given cropped area by holding rain water and prolonging the time for infiltration. This system works better where the soil water holding capacity is large enough and the rainfall is equal or more than the crop water requirement, but moisture amount in the soil is restricted by the amount of infiltration and or deep percolation (Hatibu and Mahoo, 1999). To mitigate effects of drought researchers and farmers have introduces a number of in-situ rainwater harvesting technologies. In-situ rainwater harvesting is broadly defined as the collection and concentration of runoff for productive purposes such as crop, fodder, pasture or trees production, livestock and domestic water supply in arid and semi-arid regions (Fentaw et al., 2002; Stott, 2001).

Among the different soil water harvesting techniques tied ridges and mulch were found to be very effective in soil water conservation and yield increase in many field crops in most Sub-Saharan African countries. Tied ridges improve the availability of water in the soil profile to decrease the effects of dry periods caused by the seasonal variation of rainfall. Soils contemporarily hold water, so in-situ water harvesting prolongs the availability of water in the root zone by reducing runoff and evaporation losses (Vohland and Barry, 2009). In soil with low organic matter, fine texture, compacted soil surface with low infiltration rates high runoff and soil loss tied-ridges (ridging with additional cross in the furrow at short intervals) has been found to efficient and effective method for conserving soil moisture. The main reasons for effective soil water conservation through tied ridges include high rates of water penetration into the stirred soil, the action of tied-ridges in preventing run-off from the rain and increasing the opportunity time for infiltration. Thus, it enhances rapid build-up of soil moisture needed for rapid seed germination, and early plant growth. Mulch can absorb the energy of raindrops and prevents the soil surface from crusting. Thus surface mulching has been proven to be effective in soil water conservation, maintaining favorable temperature conditions and improving soil structure through enhanced biological activity (Lal 1979). It is also increase soil organic matter by improving soil physical conditions as well as nutrient and moisture retention capacity. At the same time, it has a distinct advantage of controlling weeds that compete with crop plants for water and nutrients. In the dry land farming research work carried out at Katumani in Kenya, stover mulching was found to be very effective in controlling run-off, reducing evaporation, an increasing infiltration rates, and maize yield was increased by about 100% during a low rainfall season (Nijihia, 1979).

Adoption of soil moisture conservation techniques such as tie-ridges and mulching has shown improved soil moisture retention in a wide range of environments (Balenchew and Abera, 2010). Furthermore, Ndlangamandla et al., (2016) reported that combination of tied ridges and mulch was effective in retaining soil moisture. For low soil infiltration and high rainfall intensity, runoff is responsible for severe soil and the associated nutrients losses even in flat and gentle slopes (Breman et al., 2001). Thus, to improve water use efficiency for crop production, increasing rainwater infiltration into the rooted soil zone is needed in order to be used through the processes of transpiration for biomass production. Because, limited water and nutrients interaction can limit crop growth; there is a need to be tackled in synergy while improving crop yields in the situation of northern Ethiopia. Integrated soil and crop management practices should be addressed simultaneously in order to reduce runoff and soil erosion associated nutrient losses, increase water infiltration, and nutrient availability for crop production (Breman et al., 2001). In Ethiopia especially in Tigray, tied ridges are traditionally used by small farmers as in situ water harvesting technique in different crop production system using hand hoe. Therefore, it is a traditional practice and was modified and extended through research to produce grain crops such as sorghum and maize. However, the effectiveness of the moisture conservation techniques has not been widely investigated in South Tigray. It was thus, necessary to conduct a research on developing water-harvesting techniques to use the limited water efficiently and applying sufficient amount of organic and inorganic fertilizers in a well moist soil. Therefore, the objectives of the study was: to determine the appropriate in-situ moisture conservation technique and nitrogen rate for sorghum yield and to evaluate the performance of In-situ moisture conservation techniques on yield and yield attributed traits of sorghum.

MATERIALS AND METHODS

Description of the Study Area

The experiment was carried out under rain fed conditions at Chercher kebelle, Raya Azebo district, which was located 60 kms far from Maichew to wards east direction. The experimental materials for this experiment were Urea fertilizer as a source of nitrogen and grass mulch and Meko-1 sorghum variety. In the area, sorghum production is being limited by water stress due to low and variable rainfall between season and with the seasons. Sorghum yields vary considerably between years and show a close dependence on rainfall. Short duration sorghum varieties are the most important one. Meko-1 sorghum verity is one of the short growing crops and important to that area. The verity was released by Melikassa Agricultural Research Center in 1997. The Varity is early drought resistant, white seed with injera making quality and relatively tall with higher biomass production. This variety fits well for dry semi-arid areas with short growing season.

Treatments and Experimental Procedures
The treatments were four levels of moisture conservation techniques (planting on flat bed, closed end tied ridge, flat bed + grass mulch (3 cm thick), closed end tied ridge + grass mulch); and three rates of nitrogen viz., 11.5, 23, and 46 kg N ha-1. The experiments laid out in factorial arrangement of RCBD design where the treatments were replicated three times having a gross plot size of 3.75m * 3 m. Based on treatment arrangement amount of Nitrogen fertilizer in the form of urea was applied at planting and the remaining dose at knee stage. The other crop management practices like weeding; chemical spray and hoeing were applied uniformly for all plots.

Data Collected and Measurement

Growth parameters
Plant height: was measured at physiological maturity from the ground level to the tip of panicle from five randomly taken plants and was averaged on per plant basis.Panicle length: It is the length of the panicle from the node where the first panicle branches emerge to the tip of the panicle which was determined from an average of five randomly taken panicles per net plot.

Leaf area (LA) and leaf area index (LAI)): Five plants per net plot were randomly taken to measure leaf area per plant (cm2) at 50% heading using the method described by Sticker et al. (1961) as: leaf area = length of the leaves × maximum width of leaf ×0.75 where, 0.75 is the correction factor for sorghum. Then the leaf area index was calculated as the ratio of unit leaf area per plant to the ground area covered by the plant.

Yield components and yield
Panicle weight (g): Samples of five panicles were weighed after harvesting and sun drying to determine weight per panicle.Thousand Kernels weight (g): was determined by counting 500 grains in duplicates and weighting them on an electronic balance. The weights obtained were multiplied by two to get the 1000 kernels weight. The weight was adjusted to 12.5% moisture level.Grain yield (kg): It was obtained from all plants of net plot area. It was determined using sensitive balance after the panicles were threshed, cleaned and sun dried and the yield was adjusted to 12.5% moisture level. Then, it was converted to kg ha-1 basis.
Above ground dry biomass (kg): It was measured after the plants from the net plot area were harvested and sun dried till constant weight.

Harvest index (HI): It was computed as ratio of grain yield to the bio mass yield per plot as:

$$HI = \frac{\text{Grain yield per plot (kg)} \times 100}{\text{Aboveground dry biomass per plot (kg)}}$$

Data Analysis
Data collected were subjected to analysis of variance (ANOVA) using the Genstat 18 edition, (Gen Stat, 2018) and interpretations were made following the procedure described by Gomez

and Gomez (1984). Whenever the effects of the treatments were found significant, the means were compared using least significance difference (LSD) test at 5% level of significance.

RESULT AND DISCUSSION

Soil pysico-chemical properties of the study area

Selected physico-chemical properties were analyzed for composite soil (0-30 cm depth) from the samples collected diagonally from five spots in every replication before planting. The result indicated that soils in the study area are dominantly clay loam in texture and soil pH was characterized as moderately alkaline (pH=8.28) based on ranges of soil–water pH interpretation 6.6-7.3, 7.4-7.8 and 7.9-8.4 are characterized as neutral, slightly alkaline and moderately alkaline respectively Jones, J. Benton (2003). The soil organic carbon contents (0.634%), organic matter (1.09 %), available phosphorus (9.39 mg kg-1) and total nitrogen (0.055%) of the area was low, indicating the low fertility status of the soil aggravated by continuous cereal based cultivation, lack of incorporation of organic materials in to the soils through mulching or crop residues and frequent tillage and the organic matter content of the soil is taken as a basic measure of fertility status; improve water-holding capacity, nutrient release and soil structure (Tekalign, 1991 and Cottenie,1980). Cation exchange capacity (CEC) is an important parameter of soil as it indicates the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Hazelton and Murphy (2007), top soils having CEC greater than 40 cmol (+) kg-1 are rated as very high and 25-40 cmol (+) kg-1 as high. Thus, according to this classification, the soil of the experimental site had high CEC (30.6 cmol (+) kg-1 soil). Cation exchange capacity (CEC) describes the potential fertility of soils and indicates the soil texture and the dominant types of clay minerals present. In general, soils high in CEC contents are considered as agriculturally fertile. The EC of the experimental site was (0.77 ms m -1) and this is rated as non-saline according to Hazelton and Murphy (2007) who rated soils having the EC values less than 4 ms m -1 is considered as non-saline and suitable for cereal production.

Response of Sorghum Growth and Yield Components to In-situ Moisture Conservation Techniques and Nitrogen Fertilizer

Plant height (PH): The analysis result showed that the main effect of rate of nitrogen fertilizer and the inaction effect did not have significant effect (P>0.05) on this parameter in both years. But the moisture conservation practice had significant response on plant height of sorghum in both cropping season (Table 1). Numerically, the highest plant height (123.4cm) was obtained from closed end tied ridge plus mulch and the lowest value of plant height were recorded from flat planting. This is due to moisture conservation practice that retains soil water better from being lost from runoff that improved and develop the plant growth and it implies higher result of plant height. Because of this the growth parameters can result in optimum level of fertilizer and best potential of availability of water to the crop (Gebryesus 2012).

Panicle length (PL): The main effect of moisture conservation had high significant (P≤0.01) effect on panicle length. However, main effect of rate of nitrogen fertilizer and the inaction effect did not have significant effect (P>0.05) on this parameter in both years. Numerically, the panicle length (25.78cm) was obtained from closed end tied ridge plus mulch and the least value (22.29cm) were obtained from flat planting (Table 1). This may be attributed to an increase in soil water content in these rain water harvesting techniques which lead to better root development leading to increased sorghum growth. This result was complimentary with the result of Mahamed and Shirdon (2013) on maize crop production in Jigjiga area which indicated that there was higher performance with the use of ridges and nitrogen fertilizer application.

Leaf area (LA cm2): The leaf area of sorghum was highly significant (P≤0.01) for the main effects of N fertilizer rate and moisture conservation. But there was no significant interaction effect of nitrogen rate and moisture conservation methods on this parameter. The highest leaf area (375.6 cm2) was obtained from 46 kg N ha-1 while the lowest leaf area (348.2 cm2) was recorded from 11.5 kg N ha-1. In general, as the nitrogen rate increased, the leaf area also increased (Table 1). Generally, an increasing trend in leaf area was observed with increased nitrogen application rates which might be due to improved leaf expansion in plants due to optimum nitrogenous fertilizers. In line with this result, Kidist (2013) reported as that increasing the rate of N from 0 to 130.5 kg N ha-1 linearly increased leaf area of maize. Gebrelibanos and Dereje (2015) also reported that application of high fertilizer dose increased the leaf area of sorghum. Similarly, Haghighi et al. (2010) and Asim et al., (2012) reported an increasing trend in LA on maize due to an increase in N fertilizer application rates. Jasemi et al., (2013) also reported higher LA of maize associated with nitrogen treated plants has been probably due to increased leaf production and leaf area duration.

Based on the pooled mean data the analysis result showed that the main effect of moisture conservation had significant effect (P>0.05) on this parameter. The maximum leaf area (390.3 cm2) was obtained from closed end tied rigging plus mulch and the minimum leaf area (288.03 cm2) were obtained from flat planting. This significant variation attributed to the effect of moisture conservation practice on optimum moisture retention which required for development and production especially at the critical stages of sorghum growth such as phenological growth and seed formation. The maximum leaf area indicate that sorghum with higher leaf area can produce more food through photosynthesis as leaf is responsible part for preparation of food and may have higher grain yield.

Leaf area index (LAI): Leaf area index is major factor determining photosynthesis and dry matter accumulation (Moosavi et al., 2012). The main effect of rate of nitrogen fertilizer and moisture conservation techniques had highly significant (P≤0.01) influence on leaf area index. However, the interaction effect of rate of nitrogen fertilizer and moisture conservation techniques had no significant effect on leaf area index (Table 1).

The highest leaf area index (0.417) was recorded from 46 kg N ha-1; while the lowest (0.386) was recorded from 11.5 kg N ha-1 (Table 1). Generally, an increasing trend in LAI was observed with increased N application rates which might be due to improved leaf expansion in plants due to optimum nitrogenous fertilizers. In line with the result Moges (2015) reported that increase in leaf area index with the increase of nitrogen level from 0-128 kg N ha-1 and attributed to the more vegetative growth due to nitrogen application, as it is a general truth that N enhances vegetative growth in maize. Nitrogen deficiency accelerates senescence as revealed by strong decrease in chlorophyll concentration under low N as compared to non-stressed conditions. In line with this result, Kidist (2013) reported as that increasing the rate of N from 0 to 130.5 kg N ha-1 linearly increased leaf area index of maize.

The maximum leaf area index (0.433) was obtained from closed end tied rigging and the minimum leaf area (0.335) was obtained from flat planting. This significant variation attributed to the effect of moisture conservation practice on optimum moisture retention which required for development and production especially at the critical stages of sorghum growth such as phenological growth and seed formation. The maximum leaf area index indicate sorghum can produce more food through photosynthesis as leaf is responsible part for preparation of food and may have higher grain yield.

Panicle weight (PW): The main effect of moisture conservation had high significant ($P \leq 0.01$) effect on panicle weight. However, main effect of rate of nitrogen fertilizer and the inaction effect did not have significant effect ($P>0.05$) on this parameter in both years. Numerically, the highest panicle weight (77.03 gram) was obtained from closed end tied ridge and the lowest value of panicle weight (59.44 gram) was recorded from flat planting (Table 1).

Table1. Plant height, panicle length, panicle weight and harvesting index of sorghum as influenced by main effect of conservation mechanism and Nitrogen rate

Treatment	**PH (cm)**	**PL (cm)**	**LA (cm^2)**	**LAI**	**PW (gm)**	**BY (kg ha^{-1})**	**HI**
Nitrogen Rate kg ha^{-1}							
11.5	113.7	24.33	348.2c	0.386c	63.11	6254a	0.366b
23	116.3	24.48	356.8b	0.396b	67.34	5345b	0.511b
46	117.1	24.58	375.6a	0.417a	68.13	5222b	0.552a
LSD	NS	NS	8.16	0.009	NS	870.5	0.083
Moisture Conservation Mechanism							
Flat planting	106.2c	22.29b	302.0c	0.335c	59.44c	5301	0.437b
Close end tied rig	119ab	25.76a	390.3a	0.433a	77.03a	5364	0.578a
Flatbed +Grass	114.1b	24.03ab	366.3b	0.407b	60.48c	5820	0.401b
Close end tied rig +Grass	123.4a	25.78a	382.3a	0.424a	67.81b	5844	0.420b
LSD	5.94	2.12	9.42	0.01	6.62	NS	0.096
CV%	7.7	13.0	3.9	3.9	15.0	26.9	30.3

Where: NS = non-significant, Means with the same letters in the same column are not significantly at $P< 0.05$, PH= plant height, PL= panicle length, LA= leaf area, PW= panicle weight, BY= biomass yield, HI= harvesting index and Fb= Flat bed, CET= Close end tied ridge and Gr= Grass, LSD= least significant difference CV=coefficient of variance

3.2.6. Thousand Kernels weight (TKW): The analysis of variance showed that thousand seed weight was highly significantly ($P \leq 0.01$) affected by the interaction effect of the two factors (Table 2). The highest thousand kernel weight (39.12 gram) was recorded from 46 kg N ha-1 interacting with the best moisture conservation (closed end tied riding). In contrast, the lowest thousand seed weight (30.32 gram) was obtained from 11.5 kg N ha-1 in combination with flatbed planting (Table 2). Like phenological parameters, the reason could be due to the contribution of fertilizer application and moisture conservation practices to supply optimum nutrient and moisture needed for increment of thousand kernel weight of sorghum.

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Table2. Interaction effect of Rate of N fertilizer and Conservation mechanism on thousand seed weight grain yield of sorghum

Treatment		TKW (gm)	GY kg ha^{-1}
Nitrogen rate Kg ha^{-1}	**Moisture conservation mechanism**		
11.5	Flatbed planting	30.32c	1857g
	Closed end tied riding	33.46bc	2489d
	Flatbed planting +grass	32.48c	2245e
	Closed end tied riding +grass	37.29ab	2712c
23	Flatbed planting	30.63c	2007f
	Closed end tied riding	38.05a	2856b
	Flatbed planting +grass	31.11c	2403d
	Closed end tied riding +grass	33.15bc	2649c
46	Flatbed planting	37.15ab	2145ef
	Closed end tied riding	39.12a	3633a
	Flatbed planting +grass	33.17bc	2499d
	Closed end tied riding +grass	37.31ab	2951b
LSD		4.25	138.9
CV%		10.7	4.7

Where: NS = non-significant, Means with the same letters in the same column are not significantly at P< 0.05, TSW= thousand seed weight, GY= Grain yield and LSD= least significant difference, CV=coefficient of variance

Grain yield: Closed end tied riding integrated with 46 kg N ha-1 gave significantly high grain yield (3663 kg ha-1) and the lowest grain yield was recorded from flat planting integrated with 11.5 kg N ha-1 in both cropping season (Table 2). Better in-situ moisture conservation techniques and optimum fertilizer application created favorable condition to absorb water by sorghum plants. Other research result indicated that the major reasons for the increase in yields were better moisture availability, improved soil fertility and better root growth as a result of conservation tillage application (Belay, 1998, Lal, 2000, Temesgen et al., 2008). Another report indicates that Conservation tillage resulted in optimum moisture availability, improved soil fertility and better root growth which in turn increase yield. Increase in sorghum grain yield with increase Nitrogen application also enhance attributed to production of greater head length, head girth, head weight and 1000 seed weight compared to 0 N kg ha over years (S.L. Patil 2016). This result is in agreement with the finding by (Gebreyesus (2012) reported as that tied-ridge and fertilizer, and its interaction significantly influenced the yield and yield components of sorghum and resulted in up to 48% increment. Tied ridges have been found to be very efficient in storing the rain water, which has resulted in substantial grain yield increase in some of the major dry land crops such as sorghum, maize, wheat, and mung beans in Ethiopia (Georgis and Takele 2000). The average grain yield increase (under tied ridges) ranged from 50 to over 100 percent when compared with the traditional practice or flatbed planting. Other research works indicated that conservation tillage resulted in optimum moisture availability, improved soil fertility and better root growth which in turn increase yield (Temesgen et al., 2008). Moreover, from the findings of study, which was conducted in the semi-arid areas of northern Ethiopia Gebreyesus (2012), the yield of sorghum showed increment by 7 to 48% due to the effect of conservation tillage integrated with fertilizers compared to the traditional tillage. Similar findings of Karrar et al.'s (2012) suggest that the in situ water harvesting techniques improved the soil moisture stored within the root zone compared to conventional harrowing that uses a wide-level disc, resulting in increased sorghum dry matter and grain yield. Furthermore, it was also pointed out that tied-ridge during planting time produced significantly higher grain yield (2806 kg ha-1) than other in situ moisture conservation techniques (Aklilu et al., 2015).

Biomass yield (BY): Rate of nitrogen fertilizer application had significantly influenced biomass yield of sorghum, but moisture conservation techniques and interaction effect did not significantly affect the parameter (Table 2). The maximum biomass yield (6254 kg ha-1) was obtained from 11.5 kg N ha-1 and the minimum biomass yield (5222 kg ha-1) was recorded from 46 kg N ha-1. Moisture conservation techniques have no significant difference, however the maximum biomass yield (5844 kg ha-1) was obtained from closed end tied ridging plus mulch. This result was complimentary with finding of another study; 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 (Aklilu et al., 2015). In general, the substantial biomass yield response of the crop to tied ridging on fertilized experiments revealed that in areas having poor rainfall distributions such as the Raya valley lowlands, moisture conservation technique is a necessary agricultural operation. As compared to close end tied ridging practice planting in furrow, conventional practice (flat planting) reduced sorghum biomass yield by 14.07 to 27.22% under fertilized condition, his could be ascribed to less efficiency of flat planting to conserve and hold moisture in relative to the other moisture conservation techniques (Berhane et al., 2017). These results are similar with the finding of another study, which showed that biomass yield of sorghum was significantly influenced by moisture conservation practices at which the highest (15.50 t ha-1) and the lowest total biomass weight (9.53 t ha-1) were recorded from tied ridge and farmers' practice, respectively in southern Ethiopia (Tekle and Wodajo, 2015).

Harvesting index (HI): The harvesting index of sorghum was highly significantly responding ($P \leq 0.01$ and $P > 0.05$) for the main effects of N fertilizer rate and moisture conservation techniques respectively. But there was no significant interaction effect of nitrogen rate and moisture conservation methods on this parameter. The highest harvesting index (0.552) was obtained from 46 kg N ha-1 while the lowest harvesting index (0.366) was recorded from 11.5 kg N ha-1. Based on the result nitrogen rate increased, the harvesting index also increased (Table 1). Concerning the moisture conservation techniques, maximum harvesting index (0.578) was obtained from closed end tied ridging and the minimum harvesting index (0.401) were obtained from flat planting plus mulch. This significant variation attributed to the effect of moisture conservation practice on optimum moisture retention which required for development and production especially at the critical stages of sorghum growth such as phenological growth and seed formation. The maximum harvesting index indicates that sorghum with higher grain yield. Integrated soil and crop management practices should be addressed simultaneously in order to reduce runoff and soil erosion associated nutrient losses, increase water infiltration, and nutrient availability for crop production (Breman et al., 2001).

CONCLUSION AND RECOMMENDATION

In areas with low and erratic rainfall, use in-situ moisture conservation techniques and right application of fertilizer are very important for increasing crop yield. From the findings of this study, closed end tied riding integrated with 46 kg N ha-1 gave significantly high grain yield and other yield and yield components compared with farmers' practice in particular in flat bed planting integrated with small amount of nitrogen fertilizer application in both cropping season.

Tied ridging practices are crucial for sorghum yield improvement under moisture stress areas. It was observed that closed end tied ridging proved to be more effective in preserving water and increase availability of fertilizer to the plants and it help to enhancing sorghum yield with relatively consistent effects in both seasons than flat bed planting methods with small amount of fertilizer level. Generally, integrated soil and crop management practices should be addressed simultaneously to increase water infiltration and nutrient availability and thereby increase crop productivity in moisture stress areas like Raya valley. Accordingly, efforts have to be made to disseminate tied ridging practice integrated with the recommended fertilizer to the beneficiaries and additional research works on agro-ecologically based in situ moisture conservation techniques and different fertilizer levels is imperative to improve sorghum production in areas where moisture and nutrient deficiency are the major constraints for sustainable crop production. Based on this experiment the maximum grain yield (3633 kg ha-1) and thousands seeds weight (39.12 gram) were obtained from closed end tied ridge interact with 46 kg N ha-1. Finally as recommendation closed end tied ridge intact with 46 kg N ha-1 could be recommended for study area and related agro ecology.

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