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A Review on: Effect of Tie Ridging on Crop Productivity in Dry Land Agro-Ecosystems of Ethiopia

Hailemariam Abrha Demoz
Tigray Agricultural Research Institute, Humera Agricultural Research Center. P.O.Box, 62; Humera, Ethiopia

Abstract
This review focuses on literatures made on *in-situ* moisture conservation using tied ridges on crop productivities such as sorghum, maizeand cotton in different parts of Ethiopia under rain-fed conditions. The magnitude of theyield response and the relative efficiency of the tied ridges and planting methods variedwith soil type, fertilization, and total rainfall and its distribution. Closedend tied ridge planting in furrows(CPF) gave the highest yield.Flatbed planting produced the lowest grain yields on all sets of experiments.Within the tied ridges, closed end performed betterthan open end.In sorghum compared withthe traditional (flatbed) planting method, the highest yield increment of 1361 kg/ha(34.5%) due to tied ridges was obtained on the Entisols with NP followed by 1255kg/ha (48.5%) on black clay soils (Vertisols) under fertilized condition.Highest maize yield 1616 kg/ha was achieved with closed end tied ridge planting in furrows type of water conservation technique, but the FPB (Flatbed planting) was 844.8kg/ha. In Humbo, south region of Ethiopia, open and tied ridge on Cotton variety 'Sele'wasused' revealed that, there was a significant ($p<1\%$) seed cotton yield record in open ridge planting method followed by tied ridge planting 1619 kg/ha butflatbed planting method gave significantly the lowest seed cotton yield 1273 kg/ha.

1. INTRODUCTION

Periodic low soil moisture due to erratic and poorly distributed rainfall, severe soil erosionand runoff loss of water and the resultant low soil fertility are the prominent causesfor the low agricultural productivity in the Ethiopian highlands (>1500 m.a.s.l) which form 46% of the total land area and where over 95% of theregularly cropped lands are found (Tamirie, 1986; Helufand Yohannes, 2002). Accordingly, about 50% (27 million ha) of the highlandsare significantly eroded, 25% (13.5 million ha) seriously eroded and over 4%of the former farmlands are severely eroded and converted to rock outcrops (EHRS, 1984). The rate of annual loss ofsoil due to erosion for Ethiopia vary from almost zero on lowland grasslands to over200 t/ha/yr on steep slopes of the highlands cultivated with erosionpromoting crops such as maize or sorghum (Getachew, 1998).

In addition to accelerated soil erosion and the alarming rate of land degradation, theloss of water as runoff coupled with periodic drought during the cropping season on degradedlands supporting rain-fed crop production was also equally important (Tamirie, 1986; Asfaw *et al*., 1998; Heluf and Yohannes, 2002).These problems are mainly attributed to the inadequate efforts and absence of technologiesproved to conserve the soil and water resources, the consequence of which is theneed to increase productivity on limited and marginal land and water resources. Soil andwater conservation is called upon to alleviate both the problems of erosion and droughtwhich are symptoms of two different extremes of rainfall conditions.As rainfall erosivity,soil erodibility and landform are inherent properties of climate, soil and land, respectively,only little can be done to modify their effects appreciably. Therefore, control of soil erosionand runoff water depends on judicious soil and crop management practices (Lal,1977a,b; Hudson, 1977).The practice of judicial water conservation undoubtedly playsa significant role in increasing agricultural production in arid, semi arid and sub-humidareas where agriculture is hampered by periodic droughts and low soil fertility (Tamirie, 1986; Heluf, 1989;Heluf and Yohannes, 2002).Soil or land management practices to reduce soil loss and runoff to negligible amountsare usually based on a combination of practices which help to maintain soil infiltrationrates at sufficiently high levels and on measures which help safe disposal of runoffwater from the field, should rainfall exceeds the infiltration capacity of the soil (Lal,1977a).Cultural practices, which maintain a high soil infiltration rate and feasible incultivated lands are essentially based on farming techniques, which maintain a mulch orlive vegetation (stubble mulching and no- or minimum-tillage and use of cover crops) on the soil. The safe disposal of runoff may involve physical manipulation of soil includingland shaping, contour bunds, terraces, waterways and ridges.

However, although themethods of conservation may be either known or could be predicted, more local and/orregional level studies are justified for their demonstrative values (Lal, 1977a; Hudson,1977).An erosion-promoting crop such as sorghum can be grown without causing serious soilerosion provided that proper soil and water conservation techniques are used than asoil-conserving crop grown with erosion-promoting practices (Aina et al., 1976; Lal,1977a,b). Aina et al., (1976) observed that 221 t/ha/yr of soil loss and 30% of runoff frommonoculture cassava, and a soil loss of 137t/ha/yr and runoff of 19% from NigerianAlfisols on 15% slope in a cassava-maize mixed cropping system. Management of cropresidues on the farm lands increased the grain yields of maize, sorghum and wheatcrops both by improving soil fertility and conserving water on the two major soils ofAlemaya area that are used in the present study (Heluf, 1989; Asfaw et al., 1997, 1998; Heluf*et al*., 1999; Heluf

andYohannes, 2002). Lal (1977b)observed a runoff of 1.2% and a soil lossof 0.05 t/ha with mulch at a rate of 6 t/ha and a runoff water of 50% and a soil lossof 4.83 t/ha without mulch.

Although the economic variability, availability of labor and the social factors involved ingetting widespread acceptance of suitable methods for a specific region require muchmore attention, mechanical measures in controlling soil erosion are well studied (Kowal,1970a,b; Macartney et al., 1971; Moldenhauer and Onstand, 1977; Fauck, 1977;Heluf and Yohannes, 2002; Asfaw et al., 1998).Among these, tied ridging is an effective practice particularly in lands with slopes lessthan 3-4% and by adding terrace on steeper slopes (Moldenhauer and Onstand,1977) in increasing crop yields by increasing the time for the water to penetrate intothe soil.

Helufand Yohannes (2002) observed maize yield increments of 15 to50% due to tied ridges on the soils reported in this paper and 15 to 38% for sorghum ondifferent soil types of eastern Ethiopia. Kowal (1970a,b) reported that ridges that arenot tied at intervals were not effective in controlling runoff and soil loss in the Savannahregion of northern Nigeria.In Upper Volta, tied ridges led to only 0.9% runoff ascompared to 6.3% with open graded ridges and 12.2% in the case of flat cultivation(Fournier, 1967).Proper mechanical soil and water conservation schemes increased maize and sorghumyield by 700-3400 kg/ha in the eastern Ethiopian highlands (Tamirie, 1986;Tamirie et al., 1986; Asfaw*et al*., 1998; Heluf and Yohannes, 2002).

Asfaw*et al*. (1998) reported maximum maizeyield increases of 10, 18 and 23% on Entisols and 54, 35 and 26% on Vertisols of easternEthiopia, with crop residue, with both crop residue and residualNP, respectively, due to the combinations of tied ridges and furrow planting over flatplanting. Thus, the efficiency of the physical soil and water conservation techniquesdepends on the soil type, climate, the crop grown and the cropping methods followed.However, despite the significance of the problems of soil erosion and drought in theEthiopian highlands, research aimed at generating soil and water conservation techniquesand farming practices that reduce soil erosion and harvest rain water for use by plants,on cultivated lands in the country, is inadequate. Therefore, this paper isinitiated to review the relative efficiency and effectiveness of tied ridges on crop yield ofdifferent soilsin dry land agro-ecosystems of Ethiopia.

2. LITERATURE REVIEWS

2.1 MOISTURE CONSERVATION FOR CROPS

Water required for plant growth and development is taken from the soil by the roots. Leaves and stem do not absorb appreciable quantities of water. Limited rain water in drylands areas must therefore be made to enter the soil in such a manner as to be readily available as soil moisture to the roots at the critical periods of plant growth. All the land and crop management practices which improve rainwater storage in the soil profile comprise water conservation (Rana, 2007).

Micro-basins created by tillage can reduce runoff and increase infiltration and thereby water available for crop production (Gebreyesus et al., 2006; Gebreyesus et al., 2008). Tied-ridging is a form of micro-basin tillage which consists of ridging the soil typically to heights of 0.20 to 0.30 m and is blocked with earth ties spaced considering slope of the land. Planting of the crop can be either in the furrow or on the ridge based on the expected soil moisture required for a particular crop (Tewodros et al., 2009).

Successful dry faming depends chiefly upon the success with which the rains that fall during any season of the year may be stored and kept in the soil until needed by plant in their growth. Based on the quantity of rainfall, water conservation may be classified as in situ and ex-situ water conservation. In situ water conservation refers to storage of rain water in the soil profile, where it falls. In situ water conservation is followed and successful in those areas where rain water stored in the soil profile after uncontrollable run-off and other losses is sufficient to meet the crop requirement. In some areas, soils are shallow and water stored in the shallow soil is not sufficient to meet the crop requirement according Rana (2007); under such situations, reducing run-off and increasing infiltration rates are ineffective. In these areas, ex-situ water conservation measures are adopted. Under such situation, water conservation consists of using water derived from a catchment area that has been treated to increase runoff of precipitation to supplement soil moisture in the adjacent cropped area, situated at a lower elevation.

The beneficial effects of tillage such as tied-ridging on crop yield vary due to differences in amount and distribution of rainfall, soil type, slope, landscape position, crop type, time of ridging, and the condition where rainfall events to result in significant runoff. Tied-ridging increased sorghum grain yield by more than 40% and soil water by more than 25% compared to the traditional tillage practice in northern Ethiopia (Gebreyesus et al., 2006).

Ridging and tied ridging involves making ridges and furrows, then tying or damming furrows with small mounds to increase the surface water storage and avoid runoff. The tie act as a barrier for the rain water movement and increases contact time available for infiltration thus enhances the availability of soil moisture to the crops (Rana, 2007).

Studies also showed that lack of greater response to applied N and P fertilizer in Ethiopia was probably due to soil water deficit which is the major yield-limiting factor and profitable crop response to applied nutrients depends on soil water availability (Tewodros et al., 2009). However, improper use of tied-ridging can result in

problems such as ridge over-topping, ridge failure, water logging, and total loss of the crop in severe storms (Gebreyesus et al., 2006). Despite the above facts, however, there has been insufficient published works that evaluate the role of tied ridging and other tillage practices as part of moisture harvesting technique integrated with fertilizer at farmers' fields (Gebreyesus, 2012)

2.2 TIED RIDGING AS IN SITURAIN WATER HARVESTING METHOD FOR IMPROVING SORGHUM (SORGHUM BICOLOR L.) YIELD

Sorghum (*Sorghum bicolor* L. Moench) is believed to have originated from Ethiopia (Doggett, 1970; Hulse *et al*., 1980). It is the dominant crop in the semi-arid lowlands such as the Abergellearea in Tigray region and in some other highland areas of the region and the country at large. It isone of the leading traditional food crops of Ethiopia comprising 15-20 percent of the total cerealproduction in the country (Yilma and Abebe, 1984).

Sorghum is the third most important crop inthe country following maize and teff in total production, and covers 1.3 million hectare (ha) withan annual production of 1.7 million metric tons. Sorghum is the second major cerealcrop next to teff in consumption and cultivable area and accounts for 14.5% of the total cultivatedarea in Tigray region. However, yield per unit area in the region is not more than1.3 t/ha (CSA, 2000), which is below the world average of 2.3 t/ha (Benti and Ransom, 1993).

Sorghum ranks second to teff in making quality injera (*staple Ethiopian bread*). The crop is alsoutilized in different forms. Nearly all of the sorghum grains produced annually in Ethiopia is used for human consumption. Of this, about 80% is used for making *injera*, and 10% for homebrewed beverages. The rest of the sorghum grain produced in the country goes into makingporridge (gonfo), unleaved bread (quitta), boiled whole grain (nifro), roasted grain (kolo), andanimal feed (Berhane and Belainesh, 1981).

2.3 GRAIN YIELD RESPONSE OF SORGHUM (SORGHUM BICOLOR) TO TIED RIDGES

Researches done on fertilizedand unfertilized conditions on Entisols and Vertisols of eastern Ethiopianhighlands at responded significantly ($P \leq 0.01$) to the treatments both under fertilized and unfertilized conditions of the soils studied. However, the magnitude of the yield response and the relative efficiency of the tied ridges and planting methods varied with soil type, fertilization, and total rainfall and its distribution during the cropping season. Regardless of the type of tied ridge used, furrow planting, specifically, closed end tied ridge planting in furrows gave the highest yield in three of the four sets of experiments. Flatbed planting produced the lowest grain yields on all sets of experiments except under the unfertilized condition of Entisols in which open end planting on ridges produced the lowest sorghum yield. Within the tied ridges, closed end performed better than open end in all except the Vertisols without N and P fertilizers. Compared with the traditional (flatbed) planting method, the highest yield increment of 1361 kg/ha (34.5%) due to tied ridges was obtained on the Entisols with nitrogen (N) and phosphorus (P) followed by 1255 kg/ha (48.5%) on the Alemaya black clay soils (Vertisols) under fertilized condition, indicating that the yield response to water conservation treatments was higher under fertilized than under unfertilized conditions on the two soils. Fertilization increased the yield of sorghum by as high as 1576 kg/ha (69.5%) on Vertisols and by 1468 kg/ha (38.3%) on Entisols both from planting in the furrows of closed end tied ridges. It also revealed that the yield response was higher in seasons with low or poorly distributed rains and on shallow and coarse textured soils. The results indicate that in areas with low and erratic rainfall such as the Eastern Ethiopia, soil and water conservation is indispensable for increasing crop yield (Heluf, 2003).

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. Tied ridges had brought a significant yield improved over the other moisture conservation practices in general and the famers' practice in particular. Generally, it is obvious that in Alduba areas of southern Ethiopia, where the rainfall is low in amount, erratic in nature and unevenly distribution during the cropping season is one of the most limiting factor for crop production. Hence; there is need to disseminate the results of the present study to the end users even though, further research should be carried out to put the recommendation on strong basis and also to come up with increased yield and improved sorghum production in areas, where moisture is the most limiting factor for sustainable crop production (Tekle *et al*., 2015).

2.4 ON-FARM VERIFICATION OF THE EFFECTS OF TIED RIDGER ON YIELD AND YIELD COMPONENTS OF MAIZE

Intensive rain with a high erosive usually characterizes most semi-arid regions. The reduced vegetative cover aggravates the exposure of these regions for severe erosion further. The problems of semi-arid regions are so complex that there is little interest to solve them through intervention or research. This resulted in insufficient introduction of technology to apply for improving agriculture. Jones (1985) pointed out that, in Africa, studies of water management techniques such as tillage and tied-ridging have several times shown great promise, but have been too brief, or too local, or restricted to experiment stations, and as a result they generated neither the depth and breadth of understanding of the technique (and the limitations imposed on it by soil, implements, economics,

etc.) nor the impetus and general interest that might sustain it through a long program of wider testing, adjustment, and retesting under practical farming conditions.

The low quantities of rainfall make cropping to be possible only with the use of special techniques of soil and water conservation and in this regard tied ridge should get sufficient attention. Tied-ridging has been effective in reducing surface runoff and increasing soil water storage in different countries as reviewed by Gebreyesus*et al.* (2006). Soil and water resources are usually conserved together by methods of soil and water conservation, this is true of all regions including arid and semi-arid regions. Common conservation measures direct either to soil, water or both. Use of physical structures or improved land management systems that can reduce surface run-off will also help to reduce erosion. In the same manner, reducing erosion will usually prevent splashing of soil particles by rain drop impact, surface crust formation, or breakdown of structural aggregates, which in combination improve infiltration of water and contribute to water conservation (Gebreyesus *et al*., 2006).

Field experiments conducted to determine the effects of moisture conservation techniques on yields of improved varieties of maize and sorghum crops with and without N and P fertilizer applications in the semi-arid areas of Eastern Hararghe showed an average yield increase of up to 37% due to water (Solomon, 2015) conservation practices under unfertilized conditions and up to 60% increase with NP fertilization (Tamirie *et al*., 1986; Tamirie, 1986; Heluf, 1989; Heluf, 2003).

The principle of tied ridging is to increase surface water storage by first making ridges and furrows, then damming the furrows with small mounds, or ties. Highest maize yield 1616kg/ha was achieved with closed end tied ridge planting in furrows type of water conservation technique.

There is an extensive literature reporting trials of tied ridging in many countries. Some of the reports indicate problems and failures but the great majority of them declare great success for the system that one wonders why the system has not been more widely used. It has been reported that tied ridging is beneficial for reducing run-off and soil loss, as well as for increasing crop yield (El-Swaify, 1983; Dagg and McCartney, 1968). McCarthey *et al*. (1971) indicated that in both high and low rainfall conditions, tied ridging resulted in higher maize yields in Tanzania. But, most common reports of success are in times when areas receive low quantity of rainfall. For example, research in Kenya on a maize variety called Katumani, Njihia (1979) reported that tied ridging made the production of a crop of maize possible in low rainfall years when flat-planted crops gave no crop yield.

The use of tied ridging in some areas of Botswana, however, showed negative effects on productivity due to very harsh conditions. This negative result may have brought about by the higher soil temperatures created within the ridge which can be detrimental to seed germination, and shallow penetration of moisture in to the soil compared to that on flat soil when the rainfall is light (DLFRS, 1984). However, most of the researches conducted on tied ridging showed a positive response by different crops. For example, the efficiency of a fallow before cotton has shown a great increase due to tied ridging according to a research conducted by Rawitz et al. (1983) in Israel's Negev desert. Similarly, a research report by ICRISAT (1976) from India has shown that sorghum planted on broad ridges outperform sorghum that was planted on either flat planting or narrow ridges and a similar result was reported for sorghum and castor in Gujarat by Brahmbatt and Patel (1983).

With the current change in global climate, adaptation methods like the use of conservation approaches are to be implemented if the agriculture sector is to continue to meet the ever increasing food demand especially in developing countries like Ethiopia (Solomon, 2015).

3. CONCLUSIONS

- Water conservation techniques at farm level are essential options for the semi aridBako area for improving yield through better soil water storage.
- The CPF (closed end tied ridges planting on furrow) is the best option when measured in terms of the grain yield and related parameters of the maize varieties considered the moisture contents of soil.
- In moisture scarce environments like Bako, crop plants would face shortage of moisture available in the soil throughout the growing season unless they are supplied with supplemental water through irrigation or technique of conserving the natural precipitation is employed.
- With the current change in global climate, adaptation methods like the use of conservation approaches are to be implemented if the agriculture sector is to continue to meet the ever increasing food demand especially in developing countries like Ethiopia.
- The magnitude of yield response to water conservation and the relative effectivenessof the different tied ridges and planting methods tend to vary with soil type, level of soil fertility and distribution and total rainfall during the crop season.
- Regardless of the type of the tied ridge, furrow planting proved to be more effective in conserving water and increasing the yield of sorghum with relatively consistent effects in most seasons than ridge and flat bed methods on both soils and soil fertility levels,

- Within the furrows, closed end tied ridge is more efficient than open end tied ridge as indicated by increased yield, and the relative effectiveness of the tied ridges and planting methods in increasing crop yields increased with increasing level of soil fertility
- In general, the results apparently indicated that in the Ethiopian highlands where the rainfall is low and erratic and the soils are degraded, low total rainfall or its uneven distribution during the cropping season is one of the principal factors limiting the yield of crops. Hence, regardless of the water holding capacity and fertility levels of the soils, soil and water conservation and particularly, in situ water harvesting practices are indispensable agricultural operations.

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