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Effect of Mulching and Tied Ridge on Crop Production and Soil Improvement in Dry Land Areas

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Abstract

Rain fed crop production in dryland areas is unreliable due to high evapo-transpiration, high run-off rates, delay onset, and early cessation of rains. So soil moisture deficiency is one of the primary factors that limit crop production in the area. Soil conservation is another important issue in dryland areas because high run-off rates leads to severe soil erosion. Due to shortage of soil moisture there have been attempts to optimize crop yield by planting drought-tolerant crops, particularly maize, sorghum and millet. This is not enough because crop failure due to water stress is still observed in dry lands. Therefore the proper use of soil moisture conservation structures like tied ridge helps to reduce the runoff rate, nutrient losses from soil and improve the soil moisture for plant growth which in turn, boost the productivity of land and plants. In addition to tied ridge mulching is a good practice used to reduce soil erosion and enhance water conservation. Tied ridge is one of the structures used to reduce water runoff and increase infiltration of rain water to the soil. It 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. Tied-ridging increased soil water by more than 25% compared to the traditional tillage practice in northern Ethiopia. It has been reported that tied ridging is beneficial for increasing crop yield. Tied-ridging increased sorghum grain yield by more than 40% compared to the traditional tillage practice in northern Ethiopia. It has beneficial effects of reducing runoff loss and soil loss. Mulching is also on the positive side of the balance in dry land. When adequate residues are available and conservation tillage is used, soil erosion is greatly reduced and water conservation is enhanced. Management of crop residues on the farm lands increased the grain yields of maize, sorghum and wheat crops both by improving soil fertility and conserving water at Haramaya area. Mulch conserved more water and led to higher dry matter and grain yields of maize compared to minimum tillage.

Keywords: Soil Moisture; Moisture Conservation; Mulching; Crop Yield; Crop Residues

Abbreviations: SNNPR: Southern Nations Nationalities and People’s Region; N: Nitrogen; P: Phosphorus.

Introduction

Drylands are defined by a scarcity of water. The United Nations Environmental Program defines drylands as tropical and temperate areas with aridity index of less than 0.65 [1]. Rain fed crop production in these areas is unreliable due to high evapo-transpiration, high run-off rates, delay onset, and early cessation of rains [2]. So soil moisture deficiency is one of the primary factors that limit crop production in this area [3].

Soil conservation is an important issue in dryland areas because high run-off rates leads to severe soil erosion [4]. In Ethiopia drylands consist of a wide range of agro-ecologies including the arid, semiarid and dry sub-humid and cover about 75 percent of the total land mass. They are prevalent mainly in the north, east and central areas of the rift valley [5].

The low land dryland areas in Ethiopia, cover about 55 percent of the land mass of the country (Ministry of Agriculture and Rural Development). These dry lands, forming the regional states of Afar and Somali, and large parts of Oromiya and the Southern Nations Nationalities and People's Region (SNNPR) of Ethiopia. In spite of the climatic and ecological conditions, the population follows a semi-nomadic pastoral system. Recurrent droughts, unreliable rainy seasons, degraded soils and intense erosion processes make the livelihoods of the local population highly vulnerable. Climate change effects are significant in the arid and semi-arid regions of Ethiopia and have worsened the living conditions for the pastoralists [6].

The altitude ranges from -124 to 1500 masl and the rainfall ranges from 200 to 700 mm annually, with a growing period of 90 to 180 days. It is estimated that about 80 million populations in Ethiopia live in these dryland areas [5]. As in other dry lands of the world, periodic low soil moisture due to erratic and poorly distributed rainfall, severe soil erosion and runoff loss of water and the resultant low soil fertility are the prominent causes for the low agricultural productivity in the Ethiopian dry lands [7-9]. The rate of annual loss of soil due to erosion for Ethiopia vary from almost zero on lowland grasslands to over 200 t/ha/yr on steep slopes of the highlands cultivated with erosion promoting crops such as maize or sorghum [10].

In addition to accelerated soil erosion and the alarming rate of land degradation, the loss of water as runoff and periodic drought during the cropping season on degraded lands are problems of rain-fed crop production [8,9,11]. These problems are mainly attributed to the inadequate efforts and absence of technologies proved to conserve the soil and water resources, the consequence of which is the need to increase productivity on limited and marginal land and water resources.

Soil and water conservation is called upon to alleviate both the problems of erosion and drought which are symptoms of two different extremes of rainfall conditions. Control of soil erosion and runoff water depends on soil and crop management practices [12-14]. The practice of judicial water conservation undoubtedly plays a significant role in increasing agricultural production in arid, semiarid and sub-humid areas where agriculture is hampered by periodic droughts and low soil fertility [8,9,15]. Soil or land management practices to reduce soil loss and runoff to negligible amounts are usually based on a combination of practices which help to maintain soil infiltration rates at sufficiently high levels and on measures which help safe disposal of runoff water from the field, if rainfall exceeds the infiltration capacity of the soil [12,16].

Due to climate change, there have been attempts to optimize crop yield by planting drought-tolerant crops, particularly maize, sorghum and millet. This is not enough because crop failure due to water stress is still observed in dry lands [3]. Therefore the proper use of soil moisture conservation structures like tied ridge helps to reduce the runoff rate, nutrient losses from soil and improve the soil moisture and nutrient availability for plant growth which in turn, boost the productivity of land and plants [17]. In addition to tied ridge mulching is a good practice used to reduce soil erosion and enhance water conservation [18]. Therefore the aim of this paper is to review the impact of tied ridge and crop residue management on crop production in dry land agriculture.

Literature Reviews

Tied Ridge

Tied ridge is one of the structures used to reduce water runoff and increase infiltration of rain water to the soil. It has been effective in reducing surface runoff and increasing soil water storage in different countries [19]. It is a variation of the micro catchment approach for trapping and holding water. Its construction follows the contours but, in addition, the furrows between ridges are linked by cross-ties to create closed micro basins 1 to 5 m long. The cross-ties are kept lower than the ridges so they act as spillways in the event of heavy rainfall [17]. 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 [20].

Moisture Conservation

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 [21]. Micro-basins created by tillage can reduce runoff and increase infiltration and thereby water available for crop production [19,22].

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 [21]; 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. 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 [21].

Tied ridge is an effective structure in increasing soil water storage in different countries [19]. 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 [20]. 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 [23,24]. Tied-ridging has been effective in reducing surface runoff and increasing soil water storage in different countries. Moreover, tied-ridging increased soil water by more than 25% compared to the traditional tillage practice in northern Ethiopia [19].

Effect of Tied Ridge on Crop Production

The low quantities of rainfall in dry land areas make cropping to be possible only with the use of special techniques of soil and water conservation and in this regard tied ridge is a good structure to be used. 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 [25].

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 [20].

It has been reported that tied ridging is beneficial for increasing crop yield [24,26] 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 [27] 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.

Researches done on fertilized and unfertilized conditions on Entisols and Vertisols of eastern Ethiopian highlands responded significantly ($P \leq 0.01$) to the treatments both under fertilized and unfertilized conditions of the soils studied when tied ridge was used. 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-1 (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 [28].

Tied-ridging increased sorghum grain yield by more than 40% compared to the traditional tillage practice in northern Ethiopia [19]. Highest maize yield 1616 kg ha-1 was achieved with closed end tied ridge planting in furrows type of water conservation technique.

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 [29].

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 E [30] in Israel's Negev desert. Similarly, a research report by Farming Systems Annual Reports [31] 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 BM [32]. 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 [19]. 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 [33,34].

Soil Conservation by Tied Ridge

Tied ridge has beneficial effects of reducing runoff loss and soil loss [17,23,24]. It is an effective practice particularly in lands with slopes less than 3-4% in controlling soil erosion [35]. Tied ridging had 33.7% soil moisture advantage over traditional practice [36,37], Zimbabwe [38,39], Burkina Faso [40] and Araya A [41] have revealed that it is effective in reducing surface runoff and increasing soil water storage. The simulation results indicated that tied-ridging reduced surface runoff and this increased retained rainwater within the field [34]. It is also a safe disposal of runoff in the case of water logging [12,14].

Mulching

Mulching (Crop residue management) is also on the positive side of the balance in dry land. When adequate residues are available and conservation tillage is used, soil erosion is greatly reduced and water conservation is enhanced [18].

Effect of Mulching on Crop Production

Most of the soils in the semi-arid areas have the problems of compaction or surface sealing/ crusting which lead to low water infiltration. Mulching is traditionally used to alleviate these problems and research results in central Rift Valley indicated that use of mulches at the rate of 3 tons increased yield by 30 percent compared without mulching. The mulching materials are obtained from pigeon pea and sesbania sesban drought resistant and as such results could be implemented with no problem. The use of Sesbania sesban mulches were also found to increase grain and stover yield substantially compared to the control (without mulching) [7].

Management of crop residues on the farm lands increased the grain yields of maize, sorghum and wheat crops both by improving soil fertility and conserving water on the two major soils of Haramaya area [6,11,15,42].

Grain and residue production for corn showed a highly significant linear response to amount (Mg ha-1) of residue returned to the soil surface. Over the range of residue amounts tested, only linear relationships between surface crop residues and grain or residue yield were found. Corn grain and residue production differed among the years of study; however, only corn grain production was significantly affected by the treatment X year interaction. Residue applied accounted for 81% of the variation in grain yield of corn. Also, approximately 90% of the variation in residue yield was explained by variation in residue applied. Each Mg ha-l of residue applied resulted in 0.10 Mg ha-1 of additional grain production for corn. About 0.30 Mg ha-1 of additional residue (stover) was produced for each Mg ha-1 of residue applied [43].

Moisture Conservation by Mulching

Mulch conserved more water and led to higher dry matter and grain yields of maize compared to minimum tillage. The use of mulch effectively controlled runoff through increased surface water storage, which in turn increased the time available for infiltration and also minimized evaporation, surface sealing and crusting [44].

Soil Conservation by Mulching

Removing crop residues from the field after harvest, to leave the ploughed soil bare during winter, commonly leads to soil drying and severe wind erosion. Erosion of fertile top soil, removal of crop residues (to feed animals and to be used as fuel for cooking with only partial return of manure and ashes to the cropped land) and burning of crop residues have led to nutrient depleted soils on various places [45-47]. Most of the soils in the semi-arid areas are highly degraded with poor physical, chemical and biological properties. The soils have the problems of compaction or surface sealing/crusting which lead to low water infiltration and high runoff. Mulching is traditionally used to alleviate these problems [10].

Cultural practices, which maintain a high soil infiltration rate and feasible in cultivated lands are essentially based on farming techniques, which maintain a mulch or live vegetation (stubble mulching and no- or minimum-tillage and use of cover crops) on the soil [12,14]. When adequate residues are available and conservation tillage is used, soil erosion is greatly reduced and water conservation is enhanced observed a runoff of 1.2% and a soil loss of 0.05 t ha-1 with mulch at a rate of 6 t/ha and a runoff water of 50% and a soil loss of 4.83 t/ha without mulch [13,18].

Conclusion

In general, 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 and mulching should get sufficient attention. From the above results, using tied ridge and mulching in dry land cropping systems is mandatory to get optimum yield. Farmers have to be trained and use both moisture and soil conservation practices. It is possible to use crop residues as mulching. Therefore in order to utilize their land and agricultural inputs properly they have to conserve moisture.

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