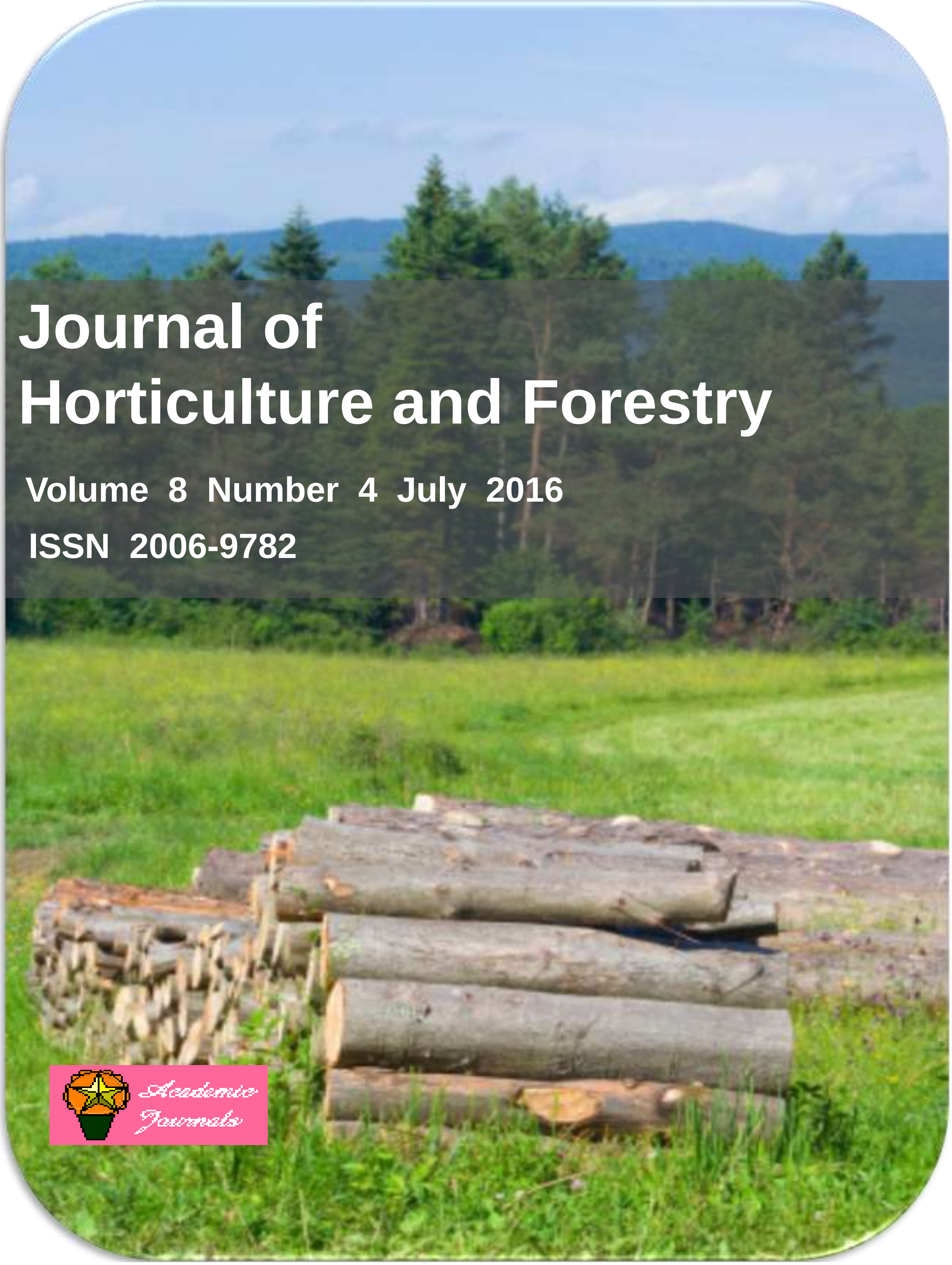

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Full Length Research Paper

Effects of negarim and semi-circular structures on growth and yield of banana in moisture deficit area of Daro Labu District, West Hararghe Zone, Ethiopia

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The study was conducted for three consecutive years (2011/2012 to 2013/2014) to evaluate the growth and production of banana (Robusta variety) with different water harvesting structure in Daro Labu districts of Oda Leku peasant association. The water harvesting structures used as treatments were semi-circular bund with and without mulch, negarim micro catchment with and without mulch and normal pit with and without mulch (control). The treatments were laid out in randomized complete block design on three farms as a replication. The data on yield, number of fingers, survival rate/6 month, number of sucker/2 years, plant height, and area coverage/1 year and 9 months were collected. The statistical analysis revealed that there was no significant difference (p>0.05) among treatments on survival rate, number of sucker, plant height, and area coverage but there was a highly significant variation (p<0.01) among treatments on yield and number of fingers. The means of plant height, area coverage and number of sucker on semicircular bund with mulch and negarim micro catchment with mulch were better than the structures without mulch and control. Both structures are therefore recommended with mulch for banana production in moisture stress areas and similar agro-ecologies.

Key words: Negarim, semi-circle, survival rate, area coverage, number of sucker, banana, mulch.

INTRODUCTION

Water is a major limiting factor to crop production in many semi-arid conditions, yet a substantial amount of it is lost from agricultural fields and adjacent land through runoff. Crop production is limited by water shortage which is caused by low storage, insufficient utilization, inter annual and annual fluctuation in precipitation and high evaporation demand (Walle and Belayneh, 2014). Several innovations have been developed in the past to improve water availability to field crops by harnessing the excess runoff. The practice of judicial water conservation undoubtedly plays a significant role in increasing agricultural production in arid, semi-arid and sub-humid areas where agriculture is hampered by periodic droughts and low soil fertility (Tamirie, 1986; Heluf and Yohannes, 2002). Degradation of soil and water resources is a worldwide problem that takes many forms (Napier, 2000)

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It is especially severe in developing countries where people are struggling to supplement an existence and are more concerned with survival than with conservation.

The dry lands of Ethiopia comprise about 70% of the total landmass and 45% of the arable land, including arid, dry semi-arid, moist semi-arid and parts of the sub-moist zone. However, these areas contribute only 10% of the total crop production. About half of the arable land is in the arid and semi-arid regions, and most rural people living in such areas depend on small-scale dry land agriculture. The dry lands are characterized by a very fragile natural resource base. Soils are often coarse-textured, sandy, and inherently low in organic matter and water-holding capacity, thereby making them easily susceptible to both wind and water erosion. As a result, crops can suffer from moisture stress and drought even during normal rainfall seasons. Farm productivity has decreased substantially and farmers have found themselves sliding into poverty (Kidane, 1999).

Banana (*Musa* species) is one of the most important tropical fruits and evolved in the humid tropical regions of South East as one of its centers of origin. Banana represents the world's second largest fruit crop with an annual production of 129,906,098 metric tons (FAO STATS, 2014). It ranks as the fourth most important global food commodity after rice, wheat and maize in terms of gross value of production (INIBAP, 1992). Banana produces fruit throughout the year and adds to its importance as a food security crop in Africa. It is a major food crop in the region meeting more than a quarter of the food energy requirements in the continent (Robinson, 1996). It is a staple food and good source of income for a number of African countries especially East and Central Africa (Viljoen, 2010).

Uganda is Africa's largest producer while Rwanda and Burundi are the second and third largest producers in East Africa, respectively (FAO, 2009). Banana has been cultivated for several years in Ethiopia as a garden plant. In Ethiopia, the major banana producing regions are Southern Nations and nationalities, Oromia and Amhara regions (MOA, 2011). During the 2010/2011 production season about 31, 885.86 hectares of land has been covered with banana and the estimated annual production was about 270, 571.516 tones (CSA. 2011). The actual yields are less than 40 t ha^{-1} $year^{-1}$ (Wairegi and van Asten, 2010); whereas, the potential yield of banana is greater than 70 t ha^{-1} $year^{-1}$ (Van Asten et al., 2005). In Uganda the poor productivity of banana has been attributed to a number of biophysical factors (Gold et al., 1999). Among these, moisture stress is the critical problem for banana production particularly in arid and semi arid areas. Similarly in arid and semi arid areas of Ethiopia such as Oromia, Amhara and Southern Nation Nationalities Regional State, the production of banana has been faced to moisture stress due to erratic rain fall and recurrent droughts. *Musa* production requires at least 1,000 to 1,500 mm per year average rainfall (Landon, 1984, Blomme et al., 2000). Because the plants can store a significant amount of water within their pseudostem and rhizomes, they can survive extended periods of drought, although their growth will slow down or cease under such conditions (Nelson et al., 2006).

Water conservation is a method used to increase the amount of water stored in the soil profile by trapping or holding rain where it falls or where there is some small movement as surface run-off (SUSTAINET EA, 2010). Water conserving schemes which are more concerned with catching and storing runoff water for later use or at a distance from storage. Some writers have used the terms internal and external catchments to identify command area and runoff generating areas. Internal catchments are areas where the runoff producing areas is within the cropped area and external catchments are runoff areas outside the cropped area.

Although the first report of negarim micro catchments was derived from southern Tunisia (Pacey and Cullis, 1986) the technique has been developed in the Negev desert of Israel. Where precipitation is less than crop water requirements; here the strategy includes land treatments to increase runoff onto cropped areas, following for water conservation and the use of drought tolerant crops with suitable management practices and where precipitation is equal to crop water requirement; here the strategy is local conservation of precipitation, maximizing storages with in soil profile and storage of excess runoff for subsequent use. Thus, negarim and semi-circular micro catchment is the well known *in-situ* water conservation systems. Negarim micro-catchments are diamond-shaped basins surrounded by small earth bunds which collect runoff from within the basin and semi-circular bunds are earth embankments in the shape of a semi-circle with the tips of the bunds on the contour (Seleshi et al., 2009). The weakness of using these approaches is that the rain fall in semi-arid regions is very erratic and completely unpredictable. Therefore, a wide variation of moisture shortage and surplus, both within and between seasons can occur.

In West Hararghe zone, high moisture deficit is the primary problem, which highly constrains the productivity of small holders' farmers particularly of mid and lowland parts of the districts (priority problems raised in REFLAC 2009/2010). Extreme dry spells and recurrent drought is usual and late start, early finish and little amount of rainfall is becoming the main characteristic of rainfall in the areas (Eshetu *et al*., 2010). Banana is the most important cash crop in some parts of Western Hararghe zone. Though, the crop is important in the target area, a number of factors constrained productivity of the crop in Western Hararghe zone. Among this, moisture stress has been appreciated as one of the primary sources of lower banana production in the target areas. Hence, there is a need to introduce *in-situ* moisture conservation to the target area for banana production and productivity.

Therefore, the study was aimed at evaluating *in-situ* moisture conservation structures on growth and yield of banana and to overcome moisture deficit using structures in the study area.

MATERIALS AND METHODS

Description of the study area

The field experiment was conducted in Western Hararghe zone of Oromia Regional State, in Daro Labu district, Ethiopia. It is located at 434 km to the east of Addis Ababa and 115 km from Chiro (Zonal Capital) to the south on a gravel road that connects to Arsi and Bale Zones. Its latitudinal and longitudinal positions are 40°19.114 North and 08°35.589 East, respectively. The area has bimodal type of rainfall distribution with annual rainfall ranging from 900 to 1300 mm (average annual rainfall of 1094 mm) and ambient temperature of the district varies from 14 to 26°C with an average of 20°C (Climate data obtained from Mechara metrological station (2009 to 2014)).

The nature of rain fall is very erratic and unpredictable causing tremendous erosion. The major soil type of the area is sandy loam clay which is reddish in color. (Report on farming system of Daro Labu and Boke districts, Mechara agricultural research center (unpublished data)). The altitude range for Daro Labu is 1350 to 2450 m.a.s.l with area coverage of 434,280 ha and the predominant production system in the district is mixed crop-livestock production with peculiar sub-systems. The crops grown in the area ranges from small cereals such as Teff to tree and fruit crops including coffee, mango and avocado.

Experimental design

The experiment was designed in Randomized Complete Block Design and planted on three farmers' field used as replication. The treatments used consist of semi-circular bund; negarim micro catchment and Normal pit (local check) each with and without mulch. Sugar cane straw was used as a mulch which is the available mulch materials in the area. The semicircular structure was constructed with 2.5 m diameter and 1.25 m radius and negarim was constructed with 1.25 m length for each side and 30 cm height and width of its embankment. For all treatments, spacing between two banana seedlings and between rows was 2.5 m arranged in staggered manner to control erosion as well as for conserving moisture on a plot area of 5 × 7.5 m. Two banana suckers per treatment per farmer were planted (giving a total 12 suckers per farms).

Data collection and analysis

Plant survival rate recorded each 6 months and growth traits such as plant height, area coverage at 1 year and 9 month, number of suckers at 2 years, number of fingers and bunch weight was recorded. Survival rate was recorded by counting the survived number of planted sucker. Plant height was recorded by using meter tape measured from the ground up to apical. Area coverage was recorded by determining the leaf that cover the ground by its shade. Number of sucker was recorded by counting after it reach for planting. The matured bunch was harvested for determination of bunch yield by weight measuring device. Number of fingers per hand and bunch weight, were measured and yield was calculated as ton/ha. The data recorded throughout the growing periods were averaged over every harvest in the growing seasons for data analysis and computation. Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.0. Treatment effects were considered significant in all statistical calculations if the P-values were <0.05. Means were separated using Least Significant Difference at 5% level of significance (LSD) test.

RESULTS AND DISCUSSION

The statistical analysis reveals that there was highly significant difference ($P<0.01$) among treatments on yield and number of fingers. But there was no significant difference among treatments on survival rate, plant height, area coverage, and number of sucker. Higher yield (ton/ha) and number of fingers per bunch was recorded on both structures (negarim and semicircular bund) with mulch and normal pit with mulch and also negarim without mulch. The maximum number of yield weight per ha (22.523, 14.933, and 14.571 ton was recorded from negarim, normal pit and semi-circular micro catchment with mulch, respectively) and there was no yield from normal pit without mulch for local check (the minimum bunch yield of 0 ton ha^{-1} was noted from the local check). The maximum number of fingers per hectare 160533, 126400, 115200, and 112533 were recorded from negarim and semi-circle with mulch, negarim without mulch and also normal pit with mulch, respectively (Table 1).

However, there was no yield recorded from normal pit without mulch (local check) during the experimental period signaling that the banana production in the study area is highly limited by insufficient soil moisture, thus impacting the yield potential of the improved varieties used for production (i.e. up to 45 t ha^{-1} under research farms) (Tekle *et al.,* 2014). It is reported that banana production is greatly affected by environmental stresses such as drought (Turner, 1998). The banana is sensitive to soil water deficits, expanding tissues such as emerging leaves and growing fruit are among the first to be affected. As soil begins to dry, stomata close and leaves remain highly hydrated, probably through root pressure. Productivity is affected because of the early closure of stomata (Turner, 1998). In addition to moisture conservation structure, surface management (soil mulch) is used to protect the soil surface from rain, wind and sun and also increases soil moisture by allowing more water to sink into the ground and by reducing evaporation (FAO, 2005). Therefore, according to the above findings, the constructed structure had resulted in greater bunch yield and number of fingers than the local check (normal pit without mulch) with surface soil management. This finding has confirmed that the potential of moisture conservation with soil surface management over the normal pit without mulch. Therefore, it could be suggested that use of the *in situ* moisture conservation structure had brought a proportional yield increment than the normal pit without mulch.

CONCLUSION AND RECOMMENDATION

Integrating *in-situ* moisture conservation structures to

Table 1. The mean value of yield and other growth parameters of banana (2011/2012-2013/2014).

Treatments	Mean value of collected parameters					
	SR	PHT	AC	NS	Yield (ton/ha)	Average number of fingers/bunch
Semi-circle without mulch	98.33	0.80	1.066	5.00	2.667[bc]	19[b]
Semi-circle with mulch	100	1.7833	1.783	7.66	14.571[a]	79[a]
Normal pit without mulch	100	1.26	1.433	4.66	0.000[c]	00[b]
Normal pit with mulch	100	0.9333	1.166	7.00	14.933[a]	71[a]
Negarim without mulch	100	0.936	1.1933	5.00	12.693[ab]	72[a]
Negarim with mulch	100	1.566	1.7833	7.667	22.523[a]	101[a]
Mean	99.72	1.21	1.35	6.166	11.231	57
P-value	0.46	0.1646	0.4339	0.50	0.0075	0.0037
CV (%)	1.18	39.81	32.6	41.55	52.45	43.27
LSD 0.05	2.1	0.88	0.80	4.66	10.717	44.656

Means with the same letter within the columns are not significantly different. Banana that was planted in normal pit without mulch was not given yields (0 ton ha^{-1}). SR: Survival rate; PHT: plant height; AC: area coverage; NS: number of sucker.

crop production could make an important contribution to increase agricultural production and productivity where there is high moisture stress. To this end, use of appropriate soil and water technologies such as negarim and semicircular micro catchment could be some of the alternatives in order to improve productivity of smallholder farmers. During the field implementation, two structures negarim and semi-circular micro catchment and normal pit with and without mulch were used. Analysis of variance revealed that, yield and number of finger per bunch were significantly affected by structures except for growth parameters. Therefore, it can be concluded that the use of the moisture conservation structures with mulch such as negarim and semicircular micro catchment is advisable and could be appropriate for banana production in the test area even though further testing is required to put the recommendation on a strong basis.

Conflict of Interests

The authors have not declared any conflict of interests.

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