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Evaluation of Moisture Conservation Practices, Inter and Intra Row Spacing on Yield and Yield Components of Pearl Millet (*Pennisetum glaucum*) at Alduba, Southern Ethiopia

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Abstract
A field experiment was conducted at Alduba to determine the effects of moisture conservation practices, inter and intra row spacing on yield and yield components of pearl millet (Penisetum glaucum L.) under rain fed conditions in 2012-2013. The experiment was conducted with two levels of moisture conservation practices (farmers practice and tied ridge), three levels of inter row spacing (40, 60 and 80 cm) and three levels of intra row spacing (15, 25, and 35 cm). The experimental design was split-split plot with three replications where, moisture conservation practice was arranged as main plot factor, inter and intra row spacing were arranged as sub and sub-sub plot factors, respectively. Phenological and growth parameters such as yield and yield components, total biomass and harvest index were studied. The result showed that out of the studied phenological and growth parameters; number of tillers per plant and days to maturity were significantly affected by moisture conservation practices while days to flowering, plant height and panicle length were not significantly affected by moisture conservation practices. The number of days required to reach at mid flowering and maturity were delayed when tied ridge was used. Use of tied ridge increased both plant height and panicle length. Grain yield was significantly affected by moisture conservation practices. The grain yield obtained from tied ridge (3.634 t ha^{-1}) was higher by 12.52% compared to farmers practice (3.179 t ha^{-1}). Both total biomass and 1000 seeds weight were significantly influenced by moisture conservation practices. Inter row spacing did not affect significantly phenological and growth parameters except days to flowering and days to maturity. Inter row spacing did not bring significant variation on grain yield, yield components, total biomass and harvest index. The highest total biomass (4.611 t ha^{-1}) and the highest thousand seeds weight (11.33 gm), obtained from tied ridge were 10.11% and 82.34% increase over farmers practices, respectively. All the phenological and growth parameters were not significantly affected by intra row spacing. Intra row spacing significantly affected grain yield and total biomass but it did not affect significantly 1000 seeds weight and harvest index. Grain yield advantage of 6.26% was recorded under inter row spacing of 60 cm over 40 cm. The grain yield advantage of 28.77% was observed under the intra row spacing of 25 cm over 15 cm. Therefore; it could be concluded that inter row spacing of 60 cm could be better for pearl millet production in the study area. The highest grain yield (3.71 t ha^{-1}) and biomass (4.788 t ha^{-1}) were obtained from the intra row spacing of 25 cm showing 22.34% and 20.59%, respectively increase over 15 cm intra row spacing. The highest grain yield and total biomass from 25 cm was contributed by increased number of tillers per plant and heavier seed weight. There was no significant interaction between moisture conservation practices, inter and intra row spacing for all studied parameters except grain yield and harvest index. Therefore, it can be concluded from this result that use of tied ridge, inter row spacing of 60 cm or intra row spacing of 25 cm is advisable and could be appropriate for pearl millet production in the test area even though further testing is required to have strong recommendation.
Key words: Tied ridge, farmers practice, inter row spacing, intra row spacing, pearl millet

1. Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br., Poaceae] is an annual crop and one of the minor cereals that has been historically grown for forage production and cattle grazing in the US. It is widely grown as a multi-purpose cereal grain crop principally for food, and also for feed, fodder, fuel, and mulch on more than 26 million hectares, primarily in arid and semi-arid regions of India and Africa (FAO 2000). It is a staple grain for about 90 million people living in the semi-arid tropical regions of Africa and the Indian sub-continent. As a new-use grain crop, it currently occupies relatively small acreage in the US, but has high potential because of its ability to tolerate drought and low fertility, better nutritive properties and diverse use over other cereals (Gulia et al. 2007). It performs best and can be widely adapt in marginal areas, it accounts for a larger share in daily diets than wheat and rice (Ramaswami 2002). Pearl millet can be cultivated in arid and semi-arid areas with the annual precipitation of 200 - 800 mm where it is difficult to grow other cereals, and hence it is important as the food resource under poor environments. Pearl millet has differentiated into many ecotypes owing to diverse kinds of environmental isolation or to various cropping systems (Kurauchi *et al*., 2000).

Drought has major implications for global food supply because of the expected effects gradual climatic change and the variations in climatic in short term that it is to bring (Edmeads, 2013). Although the temperature is a

more predictable outcome than the changes in rainfall patterns accompanying climate change (Edmeads, 2013), it is generally considered that use of drought tolerant crop varieties with effective soil moisture conservation practices and optimum plant population is an important for improved crop production in an advanced manner.
Production of pearl millet with yield improvement would have a direct impact on the drought prone areas of Ethiopia since pearl millet is drought tolerant and early maturing with high water use efficiency. Soil moisture conservation practices to conserve water are lacking in West Africa (Payne, 1999). In order to improve pearl millet yield in the study area there is need to include the best moisture conservation technologies with optimum plant population is crucial. Pearl millet responds very favorably to slight improvements in growing conditions such as irrigation and tillage (Leisinger et al., 1995). Especially in South Omo Zone, production of pearl millet needs critical attention since drought is the major problem in this area because moisture is the limiting factor for crop production in general and pearl millet production in particular. Therefore; this study was initiated with the following objectives:-

Objectives

-to determine the best moisture conservation practices for pearl millet production
in the study area
-to determine the optimum inter row spacing for pearl millet in the study area
-to determine the optimum intra row spacing for pearl millet in the study area

2. Materials and Methods

2.1. The Treatments, The Study Area and Experimental Design

Field experiment was conducted at Alduba research field in Bena Tsemay woreda of Southern Ethiopia in 2012-2013 under rain fed conditions. Alduba is located about 720 kms from South of Addis Ababa. Geographically, Alduba is found at E 36^0 36’ 30.8” Longitude and N 05^0 25’ 00” Latitude and at an altitude of 1343 meters above sea level. The experiment consisted of 18 treatments with a total of 54 plots. The experiment was laid out in a split- split plot design with three replications during the 2012-2013 cropping seasons under rain fed conditions. Two levels of Moisture conservation practices(Tied Ridge and control), three levels of Inter row spacing (40 cm, 60 cm and 80 cm) and Intra row spacing (15 cm, 25 cm and 35 cm), respectively were used as main plot, sub-plot and sub-sub plot factors, respectively.

2.2. Data collection

Phenological Parameters and Growth Parameters

Phenological parameters such as days to flowering and days to maturity were recorded. Days to flowering was recorded by counting the number of days after emergence when 50 % of the plants per plot had the first open flower. Days to maturity was recorded when 90% of panicles per plot. At mid flowering stages five plants from each of the plots were selected randomly and uprooted carefully to determine crop growth parameters such as plant height and number of tillers.

Grain Yield, Yield Components, Total Biomass and Harvest Index

Three central rows were harvested for determination of grain yield. Grain yield was adjusted to 12.5% moisture content. Five plants were randomly selected from the three central rows to determine yield and yield components, which consisted of thousand seeds weight. Seed weight was determined by taking a random sample of 1000 seeds and adjusted them to 12.5% moisture content. Total biomass yield was measured from the three middle rows when the plant reached harvest maturity. Harvest index was calculated as the ratio of seed yield to total above ground biomass yield.

2.3. Statistical Analysis

All the agronomic data were recorded and being subjected to analysis. Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.1. Effects were considered significant in all statistical calculations if the P-values were < 0.05. Means were separated using Fisher’s Least Significant Difference (LSD) test.

3. Result and Discussion

The combined analysis of variance over two years revealed that days to maturity was highly significantly ($P < 0.001$) and number of tillers plant^{-1} affected significantly ($P < 0.05$) by moisture conservation practices while days to flowering, plant height and panicle length were not significantly affected by moisture conservation practices (Table 1). Though moisture conservation practices had brought a non significant effect on some of the phenological and growth parameters, tied ridge gave consistently higher plant height and panicle length for pearl millet. Also the combined analysis of variance result over two years depicted that, inter row spacing had significantly ($P < 0.05$) affected days to flowering and days to maturity whereas, it had brought no significant effect on plant height, number of tillers and panicle length (Table 1). Also there were no significant interaction effects of inter row spacing with moisture conservation practices observed for all the studied growth and phenological parameters. Intra row spacing, interaction effects of intra row spacing with moisture conservation practices as well as inter row spacing had no significant effect on all the studied growth and phenological parameters (Table 1).

Table 1: Mean Square Values for Crop Phenology and Growth Parameters of Pearl Millet at Alduba, in 2012-2013.

Source	DF	Days to flowering	Days to maturity	Tiller number ($plant^{-1}$)	Plant height (cm)	Panicle Length (cm)
Replication (R)	2	1.16ns	2.17^{ns}	0.92^{ns}	215.54^{ns}	6.92ns
Moisture Con (MC)	1	7.66ns	417.83***	13.04*	108.71^{ns}	0.006ns
Error a	2	0.34	0.22	0.20	136.49	0.005
Inter Row (ER)	2	14.90*	13.75*	0.11ns	56.42ns	0.60ns
MC * ER	2	3.78^{ns}	3.90^{ns}	0.97ns	449.52^{ns}	0.03ns
Error b	6	1.09	0.99	0.98	168.20	4.06
Intra Row (IR)	2	2.80	4.31ns	3.98ns	359.18ns	2.90ns
MC * IR	2	1.23	0.61ns	2.32ns	463.07ns	0.006ns
ER * IR	4	0.68	0.78ns	1.48ns	237.23ns	0.87ns
MC *ER * IR	4	1.80ns	1.49ns	3.65ns	279.27ns	0.033ns
Error c	24	2.73	3.13	1.96	363.72	1.85

*, ** and *** indicate significance at P< 0.05, P< 0.01 and P< 0.001, respectively and 'ns' indicate non significant

Table 2: Crop Phenology And Growth Parameters of Pearl Millet as Affected By Moisture Conservation Practices, Inter And Intra Row Spacing at Alduba, in 2012- 2013.

Treatments	Days to lowering	Days to maturity	Tiller number ($plant^{-1}$)	Plant height (cm)	Panicle length (cm)
Moisture Con (MC)					
Flat Land	45.81b	75.81b	4.62b	110.6a	16.34a
Tied Ridge	46.66a	81.48a	4.62a	113.68a	16.37a
LSD 0.05	**0.68**	**NS**	**0.53**	**NS**	**NS**
CV%	**1.26**	**0.55**	**10.85**	**10.41**	**0.43**
Inter Row (ER)					
40 cm	45.22d	77.50a	4.22a	111.54a	16.31a
60 cm	46.00a	79.00a	4.10a	110.70a	16.60a
80 cm	46.22a	78.5a	4.08a	114.47a	16.62a
LSD 0.05	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**2.25**	**1.26**	**24.02**	**11.56**	**12.30**
Intra Row (IR)					
15 cm	45.88a	78.11a	3.94a	112.00a	15.91a
25 cm	46.27a	78.77a	3.77a	107.75a	16.42a
35 cm	46.55a	79.05a	4.66a	116.68a	16.75a
LSD 0.05	**NS**	**NS**	**NS**	**NS**	**NS**
CV (%)	**3.57**	**2.25**	**5.82**	**17.00**	**8.32**

Note: Means with the same letters within the columns are not significantly different at P <0.05.

All the yield and yield components of pearl millet were significantly affected by moisture conservation practices while moisture conservation practices did not affect significantly harvest index (Table 3). Similar results were observed for annual crops under tied ridge than flat land (Heluf, 2003; Anteneh et al. 2006). The increase in pearl millet grain yield under tied ridge may be attributed to the efficient utilization of the retained soil moisture conserved by the ridge during the rainfall period. The maximum 1000 seeds weight of 11.33 gm and the least 2.00 gm, the highest grain yield of 3.634 t ha^{-1} and the least 3.179 t ha^{-1}, the highest biomass weight of 4.611 t ha^{-1} and the least 4.142 t ha^{-1} and the maximum harvest index of 0.78 and the minimum 0.76 were obtained from tied ridge and farmers practice, respectively (Table 4). According to this result it could be concluded that, the highest 1000 seeds weight and biomass weight leads to the highest grain yield. Grain yield advantage of 12.52%

was obtained from tied ridge over farmers practice. This indicates that instead of using farmers' practices in moisture stress areas; it is paramount important to use tied ridge than flat land for maximum grain and biomass yield.

Yield and yield components of pearl millet were not affected significantly due to inter row spacing. Inter row spacing and moisture conservation practices did not interacted significantly for yield and yield components of pearl millet (Table 3). Though yield and yield components of pearl millet were not significantly affected by inter row spacing, but there was a relative advantages of yield and yield components observed among the inter row spacing in this experiment. As indicated in (Table 4), there was advantages of 16.61%, 6.26% and 3.85% under inter row spacing of 60 cm over 40 cm inter row spacing for 1000 seeds weight, grain yield and harvest index, respectively. This result is in agreement with the study by (Gulia et al., 2007) who reported that, for consistent high grain yield of pearl millet it is recommended to maintain use of row spacing 36-53 cm. Therefore; it could be concluded that inter row spacing of 60 cm could be better for pearl millet production in the study area.

Grain yield and biomass weight of pearl millet were affected significantly (P< 0.01) by intra row spacing (Table 3). This indicates that the maximum biomass production enhances more accumulation of assimilates leading to increased grain yield. Moisture conservation practices, inter row spacing and intra row spacing were interacted highly significantly (P< 0.001) for grain yield and also interacted significantly (P< 0.01) for harvest index (Table 3). Also the highest grain and biomass yields of 3.71 t ha^{-1} and 4.788 t ha^{-1} and the least grain and biomass yields of 2.881 t ha^{-1} and 3.802 t ha^{-1}, respectively were obtained from the intra row spacing of 25 cm and 15 cm, respectively while the maximum 1000 seeds weight of 8.98 gm and the minimum 7.63 gm were recorded from the intra row spacing of 25 cm and 35 cm, respectively (Table 4). There was grain yield and biomass yield advantages of 28.77% and 20.59%, respectively were observed under the intra row spacing of 25 cm over 15 cm. This result is in line with the findings of Payne (1997) when increasing plant population from 5000 to 20000 ha^{-1} yield increment was observed. Also, 1000 seeds weight advantage of 17.69% was recorded from the intra row spacing of 25 cm over 35 cm. Therefore; it could be concluded that the intra row spacing of 25 cm could be better to improve pearl millet production in the study area.

Table 3: Mean Square Values for Yield and Yield Components, Total Biomass and harvest Index in Pearl Millet at Alduba, in 2012-2013

Source	DF	Grain yield (t ha^{-1})	1000 Seeds wt(gm)	Total biomass (t ha^{-1})	Harvest index
Replication(R)	2	9.8082ns	1.99^{ns}	3.713ns	0.01ns
Moisture Con (MC)	1	3.0317**	581.15***	29.674*	0.005ns
Error a	2	4.048	1.35	10.043	0.02
Inter Row (ER)	2	2.148ns	4.50ns	0.273ns	0.007^{ns}
MC*ER	2	7.544ns	4.53^{ns}	5.024ns	0.012^{ns}
Error b	6	1.111	2.17	3.394	0.013
Intra Row (IR)	2	32.112**	2.75ns	43.857**	0.0053ns
MC *IR	2	1.239ns	2.07ns	2.114ns	0.0018ns
ER * IR	4	7.569ns	7.25ns	5.003ns	0.0413*
MC * ER *IR	4	2.5032***	4.73ns	3.889ns	0.059**
Error c	24	3.509	5.44	6.317	0.011

*, ** and *** indicate significance at P< 0.05, P< 0.01 and P< 0.001, respectively and 'ns' indicate non significant

Table 4: Yield and Yield Components of Pearl Millet as Affected By Moisture Conservation Practices, Inter and Intra Row Spacing at Alduba, in 2012- 2013.

Treatments	Grain yield (t ha^{-1})	1000 seeds Weight (gm)	Total biomass (t ha^{-1})	Harvest Index
Moisture Con (MC)				
Flat Land	3.179a	2.00b	4.142a	0.76a
Tied Ridge	3.634a	11.33a	4.611a	0.78a
LSD 0.05	**NS**	**5.02**	**NS**	**NS**
CV%	**18.67**	**14.13**	**22.90**	**18.36**
Inter Row (ER)				
40 cm	3.323a	7.38b	4.372a	0.75a
60 cm	3.545a	8.34ab	4.421a	0.78a
80 cm	3.328a	8.85a	4.322a	0.76a
LSD0.05	**NS**	**1.41**	**NS**	**NS**
CV (%)	9.78	17.92	13.31	14.80
Intra Row (IR)				
15 cm	2.881b	8.20a	3.802b	0.75a
25 cm	3.71a	8.98a	4.788a	0.78a
35 cm	3.628a	7.63a	4.539a	0.79a
LSD0.05	0.**407**	**NS**	**0.546**	**NS**
CV%	**17.38**	**28.37**	**81.17**	**13.122**

Note: Means with the same letters within the columns are not significantly different at P <0.05.

Conclusion

According to the findings of this research, use of tied ridge increased both plant height and panicle length and biomass weight. Grain yield was significantly affected by moisture conservation practices. The grain yield obtained from tied ridge (3.634 t ha^{-1}) was higher by 12.52 % compared to farmers practice (3.179 t ha^{-1}). The highest total biomass (4.611 t ha^{-1}) obtained from tied ridge. Grain yield advantage of 6.26% was recorded under inter row spacing of 60 cm over 40 cm. The grain yield advantage of 28.77% was observed under the intra row spacing of 25 cm over 15 cm. Therefore; it could be concluded that inter row spacing of 60 cm could be better for pearl millet production in the study area. The highest grain yield (3.71 t ha^{-1}) and biomass (4.788 t ha^{-1}) were obtained from the intra row spacing of 25 cm showing 22.34% increase over 15 cm intra row spacing. There was no significant interaction between moisture conservation practices, inter and intra row spacing for all studied parameters except grain yield and harvest index. Therefore, it can be concluded from this result that use of tied ridge, inter row spacing of 60 cm or intra row spacing of 25 cm is advisable and could be appropriate for pearl millet production in the test area even though further testing is required to put the recommendation on a strong basis.

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