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Influence of In-Situ Moisture Conservation Methods on Growth, Development and Productivity of Maize (*Zea mays* L.) Varieties in Hamelmalo area, Eritrea.

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ABSTRACT

In the semi-arid tropics of Eritrea among various constraints the low soil moisture content due to the low and erratic distribution of rainfall coupled with high temperature and lack of suitable varieties cause significant reduction in productivity of the maize. To tackle these problems, a field experiment was carried out to study the "Influence of *in-situ* moisture conservation methods (MCM) on the growth, development and productivity of maize (*Zea mays L*) varieties in semi-arid tropics of Hamelmalo area, Eritrea". The experiment was conducted in split plot design using three *in-situ* MCM (tied ridge, ridge and furrow and flat-bed) as main plots and two maize varieties viz early local and 04sadve as sub plots with three replications. The results of the experiment indicated that tied ridge resulted in significantly highest moisture conservation and produced the highest dry matter per plant and grain yield. Ridge and furrow and flat bed being statistically equal in soil moisture conservation helped the crop to take more time for its proper growth and development to produce significantly higher yield. 04Sadve variety was significantly superior to the early local variety in growth, development and yield. Among all the treatment combinations, 04sadve variety sown in ridge and furrow method or in tied ridge method and early local variety sown in flat-bed method being statistically at par resulted in significantly higher moisture conservation and consequently higher growth parameters, yield attributes and grain yield (4509kg ha^{-1}). It can be conclude that tied ridge and ridge and furrow *in-situ* moisture conservation methods were effective to conserve more moisture and the variety 04sadve was more efficient to utilize the conserved moisture under semi-arid conditions of Hamelmalo area of Eritrea.

Introduction:

Among food grain crops, it ranks third after wheat and rice in area, first in production and productivity in the world with an area of 142,685 thousand hectares, production of 638,087 thousand metric tonnes and productivity of 4472 kg/ha. In Africa it is been grown in an area of 27114 thousand hectares with a production of 435,182 thousand metric tonnes and average productivity of 1605 kg/ha (FAO, 2003). By 2050 demand for maize will be double in the developing world, and maize is predicted to become the crop with the greatest production globally (Rosegrant *et al.,* 2008). According to them the yield of maize at farmer's field in developing countries especially under semi-arid tropics is very low as compared to other maize producing countries such as U.S.A, Canada, Egypt etc. Many farmers in under developed countries do not apply fertilizer, lack adaptive and drought resistant varieties and face inadequate and extreme fluctuations in the availability of water for plant growth. To boost up maize production in such countries development and adoption of modern agro management practices seems imperative and one of the major techniques is the proper method of moisture conservation methods.

In Eritrea maize(*Zea mays L.)* is used for livestock feed, foods (*Kicha, Hinbasha, Tituko* and *Geat* etc.) and local beverages production (*Suwa*), soft cob for fuel, source of charcoal, and used for production of beer and whisky. It ranks third after sorghum and pearl millet among summer food grains and fifth among all food grains after sorghum, pear millet, wheat and barley in both area and production. It covers an area of 19,621hectares with annual production of 29,053 tonnes and average productivity of 1480.7kg/ha, which is not sufficient to meet demand of all the consumers (FAOSTAT, 2010). The low productivity of maize is attributed to its cultivation in very marginal areas of highland, the lack of seeds of high yielding varieties, moisture stress due to low and erratic rainfall, high temperature, low soil fertility, competition by weeds, inappropriate tillage and sowing system, lack of nutrient supplying capacity of the soil and non-availability of the fertilizer to the farmers at required time and amount (MOA, 2011). In addition to these, the degraded land without adequate available soil moisture at critical stages of crop growth is another major constraint of low productivity. Among these moisture stress due to low and erratic rainfall, lack of appropriate methods of soil moisture conservation, lack of adaptive varieties to moisture stress are the major factors.

In the absence of effective soil moisture conservation technologies farmers grow maize only in limited areas and have no choice except to grow monoculture of sorghum and pearl millet. No systematic research has been conducted on moisture conservation methods and the response of maize varieties to the conserved moisture. Keeping in view the above facts, the present study was conducted to assess the response of moisture conservation methods on the growth, development and yield of maize varieties under semi-arid conditions.

Materials and Methods:

The field study was conducted during summer season, 2014 at the experimental farm of Hamelmalo Agricultural College (HAC) representing semi-arid ecological zone of Eritrea. The site is located at a latitude of $15^0$52'21" N, longitude of 38^0 27'42" E and at an altitude of 1285m above mean sea level. The climate of the area is semi-arid with average annual rain fall of 468mm, average annual maximum and minimum temperatures of 34.8°C and 10°C, respectively (MoA, 2014).

Before sowing of the crop a composite representative soil sample was taken from 15cm and 30cm soil layers. The sample was thoroughly mixed and analyzed for its physico-chemical properties. The soil of the experimental field was sandy loam in texture, alkaline in reaction (pH 8.2), very low in organic matter content (0.27%), available nitrogen, available phosphorus and potassium (Million, 2014).

The experimental area was ploughed and harrowed with tractor operated disc plough and harrow, respectively. Field was leveled and surface of plots was configured manually with hoe and shovel. The field experiment was conducted in split-plot design with three replications using three MCM (Tied ridge, Ridge and furrow and flat-bed) in main plots and

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two varieties (Early local and 04sadve (hybrid)) in sub plots. The crop was sown on 28th June, 2014 at 75cm spacing between the rows and 25cm between the plants at 5-6cm depth by dibbling method with hand tool. Total nutrient of 41 kg N and 46 kg P_2O_5 per hectare were applied through Diamonium phosphate and Urea drilled at the time of sowing. Out of this 23kg N was top dressed in two equal split at an interval of 20 DAS. Harvesting was done when the cob husks dried and turned yellowish in colour. Soil moisture content was determined by gravimetric method (Walter, 1986) at 20 days interval from time of sowing up to 100 DAS. Soil samples were taken by tube auger from 15 cm and 30 cm soil layers from the net plot area and were weighed and oven dried at 105^0C till constant weight was obtained. Per cent soil moisture content on dry weight basis was calculated by the following formula:-

$$\text{Soil moisture } (\%) = \frac{W1-W2}{W2} \times 100$$

Where W_1 = Fresh weight of soil, and W_2= Weight of oven dried soil.

The data on growth and developmental parameters including plant height, days taken to tasseling and days taken to maturity and yield attributes including cob length, number of cobs per plant and number of rows per cob, and grain yield were collected. The data on progressive growth was recorded at 20 days interval and the days taken for tasseling and maturity developmental stages were recorded. Data was analysed by using the GENSTAT software (4th ed) and IBM SPSS statistical package version 20. The treatment means were compared with LSD at 5 per cent level of significance.

Results and Discussion:

The weekly rainfall distribution at Hamelmalo Agricultural College during the experimental period is presented in (Figure 1). A cursory glance of the Figure indicated that out of total rainfall of 429.1mm received during crop season, weekly rainfall was uniformly distributed throughout the growing season of the crop with amount of 0-10mm rainfall during 25 and 38 weeks, 10-20mm rainfall during 25, 30, 31 and 33 weeks, 30-40mm during 28, 29, 32, 34 and 35 weeks, 40-50mm during 36 weeks and 50-60mm during 26 and 37 weeks.

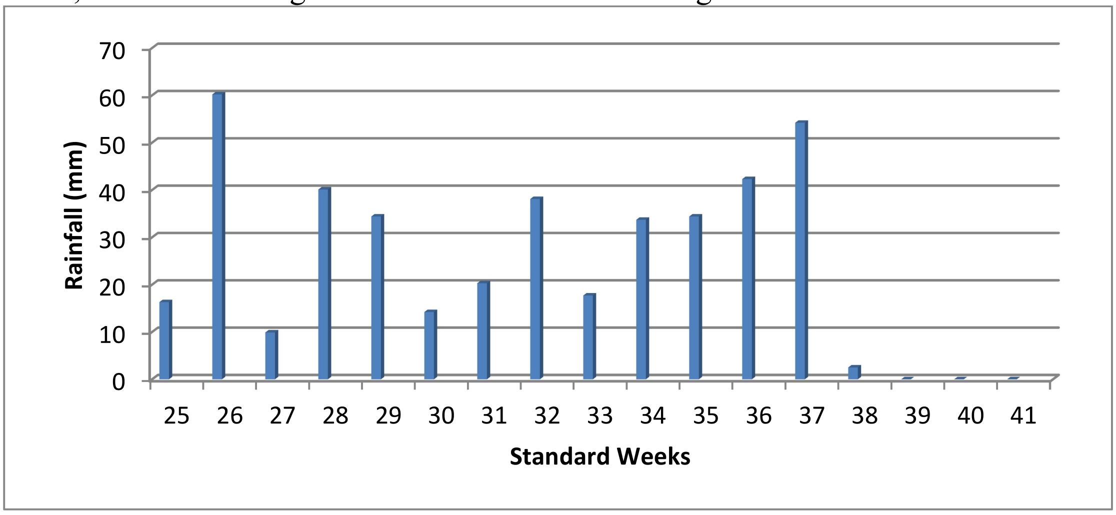


Figure 1 Weekly Rainfall distributions at experimental site

Effect on soil moisture content.

The effect of *In-Situ* MCM and varieties on soil moisture content at different soil depth in 15cm and 30cm had taken. The data in (Table 1) revealed that moisture conservation methods significantly influenced the soil moisture content in both soil layers at all the observation stages except at 15cm at 60 DAS. Among the moisture conservation methods, tied ridge was effective in checking runoff losses and increasing infiltration of water which resulted in significantly highest soil moisture content in both the layers of the soil at all the stages of the observation. Flat-bed method was inferior to ridge and furrow method at 15 cm soil layer during sowing and at 30cm soil layer at harvesting. However, at 40 DAS flat-bed method and ridge and furrow method were inferior in moisture conservation. Hulugalle *et al*., (1990) have also revealed and supported this finding that tied ridge was effective in reducing runoff and increased soil water storage, which ultimately increased the yield of the crop.

Varieties did not significantly influence the moisture conservation in two soil layers at all stages of observation except in 30 cm layer at 80 DAS and at harvest or 100DAS. The significantly higher soil moisture content at 30 cm soil layer in the early local grown at 80 DAS may be attributed to density of its lesser roots in the 30cm soil layers which could utilize less moisture from the deeper layer as compared to the hybrid variety. Similar observations were made by Wiyo *et al*., (2000).

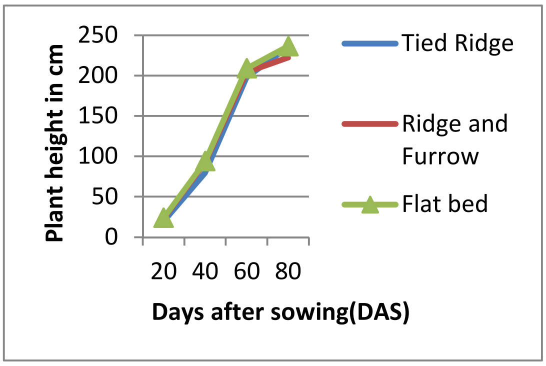
Table (1) Effect of treatments on periodic soil moisture content (%) at different soil depth

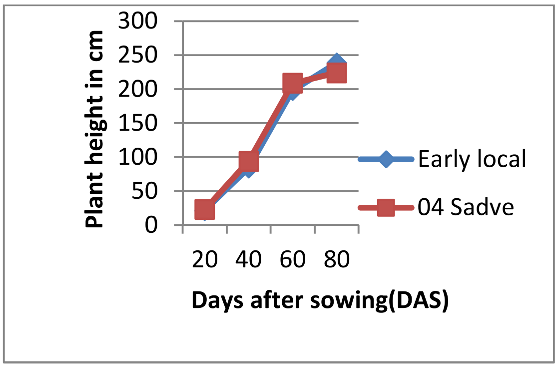
Treatments	Moisture %							
	At sowing		40 DAS		80 DAS		100 DAS	
	Depth(cm)							
	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm
(MCM)								
Tied Ridge	10.4a	9.33a	11. 13a	13.62a	12.26a	12.03a	5.52a	5.48a
Ridge and Furrow	8.78b	6.38b	9.01c	9.12b	9.54a	9.45b	4.01b	5.42b
Flat bed	7.58c	6.91b	10.74ab	10.67b	11.42a	9.17b	4.38b	4.71c
CV%	4.4	11	2.5	9.5	4	6.4c	8.8	0.1
LSD(0.05)	0.9	1.89	0.59	2.39	NS	1.49	0.93	0.013
Varieties								
Early local	8.88a	7.33a	10.08a	11.48a	11a	10.79a	4.78a	4.79b
04Sadve	8.99a	7.75a	10.5a	10.78a	11.14a	9.64b	4.49a	5.61a
CV%	8.3	16.6	7.5	13.7	6	3.9	16.5	0.2
LSD(0.05)	NS	NS	NS	NS	NS	0.46	NS	0.01

Effect on Growth

Plant height (cm)

The data in (Figure 1) on effect of different treatment on progressive plant height indicate that plant height increased up to 60 DAS and thereafter it was increased at decreasing rate. No significant difference among different MCM was observed in influencing the plant height up to 60 DAS. However after 60DAS numerically higher plant height was obtained in tied ridge and flat bed methods. Similarly the difference in plant height of early local and hybrid variety was not significant at all the stages of observation. However, at 60 DAS plant height of early local variety was comparatively higher than the 04sadve hybrid variety.





(a) Effect of moisture conservation methods (b) Effect of Varieties

Figure 2: Effect of moisture conservation methods (MCM) and Varieties on progressive plant height(cm)

Dry matter production (g/plant):

The data on main effect of soil moisture conservation method and varieties on dry matter production per plant have has been presented in (Figure 2). The perusal of the figure indicated that at dry matter accumulation per plant increased at increasing rate from knee high stage to tasseling stage there after it increased at decreasing rate up to the maturity of the crop. Furthermore the data in the figure 2 (a) indicated that MCM did not significantly influence dry matter accumulation up to tasseling stages of the crop. However at maturity differences were significant. Among the entire MCM tied ridge resulted in significantly higher dry matter production per plant followed in ridge and furrow method due to more rain water conservation. Similarly the data in Figure 2(b) indicated that difference in dry matter production per plant due to varieties increased with the advancement of stages of the crop. At maturity dry matter production per plant was significantly higher in 04sadve variety than early local variety. Similar to this study dry matter production in crop plants is directly related to the utilization of solar radiation, which is influenced by canopy structure (Daughtry *et al.,* 1983).

(a)Effect of moisture conservation methods (b) Effect of Varieties

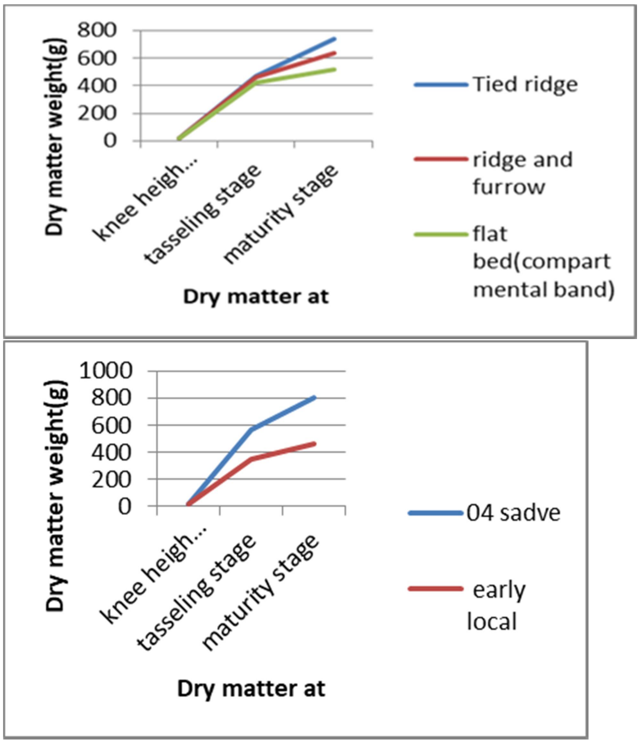


Figure 3: Effect of moisture conservation methods (MCM) and Varieties on dry matter of maize

The interaction effect of Moisture conservation methods and varieties was significant on dry matter accumulation per plant at maturity stage of the crop (Table 2). Combination of tied ridge or ridge and furrow method and 04sadve being statistically at par resulted in significantly higher dry matter production per plant due to higher soil moisture conservation and its efficient utilization as compared to early local variety. Among all the combination of MCM and variety, tied ridge and 04sadve variety being statistically at par with resulted in significantly higher production per plant as comparing to their combinations with early local variety. These findings are inconformity with those of Wiyo *et al*., (2000) who reported that tied ridge decreased surface runoff from the field and increased retention of rain water with in the soil.

Table (2) Interaction effect of MCM and Varieties on dry matter at maturity (g)

	Varieties	
MCM	Early local	04Sadve
Tied Ridge	503c	976a
Ridge and Furrow	383c	885ab
Flat bed	506c	535c
	LSD(0.05)	CV%
Comparison between two Varieties means at same level of MCM means	226.2	19.7

Effect on development

Days taken to tasseling

Numbers of days taken from sowing to tasseling were significantly influenced by different treatments (Figure 4(a). Among the MCM, tied ridge method is significantly the highest number of days to tasseling as comparing the other treatments. It is attributed because of higher moisture conservation roots more number of days for completion of vegetative phase and thus significantly highest number of days for tasseling (46.6 days).

Varieties were significantly influencing days taken for tasseling of 04sadve variety as comparing to early local (Figure 4(b)). The highest number of days taken to tasseling may be because of its higher density of roots in the deeper layer which could utilize high moisture from the deeper layer. Similar to this study in maize hybrid varieties, tasseling was found to be delayed by one day for each additional plant per m^2 (Long *et al*., 1956).

Days taken for maturity.

Number of days taken sowing to maturity was significantly influenced by all the treatments (Figure 2(a)). Among the MCM, tied ridge resulted in significantly highest days taken to maturity. Within the tied ridge MCM the higher days taken to maturity, as comparing to the other treatments was attributed due to moisture available at 100 DAS was significant higher in tied ridge followed by flat bed. However, ridge and furrow was the lowest in both stages of the developments. Hulugalle and Wiyo., (1990) have revealed that tied ridge is effective in reducing runoff and increase soil water storage, which ultimately increased days to maturity.

The data presented in (Figure 4(b)) indicated that varieties were significantly influence the days taken to maturity. Significantly highest number of days taken to maturity by 04sadve variety could be attributed due to higher density of roots in the deeper layer which could utilize high moisture from the deeper layer where as early local variety was less moisture utilization from the deeper as compared to hybrid. The study on the maize hybrids show that effect of reduced number of pollen grains on the number of grain occur when pollen quantity reduced to 80% or more or when anthesis-silking interval reached to 8 days or more (Bassetti and Westgate, 1994).

(a) Effect of moisture conservation methods (b) Effect of varieties on maize

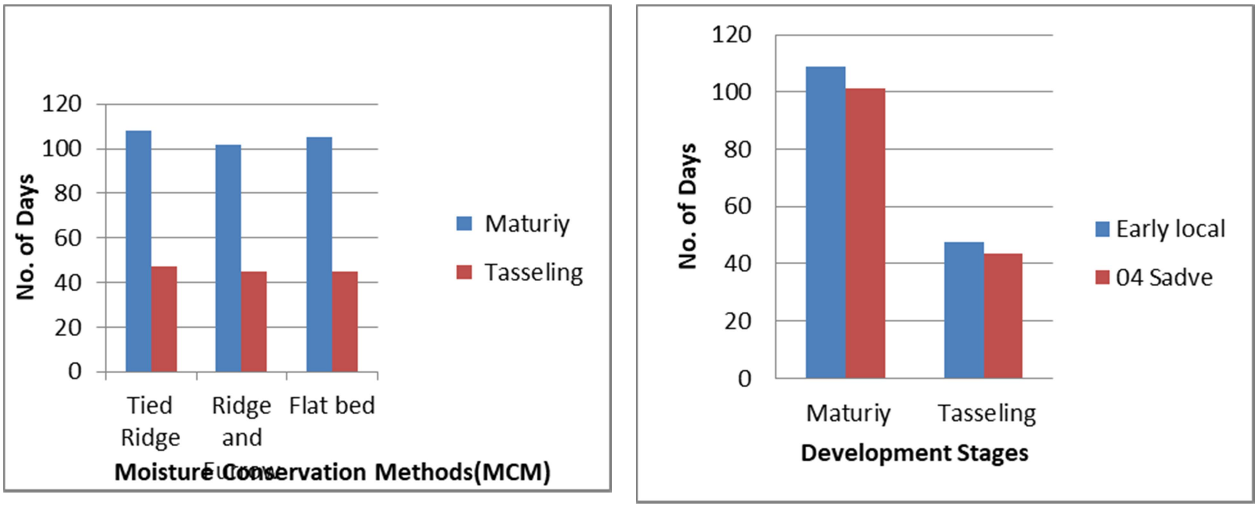


Figure 4: Effect of moisture conservation methods and Varieties on developmental stages of maize

Effect on yield and yield attributes

Number of cobs per plant

The data on the effect of different treatments on number of cobs per plant presented in (Table 3) indicated that moisture conservation methods was significantly influenced, however varieties did not significantly influence the number of cobs per plant, but numerically highest number of cobs per plant (1.48) was obtained with 04sadve. Among all MCM, flat bed method resulted in significantly highest cob number per plant followed by tied ridge method.

Cob length.

The data presented in (Table 3) indicated that MCM did not significantly influence the cob length but numerically tied ridge methods produced longest cob due to more retention and infiltration of rain water. Varieties significantly influenced the cob length. 04Sadve variety was significantly superior to produce the longest cobs over early local variety that may be attributed to its deep root system and vigorous vegetative growth because of which it could extract more moisture from the deeper layers of the soil. Esechie (1992) also obtained maximum and minimum cob length from the hybrid variety Azam and local variety Pahari, respectively.

Number of rows per cob

The data in Table 3 indicated that MCM and varieties significantly influenced the number of rows per cob. Among the MCM tied ridge and flat-bed methods being statistically equal produced significantly higher number rows per cob because of higher moisture contents conserved by the two methods (Table 1) which produced better growth and development of the crop. These results are partly in agreement with those of Maqsood *et al.,* (2001) who reported that rows per cob were increased at certain levels of moisture due to increase in cob size. Similar to this finding Obi (1999) reported the superiority of hybrid maize over composite cultivars in increasing number of rows per cob due to its uniformity in flowering and disease resistance and genetic potential.

Grain yield (kg ha^{-1})

The grain yield was not significantly influenced by the MCM due to uniform distribution of rainfall (Figure 1) and the moisture conserved by MCM at almost all the critical stages (Table 3). However, ridge and furrow method produced numerically highest grain yield (3316kg/ha). In agreement to this Asefaw *et al.,* (1998); revealed that furrow with closed tied ridge, as in situ soil and water conservation technique is to be beneficial for increasing crop yield. Varieties were significantly influenced the grain yield. 04sadve variety produced significantly highest grain yield over early local variety because of its genetic potential which helped it to utilize available moisture, nutrient and light more efficiently and thus produced significantly higher number of grain rows per cob and numerically higher cob length (Table 3).

3.5.5 Interaction effect of MCM and varieties on grain yield kg/ha

MCM and varieties interacted significantly to influence the grain yield of maize (Table 4). The data presented in Table 4 indicated that among all the combinations of MCM and varieties, 04sadve variety in combination with ridge and furrow method resulted in significantly highest grain yield due to higher moisture conservation (Table 1) and efficient utilization of conserved moisture by the hybrid variety in the study.

Table (3) Effect of different treatments on yield and yield attributes of maize

Treatments	No. of cobs per plants	Cob length(cm)	No. of rows per cob	Grain yield (kg ha^{-1})
		MCM		
Tied Ridge	1.55ab	14.81a	12.63a	3072a
Ridge and Furrow	1.15c	14a	10.58b	3316a
Flat bed	1.57a	14.31a	11.38b	2833a
CV%	6.5	1.16	4.4	7.4
LSD(0.05)	0.21	NS	1.14	NS
		Varieties		
Early local	1.37a	13.44b	10.42b	2742b
04Sadve	1.48a	15.47a	12.64a	3404a
CV%	12.9	11.3	15.4	16.5
LSD(0.05)	NS	1.88	2.05	586

Table (4) Interaction effect of MCM and Varieties on Grain yield kg/ha of maize

	Varieties	
MCM	Early local	04Sadve
Tied Ridge	3046b	3098b
Ridge and Furrow	2122c	4509a
Flat bed	3059b	2606bc
	LSD(0.05)	CV%
Comparison between two Varieties means at same level of MCM means	778.2	16.5

Interaction effect of MCM and varieties on number of cobs per plant

MCM and varieties interacted significantly to influence the number of cobs per plant (Table 5). The data presented indicated that among all the combinations of MCM and varieties, tied ridge and 04sadve hybrid variety combination being statically at par with combination of flat-bed and early local variety resulted in significantly higher number of cob per plant due to higher moisture conservation by these methods (Table 1) and efficient utilization of conserved moisture by both the varieties.

Table (5) Interaction effect of MCM and Varieties No of cobs per plant

MCM	Varieties: Early local	Varieties: 04Sadve
Tied Ridge	1.30cd	1.80a
Ridge and Furrow	1.1d	1.20
Flat bed	1.70ab	1.43bc
	LSD(0.05)	CV%

Interaction effect of MCM and Varieties on number of kernel per cob

Interaction effect of MCM and Varieties significantly influence the number of kernel per cob. The data presented in Table 6 indicated that among all the combinations of MCM and varieties, tied ridge and 04sadve hybrid variety resulted in significantly highest number of kernels per cob. However, 04sadve variety due to its higher moisture extraction ability from the deeper soil layer was numerically superior to early local variety in each of the MCM to increase the number kernel per cob. The main reason could be the tied ridge have high moisture conservation ability and 04sadve is also hybrid variety had high moisture utilize for better growth (Table 3) to produce more number of cobs per plant. These results are partly in agreement with those of Maqsood *et al*., (2001) who reported that number of kernels per cob was increased at certain levels of moisture.

Table (6) Interaction effect of MCM and Varieties on No. of kernels per cob

MCM	Varieties: Early local	Varieties: 04Sadve
Tied Ridge	302e	502a
Ridge and Furrow	358d	387b
Flat bed	293f	378c
LSD(0.05)	CV%	
Comparison between two Varieties means at same level of MCM means	01.1	6

Conclusion and Recommendation:

The study demonstrated that tied ridge method of moisture conservation resulted significantly the highest rain water conservation as compared to ridge and furrow and flat bed methods which. Variety 04sadve Hybrid was found to be superior to the early local variety in producing in significantly higher dry matter per plant, taking more number of days to tasseling and maturity, higher yield attributes such as cob number per plant cob length and grain yield. Among all the combinations 04sadve hybrid variety in ridge and furrow method of moisture conservation produced significantly highest grain yield (4509kg ha^{-1}). It is, therefore, recommended that 04Sadve hybrid variety in ridge and furrow method in tied ridge moisture conservation methods may be introduced and demonstrated in semiarid conditions of Hamelmalo.

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