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Nitrogen Fertilization and Moisture Conservation Practices on Maize (*Zea mays L.*) Grown Under Dryland Conditions of Ethiopia

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ABSTRACT

A Field experiment was conducted during the rainy season of 2003 to study the effect of nitrogen levels and moisture conservation practices on soil, water, yield and yield components of maize (*Zea mays* L.) in the rift valley of central Ethiopia.

Grain yield was influenced by nitrogen fertilizer levels but 1000 grains weight, total biomass, straw yield, soil temperature, soil moisture content, and infiltration rate were not affected by nitrogen levels. Signifcant effects of harvest index and water use efficiency by nitrogen levels were observed only at Dera and Melkassa respectively.

Moisture conservation practices gave more improvement in grain and straw yields, harvest index, and total biomass over flat bed due to availability of moisture than separate application. Bulk density, infiltration rate, water use efficiency, and soil moisture content were also affected by moisture conservation practices. The effect of mulch to reduce the soil temperature was observed prior to maize maturity.

Key words: yield components, soil conservation, water use efficiency, maize

INTRODUCTION

In situ moisture conservation practices not only reduce the run-off, soil and nutrient losses but also improve soil physical properties, nutrient status and moisture content, thereby improving the crop yields. Besides, dryland soils are not only thirsty but also hungry. Maize (*Zea mays L.*) is one of the most important cereal crops grown in Ethiopia. It is grown from moisture stress areas to high rainfall areas and from low lands to high lands (Kebede *et al.*, 1993). The drought stressed maize growing areas occupy about 40% of total maize growing area, but contribute less than 20% of the total cultivated maize area.

Rainfall in the semiarid areas of Ethiopia is relatively low, often poorly distributed and highly variable (NMSA, 1988). High evapotranspiration exists owing to high temperature, which is normally over 25 °C during the rainy season with occasional strong winds. Monthly potential evapotranspiration usually exceeds rainfall in most parts of semi-arid area except during July and August. Because of low precipitation and high temperature, these areas are characterized by shortage of water, thereby reducing the period of available water for crop

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growth (Daniel, 1977).

The crop sowed at optimum planting date experiences acute shortage of moisture for germination of seeds. As a result, germination is greatly affected and thus, the productivity of maize is very low. Ahmed and Srivasta (1980) reported that adequate soil moisture conserved by mulch in conjunction with nitrogen increased the crop yield significantly over the control at the same level of nitrogen. Low fertility of the soils and the prevalent inability of the farmers to apply chemical fertilizers aggravate the problem. Supplementing the nurtrient, especially nitrogen, through inorganic sources not only supplies the required nutrients for crop growth.

The efficiency of soil –moisture use could possibly be increased if the evapo-transpirational losses can be decreased. Various mulching techniques have been reported to be effective in conserving soil moisture (Waggoner *et al.*, 1960).

Surface mulching with crop residues has proved effective in conserving soil moisture, decreasing soil temperature and maintaining favorable soil structure through the enhancement of biological activity (Lal, 1979). Mulching also increases soil organic matter by improving soil physical conditions as well as nutrient and moisture retention capacity. Managing soil and plant to conserve water and utilize it efficiently through adequate nutrition will certainly lead to better water use efficiency. Tied ridges have been found to be efficient in moisture conservation and have led to considerable increase in crop yields in semi-arid areas of Ethiopia (Kidane and Rezene, 1989).

It is well recognized that the application of chemical fertilizers or organic manures increases the productivity of dry land crops. It is generally agreed that the response of maize nutrients application for rainfed crops is not assured and their application may not be profitable unless proper soil and water conservation practices are adopted. Lack of adequate soil and water conservation measures is, therefore, considered to be a major constraint for stabilizing the yield of rainfed crops.

However, there is limited information on the effect of soil and moisture-conservation practices with added nutrients through inorganic sources on maize during rainy season of central rift valley. The investigation was conducted to explore the efficiency of nitrogen use and ridge and furrow mulching on the growth and yield of maize (*Zea mays* L.) grown under dryland conditions.

MATERIALS AND METHODS

Study site and agronomic practices

Investigations were conducted during the rainy season of 2003 at Dera sub-Center and Melkassa Agricultural Research Center in a split plot design with three replications. Dera and Melkassa Research Center, lying at an altitude of 1500 m, are located at latitude 39° 12’ N and longitude 8° 24’E in the central zone of Ethiopia.

The soil types at Dera and Melkassa are diverse, most of them are shallow and the organic matter content is quite low (between 0 and 2% in most areas), resulting in poor water–holding capacity. The soils are generally browns, grayish brown or light brown. The textures of the soil are either clay loam, loam or sandy loam.

In the experiment conducted, four nitrogen levels [0, 10, 20 and 30 kg N/ha] were assigned to main plots and four-moisture conservation practices [flat bed, ridge and furrow, flat bed plus mulching and ridge and furrow plus mulching] were also assigned to sub plots. Melkassa-1 maize double top-cross early duration was hand- planted on 8 July 2003 and 29 June 2003 at Dera and Melkassa, respectively, 75 cm between rows and 25 cm between hills of one plant. Maize crop was sown in line at the rate of 30 kg/ha at planting and thinned to one plant per hill. The total plot size was 4.5 × 4.0 m. The crop emerged on and 15/7/2003 and 6/7/2003 at Dera and Melkassa respectively.

The crop received 20 kg/ha N and 25 kg of

P_2O_5 in the form of urea and triple super phosphate. Half of the N and the full dose of P were applied at the time of planting and the rest of N was top-dressed 30 days after sowing.

Pre-emergence herbicide Primagram Gold 660 SC at 3.0 litre/ha was given within 3 day after maize planting, before weeds began to emerge. Post -emergence herbicide 2, 4-D at 1.0 litre a.i./ha was also applied three weeks after maize emergence. Hand-operated knapsack sprayer was used for herbicide application.

Straw mulch of wheat at the rate of 3 t/ha per treatment was applied uniformly on the soil surface after five weeks of growth. The mulching materials were spreaded uniformly on the soil surface after 5 weeks of growth. Maize was harvested on 17 November 2003 at Melkassa and 28 November 2003 at Dera, respectively.

Small amount of precipitation occurred between March to April and high rainfall occurred between June to September. The minimum temperatures ranged from 9.5 °C to 15.8 °C while maximum temperatures from 26.9 °C to 29.8 °c. Rainfall distribution was unimodal reaching peaks in May and September. The rainfall pattern during the crop growth period was different from previous years. The total amount of rainfall received was 813.8 mm and 885.7 mm at Dera and Melkassa, respectively, which were higher by 39.13 and 21.14 % from the last 11 years average. Soil temperature during the period of maize growing under mulch and no mulch treatments was measured daily at 14.00 hrs (maximum) with metallic probe digital thermometers installed at 5-cm depth. The soil moisture content was determined gravimetrically at 0-5 cm depth at 30, 50, 75 and 90 days after planting.

Composite soil samples (at 0-30 cm and 30-60 cm depths) were randomly collected from each plot before planting and also after crop harvest. Samples were air- dried and passed through a 2-mm sieve before analysis. Total N was determined using the semi-micro Kjeldahl digestion method (Bremner and Mulvancy, 1982). Available P was determined using the Bray II method (Murphy and Riley, 1962). Organic matter content was determined using the Walkley-Black dichromate method (Nelson and Sommers, 1982). Soil pH measurement was made with a 1:1.25 soil:water ratio with a 15 minutes standing time.

Soil physical measurements were made within the row and inter rows. Soil water infiltration rates were measured using the double ring infiltrometer as described by Landon (1991). Soil dry bulk density measurements were made using metal cylinders 25mm height and 52mm internal width. Samples were taken from each sampling point. Plant height was determined by measuring the extended leaf height of ten plants randomly selected from each plot at harvest. Dry weights of two plants per plot were measured at 30, 50, 75 and 90 days after maize emergence. Grain and straw (shoot only) yield, and 1,000 seed weight were also obtained on an oven dry basis on a dry weight base $60^O{}_C$. Harvest index was calculated as the ratio of the dry grain yield to the total dry matter yield (grain plus straw). Water use was then calculated as the ratio of grain yield to the growing season precipitation.

Data analysis

The data were analyzed using the Statistical Analysis System (SAS Inc., 1985). The analysis of variance was determined using the General Linear Model (GLM). The mean separation among treatments was obtained by using the Least Significant Difference (LSD) test where F-tests were siginificant.

RESULTS AND DISCUSSION

Grain yield and 1000 grain weight

Grain yield of maize were significantly different among the four treatments receiving N fertilizer. All treatments receiving nitrogen fertilizer produced significantly more grain yields than the control at both locations. There were no significant differences in yield of maize between flat bed with mulch and ridge planting with mulch treatments at Dera and ridging without mulch and flat bed with mulch treatments at Melkassa. At both sites, the highest average yields of maize were obtained from ridge and furrow + straw mulch treatment. The increase in the yield was owing to an increase in the harvest index and 1000 grain weight and total biomass (Table 1 and 2). The results confirmed the findings of Patel and Upadhyay(1993) and Singh and Brar (1994) which found that mulching significantly increased the grain yield of maize. These findings also corraborated by the results reported by Saraf *et al*. (1976) and De and Giri (1978). Patil *et al.* (1976) also showed the beneficial effects of ridge with mulch on crop yields in rainfed areas.

According to the results, it could be conclusively mentioned that combined application of ridge and furrow plus straw mulching resulted in higher grain yield of maize than application of only one of them. Yield response of maize to combined application of ridge and furrow plus straw mulching were 63.0 and 50.3% over the control at Dera and Melkassa, respectively. This could be ascribed to the fact that the combined application of ridge and furrow plus straw mulching offered a more effective control of evaporation losses of water over a wide range of weather fluctuations. Bhan (1976) also observed the marked improvement in the yield of rain-fed maize due to straw mulch attributed to better root development and soil moisture extraction. These findings also corraborated by the results reported by Saraf *et al*. (1976) and De and Giri (1978).

There was no significant difference between 1000 grain weight among nitrogen levels at both sites. However, the highest 17.4 and 24.3 gms, 1000 seed weight were recorded from 20 and 30 kg

Table 1 Grain yields (kg/ha) and 1000 grain weights (gm) as influenced by nitrogen levels and moisture conservation practices.

Treatment	Grain yield (kg/ha)		1000 grain weight (g)	
	L_1	L_2	L_1	L_2
N level (kg/ha)				
0	3117b	3483c	16.6	23
10	3375a	4370b	16.7	23
20	3177ab	5064a	17.4	23.7
30	3150ab	4218b	16.9	24.3
LSD (0.05%)	2.68	5.99	2.56	1.92
In situ moisture -conservation practices				
FB	2295c	3443c	14.7b	21.6b
R and F	3243b	4293b	17.5a	24.6a
FB+ SM	3593a	4223b	17.4a	22.6b
R and F + SM	3741a	5174a	18.1a	25.3a
LSD (0.05%)	2.40	5.21	1.24	1.75
CV%	8.90	14.43	8.71	8.43

* Numbers within columns under each major heading followed by common letters are not significantly different at the 5% level of probability according to Duncan's Multiple Range test. NS = non-significant. FB = flat bed, R and F = ridge and furrow, SM = straw mulch, L_1= Dera and L_2= Melkassa

N /ha at Dera and Melkassa, respectively. Ridge and furrow plus straw mulching gave the highest grain weight as compared with other treatments. The increases of grain weight of ridge and furrow plus straw mulching over flat bed due to grain weight were 22.8 and 17.0% at Dera and Melkassa, respectively. Simpson and Gumbs (1986b) reported that mulched plots gave higher seed weight than un mulched plots in maize.

The increased productivity of grain yield and 1000 grain weight in ridge and furrow with and without mulch resulted from the favorable effects of moisture conservation on growth and yield attributes. Mulching of furrow prolonged the period of water availability which consquentently supported better development of crop at later stages resulting in higher yields.

Growth and development characteristics

The applications of N fertilizer did not cause any significant change in harvest index, total biomass, and straw yield of maize in this study except at Dera on straw yield. (Table 2). However, the highest average total biomass was obtained from 30 kg N/ha. The application of ridge and furrow plus straw mulching significantly produced more total biomass and higher percentage of harvest index than flat bed treatment. Giri and Singh (1985) reported the reduction in fluctuation in soil temperature and increased biomass production.

The average increases in biomass were 40 and 19 % at Dera and Melkassa, respectively. The increase might be attributed to greater availability of moisture under straw mulch (Table 2). The reduction in transpiration and the availability of moisture were responsible for the increase in total biomass (Table 2).

Straw yield was not significantly affected by nitrogen levels. However, straw yield increased with N levels at both sites. The highest, 5.3 and 6.7

Table 2 Total biomass (t/ha), Harvest index (%) and Straw yield (t/ha) as influenced by nitrogen levels and moisture conservation practices.

Treatment	Total biomass (t/ha)		Harvest index (%)		Straw yield (t/ha)	
	L_1	L_2	L_1	L_2	L_1	L_2
N level (kg/ha)						
0	8	8.53	38ab	48	4.88	6.44
10	8.26	8.55	41a	46	5.26	6.74
20	8.01	8.58	39ab	56	4.87	5.59
30	8.6	8.73	37b	49	5.14	6.14
LSD (0.05%)	0.94	2.04	0.04	18.0	0.45	2.56
In situ moisture- conservation practices						
FB	6.64c	7.87	34b	41b	4.01c	5.53
R and F	8.09b	8.48	39a	52ab	4.91b	5.72
FB + SM	8.76ab	8.64	40a	52ab	5.27ab	6.46
R and F + SM	9.37a	9.40	42a	54a	5.63a	7.22
LSD (0.05%)	0.66	1.44	0.04	9.51	0.34	1.89
CV%	11.01	19.42	9.78	22.69	10.13	40

Numbers within columns under each major heading followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range test. NS = non-significant. FB = flat Bed, R and F = ridge, and furrows, SM = straw mulch, L_1= Dera and L_2= Melkassa t/ha, straw yields were recorded from 10 kg N/ha at Dera and Melkassa respectively (Table 2). Although the mean straw yield data obtained from different moisture conservation practices at Melkassa were not significantly different, the ridge and furrow plus mulching treatment produced about 30.5 % increase in straw yield at Melkassa.

Harvest index was non-significantly different among nitrogen levels at Melkassa. There was no significant difference in harvest index between N_0 and N_{20} kg/ha at Dera, though harvest index at N_{30} was found highest at Dera. The highest harvest index was obtained from ridge and furrow plus mulching at both sites. The increases in harvest index of the ridge and furrow plus straw mulching over flat bed were 23.5 and 31.7% at Dera and Melkassa, respectively. Adequate availability of water to plants caused by ridge and furrow plus mulching results in cell turgidity and eventual higher meristmatic activity of maize, led to more foliage development, higher photosynthetic rate and consequently better plant growth (Arnon, 1975).

Water use efficiency

Water use efficiency was significantly affected by N level only at Melakssa. At Melkassa, it increased with N application up to 20 N/ha following the pattern of increasing in crop yield at the site. Effect of N application on the water-use efficiency was also observed by Havanagi (1965). Among the different in situ moisture conservation practices, ridge and furrow without straw mulching increased the water use efficiency by 30% followed by ridging and furrow plus straw mulching which increased water use efficiency up to 22.6% at Melkassa. At Dera, ridge and furrow plus straw mulching increased the water use by 67.9% (Table 3). Therefore, the significant increase in water use efficiency was undoubtedly associated with an increase in moisture conservation under mulched condition, especially during the critical growth

Table 3 Effects of Nitrogen fertilization and moisture conservation practice on water use efficiency (Kg/ha^{-1} cm^{-1}).

Treatment	L_1	L_2
N level kg/ha		
0	38.3	41.9b
10	44.1	48.4b
20	38.7	56.9a
30	38.7	47.6a
LSD (0.05%)	0.39	0.76
In situ moisture- conservation practices		
FB	27.4c	41.2b
R and F	39.8b	53.6a
FB + SM	43.5a	49.5a
R and F + SM	46.0a	50.5a
LSD (0.05%)	0.29	0.73
CV%	8.80	17.71

* Numbers within columns under each major heading followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range test. NS = non-significant. FB = flat bed, R and F = ridge and furrow, SM = straw mulch, L_1= Dera and L_2= Melkassa

period of maize.

Water utilization coefficient of the ridge and furrow plus mulching increased by 22.6% to 67.9% over the control, which meant that more water was consumed by the plant in order to produce grain rather than merely lost in evaporation and transpirition stream under normal up land condition. The total water use by the crop was asssociated with moisture availability in the root zone. The results confirmed the findings of Pandey *et al.*(1988), Kaushik and Gautam (1991). Bhagat and Acharya (1987) also observed high water use in plant in terms of water extraction rate where mulch was applied. Gupta (1980) reported that soil mulch resulted in improvement of moisture retention capacity of the soil and decrease in soil temperature and hence less evaporation losses.

Soil temperature and moisture content

Soil temperatures were measured daily in each plot at the 5 cm depth at 14.00 hrs. The soil temperatures of plot with different nitrogen fertilizer levels were non-significant different during the three months while that of in situ moisture - conservation practices were significant different only at Dera during the above months (Table 4). Mulch application did not reduce soil temperature during the growing season because of enough soil moisture in the soil. But during maize maturity, in the month of October, mulched plots reduced soil temperature from 2-3 °C. Walker (1969) pointed out that even 1 °C difference in soil temperture could have significant effect on plant growth. Mahey *et al.* (1986) reported that mulch change the microclimate of crop-soil relation by conserving moisture and modifying soil temperature.

Soil moisture content was not significant affected by nitrogen fertilizer levels at different growth stages at both sites. But soil moisture values differed significantly as a result of mulch management although significant differences were obtained in all sampling dates except at 90 days after emergence at Melkassa. Ridge and furrow with mulching treatments gave higher soil moisture content than those without mulching at 0-5 cm depth throughout the growing period (Table 4). The result demonstrated that mulching maintained the soil moisture at the 0-5 cm depth in the available range of available moisture for plant growth during almost the entire growing period at both locations. Results of soil moisture measurement in this study revealed that plants were in a position to utilize soil moisture mulch better in the mulched plots whereas the soil moisture could be lost through evaporation from the cracking soil surface if not being mulched. When the rainfall is relatively low in the the cropping season, mulch is mostly benefical, as it slows down evaporation of surface and conserves the soil moisture for plant growth. However, under high rainfall conditions in the long rainfall period the siutation is reversed.

Bulk density and infiltration rate

Effects of N fertilizer level on bulk density were significant at planting and at harvesting in case of Dera and Melkassa, respectively. There was, however a significant difference between the bulk density taken at the beginning and at the end of each study for moisture conservation practices at Melkassa site. Statistically, there were no significant differences among moisture conservation practices at Melkassa except the flat bed at planting which gave lower bulk density than the other treatments. At harvest, ridge and furrow with and without mulch were not statistically different at Melkassa site. Soil compaction is often a problem when heavy equipment is used for row crop production. At Dera bulk density recorded at the time of planting and at harvest was higher than Melkassa site.

Nitrogen levels and in situ moisture conservation practices during the growing season had no significant effect on infiltration rates. The highest infiltaration rate (4.67 and 3.57 cm/hr) was recorded from ridge and furrow + straw mulch

Table 4 Soil temperature and soil moisture as influenced by nitrogen levels and moisture conservation practices on soil temperature and soil moisture content.

Treatment	Temperature (°c)						Moisture (%)							
	August		September		October		30 DAE		50 DAE		75 DAE		90 DAE	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2	L_1	Melkassa
N level (kg/ha)														
0	25.7	26.1	26.6	27.9	29.8	28.7	24.5	31.7	18.3	28.9	19.6	26.7	18.7	25.7
10	26.0	26.2	26.7	27.9	29.1	29.0	26.5	30.0	19.5	28.7	19.7	24.3	18.9	24.2
20	25.7	26.4	26.6	27.4	29.8	29.4	26.3	31.6	18.7	29.2	19.4	26	19.2	23.8
30	25.9	26.2	26.5	27.5	29.5	29.1	26.1	30.6	18.6	28.9	18.6	25.3	17.3	28.2
LSD (0.05)	0.37	0.37	0.06	0.54	0.93	0.73	3.16	2.70	1.44	2.50	2.32	2.90	3.48	7.50
In situ moisture conservation practices														
FB	26.3a	26.3	27.5a	28.3	31.1a	30.3	25.2b	27.2b	15.5b	25.2b	17.30b	21.6b	13.3d	23.2
R and F	25.7b	26.2	26.7b	27.3	30.1ab	30.3	26.1a	31.9a	19.3a	29.8a	19.60a	27.3a	17.6c	25.4
FB + SM	25.7b	26.3	26.3c	28.1	29.0ab	28.1	25.3ab	31.6a	20.0a	29.4a	19.32a	26a	20.5b	25.3
R and F + SM	25.5b	26.2	25.9c	27.1	28.1b	27.5	27.2a	33.2a	20.3a	31.4a	20.99a	27.3a	22.6a	28
LSD (0.05)	0.49	0.17	0.28	0.54	0.57	0.54	1.67	1.70	1.72	2.14	2.05	2.21	1.99	4.93
CV%	2.26	0.78	1.83	2.31	7.12	5.67	7.65	6.51	10.89	8.77	12.62	10.28	12.79	22.95

* Numbers within columns under each major heading followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range test. NS= non-significant. FB = flat bed, R and F = ridges and furrows, SM = straw mulch, L_1= Dera and L_2= Melkassa

Table 5 Bulk density (mg/cm^3) and infiltration rate (cm/hr) as affected by nitrogen fertilizer and moisture conservation practices in maize.

Treatment	Bulk density (mg/cm^3)				Infiltration rate (cm/hr)	
	At planting		At harvest			
	L_1	L_2	L_1	L_2	L_1	L_2
N level (kg/ha)						
0	1.35a	1.22	1.59	1.49b	3.20	3.24
10	1.29ab	1.22	1.54	1.49b	3.12	3.38
20	1.28b	1.26	1.52	1.49b	3.93	3.78
30	1.31ab	1.25	1.57	1.54a	3.85	3.17
LSD (0.05%)	0.08	0.06	0.18	0.05	1.99	2.55
In situ moisture–conservation practices						
FB	1.30	1.17c	1.51	1.48b	2.77	2.67
R and F	1.31	1.29a	1.58	1.50ab	3.02	2.99
Fb + SM	1.30	1.24a	1.59	1.50ab	3.64	3.35
R and F + SM	1.33	1.28a	1.54	1.52a	4.67	3.57
LSD (0.05%)	0.05	0.05	0.08	0.04	0.88	1.33
CV%	4.87	5.15	5.15	3.11	34.55	29.60

* Numbers with in columns under each major heading followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range test. NS= non-significant. FB = flat bed, R and F = ridge and furrow, SM = straw mulch, L_1= Dera and L_2 = Melkassa.

treatment at Dera and Melkassa followed by flat bed + straw mulch that gave 3.64 and 3.35 cm/hr at respective sites. The increases of ridge and furrow + straw mulch over flat bed were 68.5 and 33.7% at Dera and Melkassa, respectively. Polthanee (1989) reported that ridge treatments gave higher initial water infiltration rate into the soil as well as soil matrix tension than those of the flat soil planting treatments.

CONCLUSION

Grain yield was influenced by nitrogen fertilizer levels but 1000 grains weight, total biomass, straw yield, soil temperature, soil moisture content, and infiltration rate were not affected by nitrogen levels. Havest index and water use efficiency were significantly different among nitrogen levels only at Dera and at Melakssa. Bulk density was also significantly affected by N fertilizer level at planting and at harvesting at Dera and Melkassa, respectively.

Combined application of ridge and furrow plus straw mulching gave more improvement in grain and straw yields, harvest index, and total biomass over flat bed due to availability of moisture than separate application. It increased the grain yield by 63.0 and 50.3% over those of flat bed at Dera and Melkassa, respectively.

Moisture conservation practices also increased bulk density, infiltration rate, and soil moisture than flat bed treatment. Water use efficiency was improved by 67.9% with ridges and furrows plus mulching compared with flat bed. Mulches application did not reduce soil temperature during early stages but at maize maturity it reduced the soil temperature by 2-3 °C.

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