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The Effects of Planting Systems and Nitrogen and Phosphorus Combined Fertilizer on Yield and Yield Components of Maize (*Zea mays* L.) in Eastern Ethiopia.

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ABSTRACT

A field experiment was conducted during the rainy seasons of 2003 and 2004 in Eastern Ethiopia to assess the effects of planting systems and nitrogen and phosphorus combined fertilizer on yield and yield components of maize (*Zea mays* L.) and also to investigate the interaction effect of tie-ridge and NP combined fertilizer on yield. Yield and other related parameters studied were affected by planting systems and showed an increment in tie-ridge planting system as compared with flat bed, and it was concluded that the tie-ridge might have conserved larger amount of soil moisture ans this resulted in higher seed yield. NP combined fertilizer had a significant effect on yield and other parameters, among the combined NP fertilizers in this study, 41-46 kg N-P_2O_5/ha gave the highest yield, though it was statistically at par with 64-46 kg N-P_2O_5/ha. Variety had also a significant effect on yield and other parameters, and Melkassa I variety performed better than the local variety. Interaction between planting systems and NP combined fertilizer was significant for yield, indicating that there is a need to determine planting system for NP combined. N_1P_1 and N_2P_1 gave better result in tie-ridge planting system.

Key words: planting system, tie-ridge, flat bed, NP, Melkassa I, local variety, maize, Ethiopia

INTRODUCTION

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). Maize is used in many ways than any other cereals. It is used as a human food, feed for livestock and industrial purposes (Dowswell *et al.*, 1996). Although an estimated maize national average yield of 1.98 tons/ha is the highest among those obtained from each of the individual cereals grown in the country, it is far below the average figure for the world (CIMMYT, 1992). Thus, given the soil and climatic conditions in the country and the inherent characteristics of maize as a high yielder, the crop has tremendous potential as one of the main sources of food for the rapidly increasing population of the country. One of the main constraints to its high productivity is inadequate information on the appropriate practices required to give high yield. High yields are always obtained only if a proper combination of varieties, environmental conditions and agronomic practices (fertilizer application and others) are used.

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Increased crop yields and world food supplies are dependent upon the productive capacities of soils, which in turn is dependent more and more upon the fertility status of the soil. Both organic and inorganic fertilizers are applied to increase the supply of plant nutrients in the soil to ensure that crops can produce yields up to their full genetic potential under various environmental conditions in which they are grown. The quantity and type of plant nutrients to be applied depends on the parent material of the soil, soil forming processes, previous soil management practices as well as type and cultivars of crops grown. This would mean that crop responses and fertilizer recommendations for specific regions have to be established through research.

In most cereal (maize) growing regions of the world, the soils are deficient in essential nutrients, especially nitrogen and phosphorus. In the tropical and sub-tropical regions of the world, the soil fertility program is centered around nitrogen and phosphorus. In addition to use of chemical fertilizers to increase the yield of maize, it is very essential to adopt agronomic practice, which would maximize available soil moisture at the critical phases of plant growth. Tie-ridges might be efficient in conserving soil moisture, reducing the risk of drought stress and increasing seed yield substantially (IITA, 1981; Kidane, 1982). The drought stressed maize growing areas occupy about 40% of total maize growing areas, but contributes less than 20% of the total cultivated maize area. Rain fall in the semi-arid areas of Ethiopia is relatively low, often poorly distributed and highly variable. Managing soil and plant to conserve water and utilize it efficiently through adequate nutrition will certainly lead to better water use efficiency. Tie-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 rain-fed 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 rain-fed crops.

However, there is limited information on the effect of soil moisture conservation practices with added nutrients through inorganic sources on maize during growing season of Eastern Ethiopia. So this study was conducted to explore the effects of nitrogen and phosphorus combined and tie-ridge planting system on the yield and yield components of maize (*Zea mays* L.) grown under dry land conditions.

MATERIALS AND METHODS

The field experiment was conducted during the main rainy seasons of 2003 and 2004 in Eastern Ethiopia. Eastern Ethiopia covers about 21% of the total area of the country (CSA, 1996). However, most of the region is semi-arid and is characterized by low and erratic rainfall. Thus, rainfed crop production is mainly concentrated on altitudes above 1500m. The major crops in Eastern Ethiopia are maize (*Zea mays* L.) and sorghum [S*orghum bicolor (*L.*)* Moench], accounting for about 33% and 44% of the estimated total cultivated area, respectively (CSA, 1996). Farmers in Eastern Ethiopia are predominantly smallholders, who are seriously constrained by the small farm size (0.65 ha per household with an average size of 5.4 members) .

The field experiment was conducted at Babile (9° 08’ N, 42° 21’ E, 1650m altitude) and Dire Dawa (9° 31’ N, 41° 51’ E, 1160 m altitude). The soil type at Babile is a light sandy loam with a pH of 7, an organic matter content of 1.9%, potassium content of 0.97(cmolc/kg) and available phosphorus content of 3.2 ppm, while the soil type at Dire Dawa is a well drained loamy sand with a pH of 8, an organic matter content of 1.3%, potassium content of 0.87 (cmolc/kg) and available phosphorus content of 4.2 ppm.

The experiment was based on the field experiment. Grain maize *(Zea mays* L.) var. 'Melkassa I' (double top-cross, early maturing) and var. 'Local' was used as the test crop as it is a principal crop, and represents the means for survival for many farmers in the semi-arid parts of Eastern Ethiopia. The NP combined fertilizer treatments used for this field experiment were three levels (0 kg N/ha |0 kg P_2O_5/ha, 41 kg N/ha|46 kg P_2O_5/ha and 64 kg N/ha|46 kg P_2O_5/ha). The maize crop (var. Melkassa I' and var.Local) was planted on flatbed and tie-ridge planting systems in Babile location on June 13, 2003 and June 27, 2004 and in Dire Dawa on June 6, 2003 and June 10, 2004, respectively. The experiment was then conducted using a randomized complete block design (RCBD) 3x2x2 factorial arrangement with three replications. A plot size of 4 rows x 0.75m (width) x 5.1m (length) and the harvestable plot size was 7.65m^2 (central two rows of 5.1m). One border row from each side of the plot (2 rows in a plot) and two plants at each end of the harvestable rows were not harvested to avoid the border effect. The distance between rows was 70 cm and the distance between plants with in a row was 30 cm. Distance between blocks was 1.5 m. No space was left between plots in each replication. The height of the ridges were 30 cm and tied at the end of the rows, and sowing was done, two seeds per hill, and thinned at 4-5 leaf stage to one plant per hill.

Accordingly, the treatments were assigned randomly using a random number table to experimental units within the block. As per treatment, full dose of P_2O_5-fertilizer and one half of the N-fertilizer for each experimental unit were applied during planting at about 5 cm under the seed in the row and the remaining one half of N-fertilizer as urea (46% N) were applied 45 days after planting as two sides dressing at a distance of about 7 cm away from the plant. Phosphorus was applied as diammonium phosphate or DAP (46% P_2O_5 and 18% N), whereas the remaining N dose was applied as urea (46% N). Other agronomic practices like weeding and cultivation were conducted three times before the crop attained maturity and also the structure of the ridges were kept as they were throughout the growing period.

Days to emergence, days to tasseling and days to silking were recorded when 75% of the maize seedlings emerged, at the time when 50% of the plants started shedding pollen and at the time when 50% of the plants produced silk, respectively. Where days to physiological maturity was taken at the time when 50% of the plants in the plot formed black layer. Plant height (cm) was measured from ground level to the point where the tassel started branching and was determined by taking sample of 10 plants. Grain yield (kg/plot) was measured at harvest from the middle two rows excluding the plants in the border of each row. Grain yield was then recorded on 13% moisture basis after converting plot results to yield in kg/ha. The data of number of kernels/row, number of kernel rows/ear and 100-seed weight were taken. The soil moisture content was taken at 0-20 cm depth at each 15 days after planting.

Data analysis

Data were subjected to analysis of variance to determine differences among flat bed and tie-ridge planting systems, NP combine fertilizers and varieties treatments, with locations analyzed separately using the General Linear Model procedure of the SAS (SAS 1997). Duncan's Multiple Range Test was used to compare treatment means.

RESULTS AND DISCUSSION

Effects of planting systems

Estimates of means due to planting system on yield and yield related parameters in

Babile and Dire Dawa were significant (Table 1). There was a tendency of increased yield and yield related attributes in case of tie-ridge planting system as compared with flat bed planting system. In most parameters planting system had a significant effect and the result of this study agreed with the reports of Kidane and Rezene (1989) who reported that tie-ridging has been found to be efficient in moisture conservation and has led to considerable increase in crop yields in semi-arid of Ethiopia and also Honisch (1974) reported that tie-ridges significantly produced higher yields in maize, sorghum and millet than the crop planted on the flat bed when the rainfall was either below average or normal. Tie-ridge had a significant effect on days to emergency and the lowest mean value for days to emergency was recorded for tie-ridge planting system and the highest value was recorded for flat bed. This indicated that the plant showed a positive response to tie-ridge planting system in Babile and Dire Dawa areas (Table1).

For days to silking, planting system had no significant effect. The highest value was noticed for flatbed, though it was not significantly different from tie-ridge planting system in both areas (Table 1). For days to tasseling, planting system had a significant effect, and the highest days to tasseling value was noticed for flat bed in Babile and in Dire Dawa the highest value was noticed for tie-ridge. Similarly, planting system had significant effect on days to physiological maturity. The highest physiological maturity value was recorded for tie-ridge and the lowest for flat bed in Babile (Table 1). In Dire Dawa planting system had no significant effect on days to physiological maturity. Thus, relatively the optimum temperature which prevailed at Dire Dawa during the cropping season might be responsible for higher rates of plant growth and almost equal days of physiological maturity. Photosynthesis (Ingel *et al*. 1964; Boyer, 1970) respiration, cell wall permeability and enzyme activity (Younis *et al*.1965; Tisdale and

Table 1 Means [1] due to planting systems for yield and yield related Parameters.

Babile

PS	DE (days)	DT (days)	DS (days)	DPM (days)	PHT (cm)	K/R	KR/E	100SW (g/plot)	T.GY/HA (kg/ha)
FB	13a[2]	47a	54a	105a	110.3a	30.3a	13.1a	19.14a	2060.8a
TR	9b	45b	53a	109b	131.6b	43.4b	23.7b	31.3b	3563.5b
C.V. (%)	31.01	5.87	5.62	3.80	11.99	26.27	28.02	21.42	27.11

DireDawa

PS	DE (days)	DT (days)	DS (days)	DPM (days)	PHT (cm)	K/R	KR/E	100SW (g/plot)	T.GY/HA (kg/ha)
FB	12a[2]	57a	55a	95a	142.9a	33.5a	14.5a	17.5a	2826.9a
TR	7b	48b	55a	94a	162.1b	50.4b	30.3b	31.4b	4508.7b
C.V. (%)	17.41	9.46	9.84	6.92	15.04	15.55	24.75	24.61	18.99

1 Average means of three replications of two years.

2 Means with the same letter in the same column are not significantly different at 5% probability.

PS= planting system, FB= flat bed, TR= tie-ridge, DE= days to emergence, DT= days to tasseling, DS=days to silking, DPM= days to physiological maturity, PHT= plant height, K/R= kernels per row, KR/E= kernel rows per ear, 100-SWT= 100 seed weight and GY/HA= grain yield per hectare.

Nelson, 1966) and the synthesis or degradation of the various biochemical substances in plants have been reported to be sensitive to low temperatures.

A significant difference was found for plant height. The highest value was noticed for tie-ridge planting system and the lowest value was recorded for flat bed in both locations (Table 1). Due to the availability of adequate moisture might have caused the plant to have a little bit higher plant height. And This result is in agreement with the report of Arnon (1975) who reported that adequate availability of water to plants caused by ridge and furrow results in cell turgidity and eventual higher meristematic activity of maize led to more foliage development, higher photosynthetic rate and consequently better plant growth.

Significant differences were found due to planting systems for kernels per row and kernels row per ear both in Babile and Dire Dawa areas (Table 1), hence, the highest kernels per row was due to tie-ridge planting system and the lowest was due to flat bed both in Babile and Dire Dawa. The highest number of kernels row per ear was due to tie-ridge and the lowest was observed in flat bed both in Babile and Dire Dawa areas (Table 1). Significant difference was found due to planting systems for 100-seed weight, hence, the highest 100 seed weight was due to tie-ridge planting system and the lowest was due to flat bed in both Babile and Dire Dawa locations (Table 1). Tie-ridges showed greater 100-seed weight over the flat bed which could have been due to the larger volumes of seeds due to larger accumulation of assimilates. Alemayehu (1995) suggested that the main reason for decreased seed weight could be due to reduction in supply of assimilates both at anthesis and grain filling periods.

Amemiya (1968) reported that tie-ridges conserved soil moisture and increased seed yield and similar results were obtained from the present study. Yield (kg/ha) was affected significantly by planting system both in Babile and Dire Dawa areas (Table 1). The highest yield (kg/ha) was due to tie-ridge and the lowest was due to flat bed both in Babile and Dire Dawa areas (Table 1). It can be generalized from the present results that tie-ridges is one of the efficient tillage practices used for soil moisture conservation and had favorable effects on yield.

Effects of NP fertilizer

The results showed that the NP fertilizer in general in Babile and Dire Dawa areas had a significant effect. The analysis of variance revealed significant difference due to the NP fertilizer applied for days to emergence both in Babile and Dire Dawa. For days to emergence, the longest day was due to N_0P_0 in both locations and the shortest days was due to N_2P_1, though it was statistically at par with N_1P_1(Table 2). Similarly, NP fertilizer had significant effect on days to tasseling, silking and to maturity. The largest number of days to tassel and silk was observed incase of N_0P_0 in both locations. On the other hand N_2P_1 took the shortest days to tassel and silk, even though it was statistically at par with N_1P_1 in both locations (Table 2). The largest days to maturity was due to N_2P_1, though its maturity duration was not significantly different from that of N_1P_1. Simultaneous application of NP fertilizer has been reported by several researchers to have an interactive effect on maturity of crops.

NP fertilizer had significant effect on plant height. For plant height N_2P_1 consistently registered the highest value, while the lowest was seen in N_0P_0, though N_2P_1 was statistically at par with N_1P_1 in both Babile and Dire Dawa (Table 2). This is in agreement with the reports of Hari *et al*. (1997) and Behera (1998) who reported that application of higher N fertilizer increases plant height and also with report of Zaman *et al.* (1995) who reported that optimum rate of P has beneficial effects on plant height of most crops. For kernels per row, kernels row per ear and 100 seed weight, NP fertilizer had significant effect. In kernels per row, the highest value was noticed for N_2P_1, though it was not significantly different from N_1P_1, while the lowest was noticed for N_0P_0 in both locations. N_2P_1 showed the highest value for kernels row per ear in Babile, while in Dire Dawa N_1P_1 showed the highest. In both locations N_0P_0 showed the least value for kernels row per ear. The largest 100 seed weight was due to N_1P_1, though it was not significantly different from N_2P_1 and the lowest value was due to N_0P_0 in both locations (Table 2).

N_1P_1 and N_2P_1 showed significantly greater 100 seed weight over N_0P_0, which could have been due to the larger volume of seeds due to larger accumulation of assimilates. This result is also in line with the report of Alemayehu (1959) who suggested that the main reason for increased seed weight could be due to increase in supply of assimilates both at anthesis and grain filling periods. NP fertilizer had significant effect on grain yield, the highest value was noticed for N_1P_1, though it was not significantly different from N_2P_1 ans the least value was recorded by N_0P_0 in both Babile and Dire Dawa areas (Table 2). This study revelated that NP fertilizer had effect on grain yield and this result agreed with the report of Fernandez *et al.* (1959) who reported that the addition of nitrogen fertilizer results large increase in yield for all varieties of crops. Also several investigations revealed that above ground biomass and grain yields increased with application of increasing levels of phosphorus fertilizers (Walia *et al.*, 1980; Kumar and Rao, 1992).

Effects of varieties

Means due to varieties were significant for most parameters. For days to emergence, days to tasseling and days to silking, Melkassa I variety registered the shortest days while the highest days was seen in local variety (Table 3). In all cultivars, the vegetative growth was terminated by anthesis (Moss, 1962) and varieties differed significantly in tasseling and silking dates (Muleba, 1983; Moss and Stinson, 1962;). Physiological maturity also differed significantly among the varieties, the shortest days to mature was noticed for Melkassa I and the longest for local variety. This results

Table 2 Means[1] due to NP fertilizer on yield and yield related parameters.

Babile

NP	DE (days)	DT (days)	DS (days)	DPM (days)	PHT (cm)	K/R	KR/E	100-SWT (g/plot)	GY/HA (kg/ha)
N_0P_0	13a[2]	44a	57a	104a	108.8a	30a	13a	19.42a	2108a
N_1P_1	8b	47b	54b	110b	128,6b	39b	20b	28.65b	3168b
N_2P_1	7b	46b	53b	112b	129.4b	40b	21b	27.52b	3160b

Dire Dawa

NP	DE	DT (days)	DS (days)	DPM (days)	PHT (days)	K/R (cm)	KR/E	100SWT (g/plot)	GY/HA (kg/ha)
N_0P_0	11a	47a	58a	94a	140.62a	35a	15a	17.58a	2779a
N_1P_1	8b	54b	62b	110b	149.18b	46b	25b	29.21b	4261b
N_2P_1	7b	52b	59b	113b	152.4b	44b	25b	28.53b	3961b

1 Average means of three replications of two years.

2 Means with the same letter in the same column are not significantly different at 5% probability.

NP =Nitrogen-Phosphorus,N_0P_0=N(0)P_2O_5(0),N_1P_1=N(41kg/ha)P_2O_5(46kg/ha), N_2P_1=N(64kg/ha)P_2O_5(46 kg/ha), DE= days to emergence, DT= days to tasseling, DS=days to silking, DPM= days to physiological maturity, PHT= plant height, K/R= kernels per row, KR/E= kernel rows per ear, 100SWT= 100-seed weight and GY/HA= grain yield per hectare.

agreed with the observations of Stinson and Moss (1962), Yamaguchi (1974), and Muleba (1983) who reported that there is considerable variation in plant growth and maturity among maize cultivars.Similarly variety had significant effect on plant height and kernels per row. The highest value of plant height was observed in case of Melkassa I and the shortest height was due to local variety in both locations. On the other hand, the highest number of kernels per row was due to local variety in Babile and Melkassa I in Dire Dawa. Variety had no significant effect on kernels row per ear in both locations. For 100 seed weight and grain yield variety had significant effect. The highest 100 seed weight was recorded in Melkassa I, and the lowest was observed in case of local variety in both locations. The highest yield value was noticed for Melkassa I, and the least value was recorded by local variety (Table 3). Several studies conducted on the yield pattern of maize cultivars showed that in almost all cases variety had considerable effects on seed yield and its components (Yamaguchi, 1974). The superior performance of Melkassa I in yield and other parameters could be attributed to its genetic background.

Interaction effect of planting systems and NP fertilizer

Significant interaction between planting systems and NP fertilizer was found for yield both in Babile and Dire Dawa locations (Table 4). The maize crop used in this present study gave the highest mean value of grain yield in tie-ridge planting system with NP fertilizer more than in the flat bed. This indicated that NP fertilizer showed positive response to tie-ridge. And the significant effect of interaction on yield suggests that there is a specific need of a planting system for the NP fertilizer. N_1P_1 gave the highest yield in tie-ridge and N_2P_1 ranked the second in both locations. N_2P_1 gave the highest yield in flat bed in Babile and N_1P_1 in Dire Dawa. The lowest yield was recorded by N_0P_0 in flat bed in both locations (Table 4).

Table 3 Means[1] due to varieties on yield and yield related parameters.

Babile

Variety	DE (days)	DT (days)	DS (days)	DPM (days)	PHT (cm)	K/R	KR/E	100-SWT (g/plot)	GY/HA (kg/ha)
Melkassa I	8a[2]	40a	48a	100a	114.3a	34a	18a	29.68a	3816a
Local	13b	50b	63b	114b	127.8b	39b	17a	20.71b	2607b
C.V. (%)	31.01	5.87	5.62	3.80	11.99	26.27	28.02	21.42	27.11

DireDawa

Variety	DE (days)	DT (days)	DS (days)	DPM (days)	PHT (cm)	K/R	KR/E	100-SWT (g/plot)	GY/HA (kg/ha)
Melkassa I	8a[2]	50a	58a	95a	162.51a	45a	23a	27.40a	3906a
Local	12b	48b	60 b	112b	148.54b	39b	21a	21.47b	3429b
C.V. (%)	17.41	9.46	9.84	6.92	15.04	15.55	24.75	24.61	18.99

[1] Average means of three replications of two years.

[2] Means with the same letter in the same column are not significantly different at 5% probability.

DE = days to emergence, DT= days to tasseling, DS=days to silking, DPM= days to physiological maturity, PHT= plant height, K/R= kernels per row, KR/E= kernel rows per ear, 100-SWT= 100 seed weight and GY/HA=grain yield per hectare.

Table 4 Means[1] due to interaction effect of PS and NP for yield.

Level of NP	Level of PS	Grain yield (Mean±SD)	
		Babile	Dire Dawa
N_0P_0	FB	1802.58±393.9	2633±663.24
N_0P_0	TR	2413.67±759.2	2926±736.12
N_1P_1	FB	2127.67±865.32	2968±836.63
N_1P_1	TR	4208.83±1531.49	5556±1120.22
N_2P_1	FB	2252.25±844.87	2881±735.31
N_2P_1	TR	4068±1687.79	5042±1187.79

1 Average means of three replications of two years.
N_0P_0= 0 kg N/ha, 0 kg P_2O_5/ha, N_1P_1= 41kg N/ha, 46 kg P_2O_5/ha, N_2P_1= 64 kg N/ha, 46 kg P_2O_5/ha, FB= flat bed, TR= tie-ridge, PS= planting System and NP= nitrogen-phosphorus

In the present study there was an interaction effect on yield especially tie-ridge and NP fertilizer and this could be due to the high moisture in the soil and this is in agreement with the report of Lawes (1961) and Honisch (1974) who attributed the superiority of early germination and better growth on tie-ridge.

CONCLUSIONS

Yield and almost all other parameters studied were affected by planting system, variety and NP fertilizer. It was concluded that the tie-ridge might have conserved larger amount of soil moisture and this resulted in higher seed yield. N_1P_1recorded the highest value for yield and yield related parameters, though it was statistically at par with N_2P_1. Where the least value for yield and yield related parameters was noticed for N_0P_0. Melkassa I variety recorded the highest values for yield and other parameters, where variety local showed the least value for yield and other related parameters. Yield and other parameters showed an increment in tie-ridge planting system as compared with flat bed. Interaction between planting system and NP fertilizer was significant for yield and other parameters, indicating that there is a need to determine planting system for NP fertilizer. NP fertilizer gave the better results in tie-ridge.

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