Kasetsart J. (Nat. Sci.) 40 : 604 - 615 (2006)

Uptake and Response of Maize (*Zea mays* L.) *Varieties* to Nitrogen and Phosphorus Fertilizers in Semi-arid Areas of Eastern Ethiopia

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ABSTRACT

A field experiment was conducted on two locations of semi-arid areas of Eastern Ethiopia during the rainy seasons of 2003 and 2004. The objective of this study was to determine grain yield and N and P contents and uptakes of maize (*Zea mays* L.) varieties in semi-arid areas of Eastern Ethiopia. The experiment was conducted with factorial combinations of three levels of N (0, 41 and 64 kg N/ha), three levels of P (0, 46 and 69 kg P_2O_5/ha) and two maize varieties laid out in a Randomized Complete Block Design with three replications. Analysis of variance revealed significant differences due to the different levels of applied N for almost all of the yield and agronomic parameters studied, where P fertilizer had a significant effect only on stover biomass and grain yield. Interaction effect of N and P on grain yield was significant. Among all of the N and P treatment combinations, maximum grain yield of maize 3868 kg/ha in Babile and 5069 kg/ha in Dire Dawa were obtained with the application of 64 kg N/ha and 46 kg P_2O_5/ha in both locations. Melkassa I recorded the highest value for yield and other parameters, where local variety showed the least value for yield in both locations. Nitrogen and phosphorus concentrations and uptakes in the maize varieties increased with increasing levels of N and P fertilizers. Compared with the control concentration of N in the maize plant of both varieties, it increased up to the highest levels of N application, indicating possible improvement in the crude protein content of the maize grains. Generally, application of N enhanced uptakes and concentrations of N and P nutrients in the maize tissues than P fertilizer applied. Total plant N and P uptakes by the above ground parts of both varieties in both locations, the sum of uptake by grain yield and stover in kg/ha, increased relatively at the rates of 0 and 64 kg N/ha and 0 and 69 kg P_2O_5/ha, respectively. Efficiency in N fertilizer was calculated for Melkassa I and Local maize varieties in both locations and Melkassa I variety had a higher efficiency of N fertilizer than the local maize variety in both locations, indicating that Melkassa I produced much more grain and was thus more efficient in converting fertilizer nitrogen in to grain.

Key words: N, P, Melkassa I variety, local variety, concentration, uptake, maize and Ethiopia.

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Received date : 28/11/05 Accepted date : 05/04/06

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.

In semi-arid areas of Ethiopia, there is a rapidly growing demand for food. Therefore, cultivation of subsistence crops must be stimulated and production augmented in a sustainable way. The trend in all research endeavors including research on soil nutrients, therefore, is going through a development process away from agricultural production *per se* towards sustainable production (Smaling and Oenema, 1998). Among others, mineral nutrition is becoming one of the most important factors for increasing maize production in semi-arid areas of Ethiopia. Murphy (1963) conducted a survey or rapid appraisal work to assess the fertility status of Ethiopian soils and concluded that the major part of Ethiopian soils is deficient in nitrogen and phosphorus. Hence, farmers who attempted to grow crops without or with marginal fertilizer application could not produce enough even to feed their own family for one year.

It is apparent that in many farming systems of Ethiopia, input of manures and fertilizers is still low and not sufficient to sustain the productivity of the soils. Bringing more land into cultivation is not possible in the densely populated areas. Preference, therefore, should be given to raising the production of subsistence crops by increasing the productivity of the soils on which crops are being grown. Improving soil fertility is one of the major factors to improve soil productivity. Organic and inorganic fertilizers, therefore, should be applied to restore and improve the soil fertility and to compensate for the withdrawal and losses of nutrients during cultivation. Nevertheless, organic fertilizers are scarce resources in most farming households of Ethiopia where farmyard manure and crop residues are used as energy source to cook food. Therefore, efficient use of artificial fertilizers should be given due attention. The role of chemical fertilizers in increasing yield is evident. Fertilizers accounted for more than 50% of the increase in yield (FAO, 1984). Experience has shown that in seasons with good rain, farmers of semi-arid areas of Eastern Ethiopia manage to produce surplus yield through fertilization. The rates applied, however, should meet the demand of the crop, but should not exceed the demand to any major extent. For this purpose, in Ethiopia, some flat fertilizer recommendations have been developed and introduced into the extension system. This approach, however, had shortcomings in extrapolating the results to farmers' fields, because the available nutrient status on the experimental fields were either lower than, equal to or higher than that of the farmers' fields. Hence, fertilizer recommendations should take into account the available nutrient already present in the soil (Mengel, 1982).

The amount of fertilizer required may differ from one soil to another as well as with crop

type and crop variety. As a result, the significance of studying the nutritional requirement rates and establishing soil, crop and agro-ecological specific fertilizer recommendation for major agricultural areas and widely cultivated crops/varieties is crucial for increasing crop production and for sustainable use of the land resource. Hence, the purpose of this study was to determine uptake and the effects of N and P fertilizers and their interaction on growth, grain yield and yield components of maize varieties, var. Melkassa I and var. Local, in semi-arid areas of Eastern Ethiopia.

MATERIALS AND METHODS

Experimental Areas, Treatments, Procedures and Design

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 (9^0 08' N, 42^0 21' E, 1650 masl altitude) and Dire Dawa (9^0 31' N, 41^0 51' E, 1160 masl altitude). The soil type at Babile was a light sandy loam with a pH of 7, an organic matter content of 1.9%, potassium content of 0.97 (cmol/kg) and available phosphorus content of 3.2 ppm, while the soil type at Dire Dawa was a well drained loamy sand with a pH of 8, an organic matter content of 1.3%, potassium content of 0.87 (cmol/kg) and available phosphorus content of 4.2 ppm.

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 N fertilizer rates used for this field experiment were 0 kg N/ha, 41 kg N/ha and 64 kg N/ha and P rates were 0 kg P_2O_5/ha, 46 kg P_2O_5/ha and 69 kg P_2O_5/ha. The maize crop (var. Melkassa I' and var.local) was planted 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) of 3×3×2 factorial arrangement with three replications. A plot size of 4 rows × 0.75m (width) × 5.1m (length) of plants spaced at 30 cm 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 within a row was 30 cm. Distance between blocks was 1.5 m. No space was left between plots in each replication. Sowing was done, two seeds per hill, and thinned at 4-5 leaf stage to one plant per hill.

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) was applied 45 days after planting as two sides dressing at a distance of about 7 cm away from the plant. Phosphorus was applied as triple superphosphate or TSP (46% available P_2O_5), 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.

Data collection

Days to emergence was recorded when 75% of the maize seedlings emerged, 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 was measured at harvest from the middle two rows excluding the plants (two 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 stover biomass was also taken. The soil moisture content was taken at 0-20 cm depth at 15 days intervals after planting.

Soil and plant tissue sampling

A composite surface soil sample (0-25cm) was collected before sowing from 18 sub samples taken from the entire experimental field and analyzed in the laboratory for pH, organic matter, texture, total nitrogen and available phosphorus. Surface soil samples (0-25cm) were also collected from each plot after harvesting. The samples from the plot with the same treatment (replication) were bulked to form one composite surface soil sample per treatment and analyzed for total N and available P.

Similarly, the above ground parts of three randomly selected plants from the central rows of each plot (a total of six plants per plot) were collected at harvesting stage and bulked over replications to form one composite sample per treatment. These tissue samples and samples of grain yield collected from each treatment were analyzed separately for total nitrogen and phosphorus. Finally, plant uptake of N and P nutrients were obtained from the sum of their respective concentrations in the above ground biomass and grain yield.

Laboratory procedures

The surface soil samples were air-dried and passed through a 2-mm size sieve and used for various laboratory analyses. Soil texture determination was carried out by Bouyoucos hydrometer method (Bouyoucos, 1951). The soil pH was determined using a pH meter in 1:1 soil to water ratio as described by Black (1965). Organic matter was determined using the Walkley-Black wet combustion method as described by Bray and Kurtz (1954). Total nitrogen in the soil was determined by the modified Micro-Kjeldahl method and the available soil phosphorus was determined using the Olsen's $NaHCO_3$ extraction method (Olsen *et al*., 1954).

The above ground parts of the plants sampled at harvesting stage were oven-dried at 70° C until constant weight was attained. The samples were ground to pass a 0.5-mm size sieve. Total phosphorus in the plant tissues was determined using Spectrophotometer after developing color with ammonium molybdate vandate, and nitrogen using the Micro-Kjeldahl method. Seed and above ground plant part (biomass) N and P uptake values were calculated by multiplying grain and biomass yields by the respective N and P (%) contents. Total plant N and P uptakes were calculated as the sum of the seed and biomass N and P uptakes.

Calculations

The efficiency of nitrogen fertilizer was calculated according to the following equation:

Physiological efficiency of fertilizer N

$$= \frac{GY_F - GY_C}{\text{N uptake}_F - \text{N uptake}_C}$$

Where GY_F= grain yield of fertilized crop; GY_C= grain yield of control; N uptake $_F$= N uptake of fertilized crop and N uptake $_C$= N uptake of control.

Statistical analysis

Data were subjected to analysis of variance to determine differences among nitrogen,

phosphorus fertilizers and varieties treatments, with each location analyzed separately. Mean separation of treatment effects in this study was accomplished using Duncan's Multiple Range Test. All data analyses in this study were accomplished using the SAS system for Windows.

RESULTS AND DISCUSSION

Maize crop response to applied N fertilizer

The results showed that the nitrogen fertilizer in general in Babile and Dire Dawa had a significant effect. The analysis of variance revealed significant difference due to nitrogen fertilizer applied for days to emergence both in Babile and Dire Dawa. For days to emergence, the shortest days was due to N_2, though it was statistically at par with N_1 and the longest days was due to N_0 in Babile but in Dire Dawa the shortest days was due to N_1, whereas N_0 recorded the longest days to emergence (Table 1). In line with the present result, Rosan *et al*. (1997) who reported that application of N has been also reported to hasten early germination in maize. Similarly, nitrogen fertilizer had significant effect on days to maturity. The largest number of days to mature was due to N_0 in both locations, whereas the shortest days to mature was due to N_1, though it was statistically at par with N_2 in both locations (Table 1). The result is in line with the report of Chatterjjee and Maiti (1985) who reported that one of the most important function of N in crop plants is promotion of rapid emergence and growth through increasing length of root, height and size of leaves.

Nitrogen fertilizer had significant effect on plant height. For plant height N_1 consistently registered the highest value, while the lowest value was seen in N_0, though N_1 was statistically at par with N_2 in both locations (Table 1). This result is in agreement with the reports of Behera (1998) and Hari *et al*. (1997) who reported that application of higher nitrogen fertilizer increases plant height. For stover biomass, nitrogen had significant effect. In stover biomass, the highest value was noticed for N_1, while the lowest value was noticed for N_0 in both locations. Nitrogen fertilizer had significant effect on grain yield, the highest value was noticed for N_2 in Babile and N_1 in Dire Dawa and the least value was recorded by N_0 in both Babile and Dire Dawa areas (Table 1). This study revealed that nitrogen 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 in large increase in yield for all varieties of crops.

Maize crop response to applied P fertilizer

The analysis of variance revealed non significant difference due to phosphorus fertilizer applied for days to emergence and days to maturity in both locations (Table 2). Phosphorus fertilizer had no significant effect on plant height in Dire Dawa, whereas in Babile there was a significant

Table 1 Mean yields and yield related parameters as affected by level of N fertilizer.

	Babile					*Dire Dawa*				
N Levels	DE (days)	DPM (days)	PHT (cm)	SBM (kg/plot)	GY (kg/ha)	DE (days)	DPM (days)	PHT (cm)	SBM (kg/plot)	GY (kg/ha)
N_o	13.3a	111.1a	123.7a	2.3a	2280.3a	12.7a	107.9a	160.5a	3.9a	2929a
N_1	10.8b	107.1b	146.3b	3.8b	3257.0b	10.3b	103.1b	167.5b	5.7b	4260b
N_2	10.7b	107.1b	134.8c	3.4c	3338.6b	10.6b	103.1b	165.1b	5.3b	3953b

[1] Average means of three replications of two years;
means with the same letter in the same column are not significantly different at 5% probability; N_0=0 kgN/ha, N_1=41 kgN/ha, N_2=64 kgN/ha, DE= days to emergence, DPM= days to physiological maturity, PHT= plant height, SBM= stover biomass and GY= grain yield per hectare.

effect on plant height and the highest value was recorded for P_1, while the lowest was seen in P_0 (Table 2). This result was in line with the report of Zaman *et al*. (1995) who reported that optimum rate of P has beneficial effects on plant height of most crops. Phosphorus fertilizer had significant effect on stover biomass. For stover biomass P_1 consistently registered the highest value, while the lowest value was seen in P_0, though P_1 was statistically at par with P_2 in both Babile and Dire Dawa locations (Table 2). Phosphorus fertilizer had significant effect on grain yield; the highest value was noticed for P_1, though it was not significantly different from P_2 and the least value was recorded in P_0 in both Babile and Dire Dawa locations (Table 2). This is in line with the report of Walia *et al*. (1980) and Kumar and Rao (1992) who reported that several investigations revealed that above ground biomass and grain yields increased with application of increasing levels of phosphorus fertilizers. Also Zaman *et al*. (1995) reported that higher yields associated with higher P levels were due to better root growth and increased uptake of nutrients favoring better growth of the crop. However, grain yield increased marginally and decreased at a very high levels of P application.

Effects of variety

Means due to varieties were significant for most parameters. For days to emergence and days to mature, Melkassa I variety registered the shortest days, while the longest days was seen in Local variety in both locations (Table 3). This result 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. The highest value of plant height was observed in case of Local variety in Babile and Melkassa I in Dire Dawa. Variety had no significant effect on stover biomass in Babile but in Dire Dawa there was significant effect of

Table 2 Mean[1] yields and yield related parameters as affected by level of P fertilizer.

	Babile					*Dire Dawa*				
P	DE	DPM	PHT	SBM	GY	DE	DPM	PHT	SBM	GY
Levels	(days)	(days)	(cm)	(kg/plot)	(kg/ha)	(days)	(days)	(cm)	(kg/plot)	(kg/ha)
P_o	11.9a	108.9a	126.1a	2.4a	2503.0a	11..5a	104.8a	162.9a	4.3a	3293a
P_1	11.2a	108.3a	141.4b	3.6b	3263.2b	10.8a	103.7a	167.9a	5.5b	4203b
P_2	11.6a	108.1a	137.3b	3.4b	3109.3b	11.3a	103.7a	164.2a	5.0b	3645b

[1] Average means of three replications of two years;
means with the same letter in the same column are not significantly different at 5% probability; P_0=0 kgP_2O_5/ha, P_1=46 kg P_2O_5/ha, P_2=69 kgP_2O_5/ha, DE= days to emergence, DPM= days to physiological maturity, PHT= plant height, SBM= stover biomass and GY= grain yield per hectare.

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

	Babile					Dire Dawa				
Variety	DE	DPM	PHT	SBM	GY	DE	DPM	PHT	SBM	GY
	(days)	(days)	(cm)	(kg/plot)	(kg/ha)	(days)	(days)	(cm)	(kg/plot)	(kg/ha)
Melkassa I	10.4a[2]	101.1a	130.0a	3.1a	3356.6a	9.7a	97.3a	175.8a	5.3a	3881.2a
Local	12.8b	115.6b	139.9b	3.2a	2560.7b	12.7b	110.8b	152.8b	4.5b	3547.4b

[1] Average means of three replications of two years;
means with the same letter in the same column are not significantly different at 5% probability; DE= days to emergence, DPM= days to physiological maturity, PHT= plant height, SBM= stover biomass and GY=grain yield per hectare.

variety on stover biomass and the highest value was noticed for Melkassa I (Table 3). For grain yield, variety had significant effect. 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 grain yield and its components (Yamaguchi, 1974). The superior performance of Melkassa I in yield could be attributed to its genetic background.

Interaction effect of nitrogen and phosphorus

Interaction effect of N and P levels on grain yield was significant. Among the treatment combinations considered, combined of N and P increased grain yield of maize than application of N and P alone. Taking the maximum grain yields obtained, the maize crop used in this study gave the highest mean value of grain yield in N_2P_1 (64 kg N/ha and 46 kg P_2O_5/ha) in both locations and the lowest yield was recorded by N_0P_0 (0 kg N/ha and 0 kg P_2O_5/ha) (Table 4). This indicated that nitrogen fertilizer showed positive response to phosphorus fertilizer. The significant effect of interaction on yield suggested that there was a need of using nitrogen and phosphorus fertilizers together in order to get high yield.

Concentration and uptake of N and P by plants

Grain and stover were separately partitioned for the analysis of their total N and P contents. The grain N content of the Melkassa I variety in Babile was found to be increased with the application of the second unit and third unit, 41 kg N/ha and 64 kg N/ha, respectively and the maximum grain N content was obtained at 64 kg N/ha (Table 5), where the grain contents of the control plants of Melkassa I at Dire Dawa were found to be better than that of plants received 41 kg N/ha and the maximum grain N content of Melkassa I at Dire Dawa was obtained at 64 kg N/ha (Table 6). The same as Melkassa I variety at Babile, grain N content of local variety also was found to be increased with the application of the second and third units, 41kg N/ha and 64 kg N/ha, respectively and the highest grain N concentration was recorded at 64 kg N/ha (Table 5), but in Dire Dawa the highest value of grain N content of local variety was due to 41 kg N/ha (Table 6). The grain N uptakes of Melkassa I and local varieties at Babile were found to be increased with increased application of nitrogen fertilizer rates and the maximum grain N uptake were obtained for Melkassa I and local varieties at 64 kg N/ha (Table 5), where in Dire Dawa the grain N uptake of Melkassa I was found to be less than

Table 4 Means[1] due to interaction effect of N and P for grain yield.

Level of N	Level of P	Babile Mean±SD	Dire Dawa Mean±SD
N_0	P_0	2157.3±481.5	2733.1±487.4
N_0	P_1	2296.6±598.2	3055.2±933.1
N_0	P_2	2386.9±376.2	2999.6±959.0
N_1	P_0	2443.9±423.9	3730.3±1248.0
N_1	P_1	3624.8±1801.1	4486.5±1805.0
N_1	P_2	3702.4±1516.3	4564.7±1813.3
N_2	P_0	2908.9±541.2	3417.7±674.2
N_2	P_1	3868.0±1472.6	5069.0±1223.2
N_2	P_2	3238.0±942.1	3372.5±1248.4

[1] Average means of three replications of two years;
N_0=0 kg N/ha, N_1=41 kg N/ha, N_2=64 kg N/ha, P_0=0 kg P_2O_5/ha, P_1=46 kg P_2O_5/ha and P_2=69 kg P_2O_5/ha.

to that of the control plants at 41 kg N/ha and the highest value of grain N uptake of Melkassa I was due to 64 kg N/ha and the highest value of grain N uptake of local variety at Dire Dawa was due to 41 kg N/ha (Table 6). The percent N content of the stover of Melkassa I and local varieties at Babile increased almost linearly with increasing rates of applied N (Table 5), but in Dire Dawa the

Table 5 Nitrogen and phosphorus concentrations of grain and stover and uptake of the nutrients at Babile.

Treat.	Melkassa I variety					Local variety				
	Conc. (%)		Uptake (kg/ha)			Conc.(%)		Uptake (kg/ha)		
	Grain	Stover	Grain	Stover	Total (Biomass)	Grain	Stover	Grain	Stover	Total (Biomass)
N rates					N					
Kg/ha										
N_0	2.10	0.466	53.42a	24.66a	78.08a	1.97	0.463	47.79a	26.80a	74.59a
N_1	2.45	0.530	57.94a	27.56a	85.50a	2.32	0.463	54.78a	35.80b	90.58b
N_2	2.59	0.596	69.38b	36.23b	105.61b	2.43	0.530	70.91b	47.00c	117.91c
					P					
P rates										
Kg/ha										
P_0	0.210	0.043	5.34a	2.27a	7.61a	0.167	0.035	4.05a	2.84a	6.89a
P_1	0.252	0.051	7.19a	3.33a	10.52a	0.248	0.040	5.64a	3.20a	8.84a
P_2	0.301	0.058	7.99a	3.00a	10.99a	0.213	0.042	4.69a	3.58a	8.27a

Table 6 Nitrogen and phosphorus concentrations of grains and stover and uptake of the nutrients at Dire Dawa.

Treat.	Melkassa I variety					Local variety				
	Conc. (%)		Uptake (kg/ha)			Conc.(%)		Uptake (kg/ha)		
	Grain	Stover	Grain	Stover	Total (Biomass)	Grain	Stover	Grain	Stover	Total (Biomass)
N rates					N					
Kg/ha										
N_0	1.52	0.43	37.82a	20.13a	57.95a	1.58	0.50	40.02a	22.00a	66.02a
N_1	1.45	0.38	34.44a	16.98a	51.42a	1.96	0.38	80.12b	47.12b	127.24b
N_2	1.58	0.41	67.06b	39.36b	106.42b	1.91	0.39	56.89c	39.05b	95.94c
					P					
P rates										
Kg/ha										
P_0	0.181	0.038	4.50a	3.54a	8.04a	0.208	0.041	5.12a	4.26a	9.38a
P_1	0.198	0.029	5.37a	2.47b	7.84a	0.213	0.036	7.47a	3.50a	10.97a
P_2	0.154	0.023	4.24a	1.98b	6.22a	0.200	0.025	6.48a	2.80b	9.28a

N_0=0 kg N/ha, N_1=41 kg N/ha, N_2=64 kg N/ha, P_0=0 kg P_2O_5/ha, P_1=46 kg P_2O_5/ha and P_2=69 kg P_2O_5/ha;
means with the same letter in the same column are not significantly different at 5% probability.

percent N content of stover of the control plants were found to be higher than that of the plants of Melkassa I and local varieties received 41 kg N/ha and 64 kg N/ha (Table 6). The stover N uptakes of Melkassa I and local varieties at Babile were to be found increased with increased application of nitrogen fertilizer rates, and the maximum stover N were obtained at 64 kg N/ha for Melkassa I and local varieties (Table 5). Melkassa I variety recorded the highest value of stover N uptake at 64 kg N/ha and local variety at 41 kg N/ha in Dire Dawa (Table 6).

The grain P content of Melkassa I variety at Babile was increased with application of the second and third units, 46 kg P_2O_5/ha and 69 kg P_2O_5/ha respectively, and the maximum grain P content was obtained at 69 kg P_2O_5/ha, where the highest value of grain P content was obtained at 46 kg P_2O_5/ha for local variety at Babile (Table 5). Both varieties at Dire Dawa recorded the highest value of grain P contents at 46 kg P_2O_5/ha (Table 6). The percent P content of the stover of both varieties at Babile increased almost linearly with increasing rates of applied P and the highest stover P contents, 0.058% and 0.042%, for Melkassa I and local varieties, respectively were recorded at Babile (Table 6). The stover P contents of the control plants of both varieties at Dire Dawa were found to be almost higher than that of plants received 46 kg P_2O_5/ha and 69 Kg P_2O_5/ha (Table 6). Grain P uptake of Melkassa I variety revealed an increment with increased P rates at Babile and the maximum grain P uptake was obtained at 69 kg P_2O_5/ha (Table 5), while at Dire Dawa Melkassa I revealed that at high P rates, P uptake by the grain of Melkassa I was low (Table 6). The grain P uptakes of local variety at both locations revealed increment up to P rates of 46 kg P_2O_5/ha and then declined with the increase of the P rates (Tables 5 &6). P uptake by stover of local variety was increased with increased P rates, while Melkassa I variety revealed an increment up to 46 kg P_2O_5/ha and then declined with the increased rate at Babile and the maximum P uptake of stover for Melkassa I and local varieties were at 46 kg P_2O_5/ha and at 69 kg P_2O_5/ha, respectively (Table 5). The stover P uptake of the control plants were higher than that of plants of both varieties that received 46 kg P_2O_5/ha and 69 kg P_2O_5/ha and declined with the increased P rates. Total plant N and P uptakes by the above ground parts of both varieties in all locations, the sum of uptake by grain yield and stover increased relatively at the rates from 0 to 64 kg N/ha and from 0 to 69 kg P_2O_5/ha, respectively.

Efficiency of nitrogen fertilizer

Physiological efficiency was determined as the ratio of net grain yield produced to net uptake of the applied fertilizer and maximum (78.87 at Dire Dawa for Melkassa I Variety) and minimum (8.46 at Babile for Melkassa I variety) physiological efficiencies were obtained at 41 kg N/ha and 64 kg N/ha, respectively (Table 7). This also indicated that from a given unit of fertilizer N taken up by the total biomass, relatively the highest portion was used in grain formation at 41 kg N/ha whereas the least portion was used at 64 kg N/ha. According to Craswell and Godwin (1984), high agronomic efficiency would be obtained if the yield increment per unit N applied is high and high physiological efficiency on N usage in cereal crops is achieved when high portion of the N taken up is used in grain formation. And it could be concluded that Melkassa I variety had high physiological efficiency of nitrogen fertilizer than the Local variety in both locations. .

CONCLUSIONS

Compared with concentrations and total N and available P in the soil determined before planting, total soil N declined in Dire Dawa areas (0.0812% before sowing and 0.077% after harvest) and total soil N increased in Babile areas (0.035% before sowing and 0.057% after harvest), whereas

Table 7 Physiological efficiencies of N fertilizer for Melkassa I and local varieties of maize.

Variety	Location	N Rate (kg N/ha)	Physiological Efficiency
Melkassa I	Babile	41	70.95
Local	Babile	41	19.31
Melkassa I	Babile	64	8.46
Local	Babile	64	21.24
Melkassa I	Dire Dawa	41	78.87
Local	Dire Dawa	41	38.79
Melkassa I	Dire Dawa	64	60.04
Local	Dire Dawa	64	21.08

available soil P increased after harvest in both locations (4.2 ppm before sowing and 6.4 ppm after harvest in Babile and 16.6 ppm before sowing and 21.2 ppm after harvest in Dire Dawa). Yield and almost all other parameters studied were affected significantly by application of N fertilizer, where P fertilizer had a significant effect only on stalk biomass and yield. Interaction effect between nitrogen and phosphorus fertilizer were significant for yield. Among all of the N and P treatment combinations, maximum grain yield of maize 3868 kg/ha in Babile and 5069 kg/ha in Dire Dawa were obtained with the application of 64 kg N/ha and 46 kg P_2O_5/ha in both locations. Melkassa I recorded the highest value for yield and other parameters, where the variety Local showed the least value for yield in both locations. Nitrogen and phosphorus concentrations and uptakes in the maize varieties increased with increasing levels of N and P fertilizers. Compared to the control concentration of N in the maize plant of both varieties increased up to the highest levels of N application, indicating possible improvement in the crude protein content of the maize grains. Generally, application of N enhanced uptakes and concentrations of N and P nutrients in the maize tissues over P fertilization. Total plant N and P uptakes by the above ground parts of both varieties in all locations, the sum of uptake by grain yield and stover in kg/ha, increased relatively from the rates of 0 to 64 kg N/ha and from 0 to 69 kg P_2O_5/ha, respectively. In the analyzed samples biomass N uptake was increased with the increase of N rates and 60-68% was found in grain as compared with stover. Efficiency in N fertilizer was calculated for Melkassa I and local maize varieties in both locations and Melkassa I maize variety had a higher efficiency of N fertilizer than the local maize variety in both locations, indicating that Melkassa I produced much more grain and was thus more efficient at converting fertilizer nitrogen into grain as its harvest index was 0.495, whereas for the Local variety was 0.4.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the ARTP program of Ethiopian Agricultural Research Organization for funding the study. Deep appreciation is expressed to Mr. Watatu, Mr. Masrasha and Mr. Tekalegn for their help in fieldwork and data collection and also to Soil Chemistry Laboratory of Alemaya University, Ethiopia, for the provision of laboratory facilities and sincere collaboration of the staff during the research work.

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