Kasetsart J. (Nat. Sci.) 39 : 338 - 349 (2005)

Growth, Yield Attributes, Yields, and Weed Characteristics as Influenced by Integrated Nitrogen Fertilization and Weed-Control Measures of Maize (*Zea mays* L.) in Central Rift Valley of Ethiopia

Girma Woldetsadik[1] and Sombat Chinawong[2]

ABSTRACT

An experiment was conducted during the rainy season of 2003 at Dera and Melkassa, to study the influence of nitrogen fertilizer levels and weed control measures on growth, yield attributes, yields, and weed characteristics of maize (*Zea mays* L.) under rainfed condition. The experimental treatments were split plot design, comprising four nitrogen fertilizer levels [N_0, control, N_1, 10, N_2, 20, and N_3, 30 kg N/ha in main plots and four weed control measures [W_0, weedy check, W_1, atrazine/s-metolachlor at 3.0 kg/ha (pre-emergence); W_2, atrazine/s-metolachlor at 3.0 kg/ha + 2, 4-D at 1.0 kg/ha (pre + post-emergence); and W_3, 2, 4-D at 1.0 kg/ha (post-emergence)] in sub–plots and were replicated thrice.

Total biomass, straw yield, harvest index, plant height and lodging percentage were increased with an increase in N levels at both sites. Application of 30 kg N/ha was found helpful in reducing the dry matter accumulation by weeds probably because nitrogen requirement of weeds and crop was met at this level and crop could compete better with weeds due to increased growth. Leaf area increased with an increase in nitrogen, being maximum at 30 kg N and minimum in the control at Dera and Melkassa, respectively. Weed control measures not only increased the leaf area, yield attributes and the grain yield of maize but also decreased the weed population and dry matter of weeds. Suppression of weeds by weed-control measures resulted in better growth and development of maize. Weed population and dry matter production of weeds were effectively suppressed with pre and post-emergence application of atrazine/s-metolachlor at 3.0 kg/ha + 2, 4- D at 1.0 kg/ ha increased the grain yield of maize by 13.4 % over control non-weeded.

Key words: maize, nitrogen, weed control, straw mulch, ridging

INTRODUCTION

Maize (*Zea mays L.*) is one of the most important cereal crops grown during rainy season in Ethiopia. However, the productivity of the crop is low. Fertility is among the greatest constraints to maize production in Ethiopia. Nitrogen influences the plant growth, yield attributes and quality of the product. Nitrogen application among the nutrients is of fundamental importance owing to its deficiency in Ethiopian soils. The low nutrient contents in the soil are caused by removal of surface soil by erosion, crop removal of nutrients from the soil, little or no fertilizer application, total removal of plant residues from the farmland and burning, and lack of a proper crop rotation program. Low fertility of the soil and the prevalent inability of the farmers to apply chemical fertilizers

[1] Bako Agricultural Research Center P. O. Box. 3, Ethiopia.
[2] Department of Agronomy, Faculty of Agriculture, Kasetsart University, Kamphaeng Saen, Nakhon Pathom 74130, Thailand.

Received date : 28/12/04 Accepted date : 27/04/05

aggravate the problem. Supplementing the nutrient, especially nitrogen, through inorganic sources not only supplies the required nutrients for crop growth but also well recognized that the application of chemical fertilizers or organic manure's increases the productivity of dry land crops.

Weed infestation with complex flora has become a serious problem in the maize-growing areas of the country. The weeds emerging with the crop competing with them for nutrients especially nitrogen, grow faster and utilize it in larger amounts than the crop, resulting in poor crop yield (Singh and Reddy, 1988). Panwar *et al.* (1992) reported that the reduction in grain yield of maize by weeds was 20-40 %. Different herbicides are used alone or in combination to eliminate the weeds but their efficiencies differ because of the narrow spectrum of weed control. Application of more than one herbicide is useful, particularly in the absence of an effective broad-spectrum herbicide in maize to control highly diversed weed population. It is therefore imperative to provide weed free environment to enable it to utilize the costly input well. However, such information with weed control in the semi-arid areas of central rift valley region is scanty. Hence a study was carried out to find the effect of nitrogen fertilizer levels and weed control measures on yield and yield–contributing characters of maize under rainfed conditions.

MATERIALS AND METHODS

Study site and agronomic practices

An experiment was conducted during the rainy season of 2003 at the Dera Sub center and Melkassa Agricultural Research Center. The soil types are diverse, most of them are shallow and the organic matter contents are 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 soil are either clay loam, loam or sandy loam. The treatment consisted of four levels of nitrogen [F_0, F_{10}, F_{20}, and F_{30}] in main plots and four measures of weed control [W_0, control non-weeded, W_1, atrazine/s-metolachlor at 3.0 kg/ha (pre-emergence); W_2, atrazine/s-metolachlor at 3.0 kg/ha and 2, 4-D at 1.0 kg/ha (pre and post-emergence); W_3, 2, 4-D at 1.0 kg/ha (post-emergence)] in sub-plots. Thus 16 treatment combinations were tested in a split plot design with three replications. Maize variety Melkassa-1 double top-cross early duration was sown in rows 25 cm apart on 8 July 2003 and 29 June 2003 at Dera and Melkassa, respectively. Full dose of P_2O_5 and half dose of N were applied basal and remaining N was top-dressed 30 days after sowing. Nitrogen was applied through urea per treatment. Maize crop was sown in line at the rate of 30 kg/ha. The total plot size was 4.5 x 4.0 m. The crop emerged on 17/7/2003 and 11/7/2003 at Dera and Melkassa, respectively. Pre-emergence herbicide of atrazine/s-metolachlor at 3.0 kg/ha was given within 3 days before maize planting and before weeds began to emerge. Post -emergence herbicide of 2, 4-D at 1.0 kg/ha was also applied three weeks after maize emergence. Hand operated manual knapsack sprayer was used for herbicide application. Maize was harvested on 28 and 17 November 2003 at Dera and Melkassa, 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 temperature from 26.9°C to 29.8°C. The rainfall pattern during the crop growth period was higher as compared with the previous years. The total amount of rainfall received were 813.8 mm and 885.7 mm at Dera and Melkassa, respectively.

Dry weight of the crop was measured 30, 50, 75 and 90 days after maize emergence. Grain and straw (shoot only) yields, and 1,000-grain weight were also obtained on an oven-dried basis on a dry weight base of 60°C. Harvest index was calculated as the ratio of the dry grain yield to the total dry matter yield (grain plus straw).

Data analysis

The data were analyzed using the Statistical Analysis System (SAS), Inc., 1989. 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 significant.

RESULTS AND DISCUSSION

Grain yield and 1,000-grain weight

Grain yield of maize was significantly influenced by nitrogen fertilizer levels only at Melkassa (Table 1). At Melkassa, the differences in grain yield between 20 and 30 kg N/ha were non-significant, whereas these treatments were significantly higher than 0 and 10 kg N/ha. At Melkassa, application of 30 kg N (4992 kg/ha) and 20 kg/ha increased the grain yield (4851 kg/ha) compared with the control (4230 kg/ha) while these treatments were significantly higher than 0 and 10 kg N/ha. This result indicated that higher yield could be obtained even at low N rate by effective control of weed. The increase in grain yield under efficient weed control measures with increasing levels of nitrogen fertilizer was owing to reduced depletion of nutrient by weeds and concomitant increase in nutrient uptake by crop plants ultimately resulted in marked improvements in yield attributes.

The improvement in growth and yield components owing to chemical weed control was also reflected by grain yield. Pre and pre + post-emergence applications of atrazine/s-metolachlor and atrazine/s-metolachlor + 2, 4-D gave significantly higher yield than all other treatments in both sites. Although the yield from 2, 4–D applied plot was significantly higher than from non-weeded control, the values were relatively lower as compared with pre and post-emergence applications of atrazine/s-metolachlor and 2, 4-D. The effective initial weed control through pre and post-emergence application of atrazine/s-metolachlor + 2, 4-D might minimize crop-weed competition resulting in higher yields. On the contrary, uninterrupted weed growth in non-weeded control plots and for four weeks in plots receiving post-emergence application of 2, 4-D encountered a considerable competition with the crop for nutrients resulting in marked yield reduction. Significant improvement in yield attributes could be attributed possibly to increased availability of nutrients, moisture, space and sunlight to the crop as a consequence of reduced weed competition under these treatments. Thakur and Sharma (1966) also reported improvement in grain yield and 1,000-grain weight of maize to be due to reduced weed crop competition. Differences in maize grain yield and 1,000-grain weight among weed control treatments were directly associated with differences in weed control efficiency

Nitrogen caused a non-significant variation in the 1,000-grain weight (Table 1). This might be due to the higher number of grains/cob competing for the available nutrients, delayed grain formation and lodging under the higher levels of nitrogen (Agarwal *et al.,* 1972). In comparison to non-weeded control, weed control measures significantly increased the 1,000-grain weight at both sites.

Pre-emergence application of atrazine/s-metolachlor, post-emergence of 2, 4-D and pre and post-emergence applications of atrazine/s-metolachlor + 2, 4-D were at par with each other for grain yield at both sites except at for 1,000-grain weight. Lower weed population under pre-emergence application of atrazine/s-metolachlor + 2, 4-D treatments reduced crop weed competition and the plants had not to face either nutrient or moisture stress due to heavy weed infestation.

Table 1 Effects of nitrogen and weed control on grain yield and 1,000-grain weight of maize.

Treatment	Grain yield (Kg/ha)		1,000 grain weight (g)	
	L_1	L_2	L_1	L_2
N level kg/ha				
0	2737	4230[b]	17.13	23.10
10	2882	4436[b]	17.15	24.58
20	2994	4851[a]	17.75	24.75
30	3064	4992[a]	17.80	25.08
LSD (P=0.05)	1.94	2.87	1.06	2.15
F-test	NS	*	NS	NS
Weed control measures				
W_0	2803[b]	4545[c]	16.30[c]	23.67[b]
W_1	3033[a]	5007[ab]	17.83[ab]	25.30[a]
W_2	3063[a]	5153[a]	18.43[a]	26.00[a]
W_3	2978[a]	4705[b]	17.28[bc]	25.00[a]
CV %	5.62	11.09	7.39	5.95
LSD (P=0.05)	1.41	4.44	1.09	1.25
F-test	**	**	**	**

** = Significant at P<0.01 using LSD, * = P<0.05 using LSD, NS = Not significant

L_1 = Dera and L_2 = Melkassa. Values in the same column followed by the same letter are not significantly different at the ($P \leq 0.05$) according to protected LSD test.

Growth and development characteristics of maize

Total biomass, straw yield and harvest index were found to increase with an increase of N fertilizer level (Table 2). They were also significantly influenced by weed control measures for total biomass yield, straw yield and harvest index. The interaction of nitrogen fertilizer levels and weed control measures for total biomass yield, straw yield and harvest index were non-significant.

Straw yield increased by the application of pre + post-emergence application of atrazine/s-metolachlor + 2, 4-D at both sites. The effective initial weed control through pre + post-emergence applications of atrazine/s-metolachlor + 2, 4-D might not be able to minimize crop-weed competition resulting in higher straw yield. In respective of weed control measures there was significant increase in total biomass yield of herbicidal weed control.

Nitrogen fertilizer levels did not significantly influence harvest index but increased with increasing nitrogen fertilizer levels up to 30 kg N/ha at both sites. Weed control treatments recorded significantly higher values of harvest index than the non-weeded control. Maximum values of these indices were recorded in all herbicidal treatments, which were found to be at par with each other. A significant reduction in harvest index was found under non-weeded control. Soil type (sandy loam) and high June, July and August rainfall might be responsible for the increase in harvest index. Ample early season moisture levels, conducive to good crop canopy development, could result in more leaf area and thus more rapid depletion of soil water and development of moisture stress during a period of low rainfall.

Table 2 Effects of nitrogen and weed control on growth and development characteristics of maize.

Treatment	Total biomass (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	L_1	L_2	L_1	L_2	L_1	L_2
N level kg/ha						
0	7.49	10.37	4.49	6.22	35.3	59.0
10	7.69	10.70	4.60	6. 30	35.6	60.4
20	7.74	10.90	4.74	6.29	38.3	65.8
30	7.99	10.94	5.00	6.78	39.3	66.0
LSD (P=0.05)	0.86	1.36	1.08	1.52	7.54	14.41
F-test	NS	NS	NS	NS	NS	NS
Weed control measures						
W_0	6.59^b	9.82^b	4.46^b	5.22^b	35.8^a	54.0^b
W_1	7.17^a	11.14^a	4.84^{ab}	7.02^a	38.7^b	64.5^a
W_2	7.26^a	11.49^a	5.02^a	7.27^a	41.5^b	68.2^a
W_3	6.77^{ab}	10.46^{ab}	4.54^{ab}	5.89^{ab}	38.5^b	63.7^a
CV %	9.52	12.25	14.16	26.08	8.79	18.29
LSD (P=0.05)	0.56	1.00	0.51	1.26	2.86	9.62
F-test	*	*	*	*	**	*

** = Significant at P<0.01 using LSD, * = P<0.05 using LSD, NS = Not significant

L_1 = Dera and L_2 = Melkassa. Values in the same column followed by the same letter are not significantly different at the ($P \leq 0.05$) according to protected LSD test.

Growth and yield attributes of maize

Nitrogen fertilizer levels did not significantly influence lodging percentages, but it increased with increasing nitrogen fertilizer levels up to 30 kg N/ha at both sites. The higher lodging percentage at Melkassa might be due to high residual effect of fertilizer in the soil than Dera. Lodging incidence increased with increase in the level of nitrogen up to 30 kg N/ha at Melkassa.

Lodging was affected by weed control measures only at Melkassa. Among weed control treatments, atrazine/s-metolachlor + 2, 4-D recording the highest lodging was significantly higher than atrazine/s-metolachlor and post-emergence application of 2, 4-D which were at par with each other at Melkassa (Table 3). Non-weeded control recorded the lowest lodging percent at both sites.

Contribution of the weed control measures towards the enhancement of growth and development characters could be ascribed to their effect in reducing the crop weed competition and hence better utilization of natural and applied inputs by crop plants. Kaushik and Gautam (1984) also reported improvement of growth and development due to elimination severe in crop weed competition in maize.

Plant height increased with the increasing nitrogen fertilizer levels up to 30 kg N/ha at Dera and Melkassa. The differences in plant height between 10 and 30 kg N/ha were significant. Weed control treatments improved plant height significantly compared with non-weeded control only at Melkassa. Between the weed control treatments, although 2, 4-D and atrazine/s-metolachlor + 2, 4-D applications recorded the maximum plant heights, they were at par with each. All weed control treatments surpassed the non-weeded control in Melkassa.

All the herbicidal weed control treatments

Table 3 Effects of nitrogen fertilization and weed control on growth and yield attributes of maize.

Treatment	Lodging (%)		Plant height (cm) at harvest	
	L_1	L_2	L_1	L_2
N level kg/ha				
0	4.50^{b}	12.83^{c}	166.40^{b}	188.72^{b}
10	5.00^{ab}	15.58^{b}	167.73^{b}	192.17^{b}
20	5.67^{ab}	16.08^{a}	170.03^{ab}	196.57^{ab}
30	6.17^{a}	16.42^{a}	175.06^{a}	198.25^{a}
LSD (P= 0.05)	5.44	5.45	13.61	8.38
F-test	*	*	*	*
Weed control measures				
W_0	5.25	11.92^{c}	169.43	187.51^{b}
W_1	5.33	15.33^{b}	171.18	196.28^{a}
W_2	5.58	18.83^{a}	171.95	198.08^{a}
W_3	5.17	14.83^{bc}	166.68	193.83^{ab}
CV %	71.53	25.41	5.07	4.50
LSD (P=0.05)	3.21	3.26	7.26	7.35
F-test	NS	**	NS	*

** = Significant at P<0.01 using LSD, * = P<0.05 using LSD, NS = Not significant
L_1 = Dera and L_2 = Melkassa. Values in the same column followed by the same letter are not significantly different at the ($P \leq 0.05$) according to protected LSD test.

did not significantly influenced plant height compared with non-weeded control. Pre and post-emergence application of atrazine/s-metolachlor + 2, 4-D although recorded the maximum plant height, it was on a par with herbicidal weed control treatments significantly surpassed the non-weeded control only in Melkassa site. The shortest plant heights were registered in post-emergence of 2, 4-D and non-weeded control treatments at Dera and Melkassa, respectively. This may be due to the shading effect of weeds present in the plots without herbicide and poor control of grass weeds by 2, 4-D.

Dry matter yields of maize

Nitrogen fertilizer levels significantly affected the maize dry matter yield 30, 50 and 75 days after maize emergence except 30 days after maize emergence at Dera and 90 days after maize emergence at both sites.

The least maize dry matter yield was registered under non-weeded control. Lower dry matter yield of maize in non-weeded control plot was due to severe weed competition with crop plants for nutrients, light and moisture and impaired the growth of the crop which could not express its full yield potentially (Gautam, 1992).

At early growth stage (30 DAE), the highest dry matter yield was recorded from atrazine/s-metolachlor + 2, 4-D and pre–emergence application of atrazine/s-metolachlor treatments at Dera and Melkassa, respectively. 50, 75 and 90 days after maize emergence, pre + post-emergence application of atrazine/s-metolachlor + 2, 4-D treatments produced significantly higher dry matter yield of maize than herbicidal weed control treatments. Non-weeded control registered the least dry matter yield of maize at all weed control measures under all growth stages (Table 4).

Application of weed control measures had

Table 4 Effects of nitrogen and weed control on dry matter yield 30, 50, 75, and 90 days after emergence of maize.

Treatment	Maize dry matter (g/plant)							
	30 days		50 days		75 days		90 days	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
N level kg/ha								
0	36.15	74.41^{b}	84.86^{b}	131.04^{b}	120.93^{b}	131.04^{b}	168.57	189.13
10	37.62	77.57^{b}	90.02^{ab}	161.50^{ab}	146.44^{ab}	136.83^{ab}	164.69	199.57
20	40.01	83.45^{ab}	93.08^{ab}	169.98^{a}	151.90^{ab}	149.95^{ab}	167.78	200.30
30	40.41	93.35^{a}	136.18^{a}	171.70^{a}	155.14^{a}	156.71^{a}	170.02	200.60
LSD (P=0.05)	18.14	31.38	32.38	34.86	59.07	24.41	21.55	29.21
F-test	NS	*	*	*	*	*	NS	NS
Weed control measures								
W_0	31.71^{b}	76.22^{c}	78.24^{c}	142.80^{c}	126.19^{b}	115.10^{b}	163.29^{b}	194.06^{b}
W_1	40.69^{ab}	81.16^{b}	100.15^{ab}	160.78^{b}	145.52^{ab}	151.45^{ab}	167.98^{ab}	199.01^{ab}
W_2	46.62^{a}	92.45^{a}	110.44^{a}	183.05^{a}	164.58^{a}	169.64^{a}	172.45^{a}	207.72^{a}
W_3	35.19^{b}	78.95^{b}	84.36^{b}	146.58^{ab}	138.13^{b}	138.34^{ab}	166.71^{ab}	198.80^{ab}
CV%	32.10	26.69	27.46	31.75	20.60	30.54	5.86	10.45
LSD (P=0.05)	10.43	18.48	21.58	42.35	24.90	36.96	8.29	17.61
F-test	*	**	*	**	*	*	*	*

** = Significant at P<0.01 using LSD, * = P<0.05 using LSD, NS = Not significant, L_1 = Dera and L_2 = Melkassa. Values in the same column followed by the same letter are not significantly different at the ($P \leq 0.05$) according to protected LSD test.

a significant effect both at earlier and latter growth stages of maize it had a significant effect on maize dry matter production. Almost at all growth stages maize dry matter yields were increased with nitrogen fertilizer levels as compared with no fertilizer application. The highest maize dry matter yield was recorded from a combination of atrazine/s-metolachlor + 2, 4-D herbicide treated plots (Table 4). The increase of atrazine/s-metolachlor + 2, 4-D herbicide application over the weedy check ranges from 6.3 to 67.7 %.

Weed population and dry matter accumulation by weeds

The major weed flora observed in experimental plots consisted of *Argemone mexcana, Chenopodum fasculosum, Foeum vulgare, Cyprerus rotundus, Eragrostis spp, Sorghum arandeceum, and Setaria verticillata.* Population of grassy weeds, non-grassy weeds and sedges constituted 28.2, 56.1 and 15.7% of total weed population at Dera, and 18.9, 65.1 and 16.0 % at Melkassa, respectively. However, on dry weight basis, these weeds in non-weeded control plot constituted 47.6, 18.3 and 34.1% of total weed dry weight at Dera, and 46.1, 28.3 and 25.6% at Melkassa, respectively.

Crops and weeds generally compete for the same nutrient pool. Increasing the level of soil fertility can alter the competitive interacting between crops and weeds. Weed resource use often increases more rapidly with added nutrients, resulting in a greater ability of the weeds to compete for other resources (Minotti and Sweet, 1981; Walker and Buchanan, 1982; Berkowitz, 1988). In addition, the application of nutrients to a soil, particularly nitrogen, can stimulate germination of dormant weed seeds (Cavers and Benoit, 1989). Weed population was significantly influenced due to nitrogen fertilizer levels in both sites except at 30 and 90 days after maize emergence at Melkassa (Table 5). However, a marginal increase was

Table 5 Effects of nitrogen and weed control on weed population and weed dry matter accumulation at 30, 50, 75, and 90 days after maize emergence.

Treatment	Weed population (no/m^2)						Weed dry matter (kg/ha)			
	30 days		50 days		75 days		90 days		Weed dry matter	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
N level kg/ha										
0	7.75^{c}	15.25	19.83^{b}	20.25^{b}	22.08^{b}	27.33^{b}	38.50^{b}	44.50	83.19^{a}	25.29^{a}
10	26.67b^{c}	20.17	24.92^{ab}	27.50^{ab}	23.58^{b}	33.25^{ab}	37.25^{b}	48.17	36.61^{bc}	23.67^{ab}
20	29.08^{b}	20.75	26.25^{ab}	32.83^{ab}	26.25^{b}	33.35^{ab}	49.08^{ab}	52.67	54.43^{ab}	18.92^{b}
30	57.42^{a}	22.25	32.00^{a}	42.33^{a}	36.00^{a}	34.83^{a}	58.00^{a}	60.08	21.78^{c}	17.46^{b}
LSD (P=0.05)	21.23	12.15	21.0	19.72	18.52	12.97	21.89	16.88	31.64	20.96
F-test	**	NS	*	*	*	*	*	NS	**	*
W_0	42.92^{a}	33.08^{a}	40.42^{a}	34.75^{a}	35.58^{a}	36.33^{a}	57.83^{a}	61.83^{a}	58.00^{a}	56.47^{a}
W_1	26.58^{b}	15.08^{bc}	23.92^{b}	30.17^{ab}	24.92^{ab}	31.75^{ab}	41.00^{ab}	47.83^{b}	21.97^{c}	6.44^{b}
W_2	21.17^{c}	8.92^{c}	16.50^{b}	25.42^{b}	23.08^{b}	27.58^{b}	37.83^{b}	45.75^{b}	16.68^{c}	5.75^{b}
W_3	30.25^{ab}	21.33^{b}	22.17^{b}	32.58^{ab}	24.33^{ab}	33.25^{a}	46.17^{ab}	50.00^{ab}	39.38^{b}	23.41^{b}
CV %	89.32	52.21	55.49	50.13	50.14	34.39	44.12	30.02	115.24	97.58
LSD (P=0.05)	22.75	8.62	12.04	12.98	11.40	9.34	16.99	12.99	47.58	18.92
F-test	*	**	**	*	*	*	*	*	**	**

** = Significant at P<0.01 using LSD, * = P<0.05 using LSD, NS = Not significant, L_1 = Dera and L_2 = Melkassa. Values in the same column followed by the same letter are not significantly different at the ($P \leq 0.05$) according to protected LSD test.

observed in the total numbers of weed with the increase in nitrogen levels up to 30 kg N/ha. Significant differences in weed biomass production were detected among treatments in both sites. Nitrogen fertilizer levels had an effect on weed biomass production at both sites.

Weeds were not separated into grass and broad species for biomass determination. In all weeds, dry matter did not increase with weed population density (Table 5). All herbicide treatments significantly reduced weed population over non-weeded control at all recorded stages of growth in controlling weeds (Table 5). The application of atrazine/s-metolachlor as pre-planting + 2, 4-D as post-emergence was most effective and this was found to be significantly more superior in reducing weed population of all weed types than other treatments including pre-emergence application of atrazine/s-metolachlor, which was proved to be the second best treatment. The reduction in weed density and dry weight might be attributed to broad-spectrum and season-long weed control properties exhibited by the herbicide mixtures and sequential applications of 2, 4-D. Lower weed population under this treatment reduced the crop-weed competition and the plants had not face either nutrient or moisture stresses due to heavy weed infestation.

Among the herbicidal treatments, the poorest performance was observed in plots treated with application of 2, 4-D as post-emergence. This might be due to poor control of grass weeds by 2, 4-D. Kaushik and Gautam (1984) reported similar results. In general, differences in weed density were more apparent at the early evaluation period than later in the season. At all stages of observation, non-weeded control recorded significantly higher weed population and dry weight than all other treatments.

Increasing nitrogen fertilizer levels did not increase dry matter accumulation by weeds at both sites while they were significant at both sites for nitrogen fertilizer levels. The highest dry matter accumulation by weeds was observed from 0 kg N/ha at both sites followed by 20 and 10 kg N/ha at Dera and Melkassa, respectively. Application of 30 kg N/ha was found to be helpful in reducing dry matter accumulation by weeds which was probably because nitrogen requirements of weed and crop were met at this level and crop could compete better with weeds due to increased growth. Higher nitrogen fertilizer levels recorded significantly higher weed control and weed dry biomass than no fertilizer in both sites.

Dry matter accumulation by weeds was reduced markedly by all three herbicide treated plots owing to the marked reduction in weed population and dry matter accumulation by weeds. The application of atrazine/s-metolachlor as pre-planting + 2, 4-D as post-emergence was most effective and was found to be significantly superior followed by pre-emergence application of atrazine/s-metolachlor in reducing the dry matter accumulation by weeds.

Among herbicidal treatments, 2, 4-D recorded higher weed dry weight and lower weed control efficiency, indicating its effectiveness than other herbicidal weed control treatments.

Leaf area

Results indicated that applications of nitrogen fertilizer level significantly increased the leaf areas of maize up to 30 kg N/ha at both sites. As reported by Kharshe and Khuspe (1970), the leaf area also increased with an increase in nitrogen, being maximum (2540.9 and 2865.5) at 30 kg N/ha and minimum (2140.8 and 2202.3) in the non-weeded control at Dera and Melkassa, respectively. The maize plant with high rates of N produced higher maize leaf area than lower rates of N. This may be due to the high amount of nutrient available in the soil for crop growth and consequently more nitrogen uptake by the plants. Increase in leaf area was due to synthesis of more photosynthesis with nitrogen application. This might result in better partitioning of photosynthates in yield attributes with nitrogen application. Increase in LAI and yield attributes of maize resulted in significant improvement in biomass and seed yield of maize in both sites.

All weed control measures significantly increased the leaf areas of maize except at Melkassa site (Table 6). Combined application of pre and post–emergence applications of atrazine/s-metolachlor + 2, 4-D and pre-emergence application of atrazine/s-metolachlor recorded the maximum leaf areas as compared to non- weeded control at Dera and Melkassa, respectively. This was due to the combined effect of pre + post–emergence application of atrazine/s-metolachlor + 2, 4-D. Owing to increase in leaf area due to weed control measures and early season ample moisture levels, the maize harvested more energy and finally produced better yield attributes. As a result of increase in leaf areas and yield components, the seed and biomass yields of maize were also significantly enhanced by weed control measures in both sites.

CONCLUSION

Grain yield increased with nitrogen fertilizer levels owing to reduced depletion of nutrients by weeds and concomitant increase in nutrient uptake by crop plants ultimately resulting in marked improvements in the yield attributing characters. Atrazine/s-metolachlor at 3.0 kg/ha, 2, 4-D at 1.0 kg/ha and atrazine/s-metolachlor at 3.0 kg/ha + 2, 4-D at 1.0 kg/ha were at par with each other for grain yield at the both sites except at for 1,000-grain weight but significantly superior than weedy check. Total biomass, straw yield, harvest index, plant height and lodging percent were increased with an increase in N levels at both sites. The straw yield increased due to application of atrazine/s-metolachlor and 2, 4-D at Dera and Melkassa. Atrazine/s-metolachlor recorded the highest lodging and significantly higher than herbicides

Table 6 Leaf areas as influenced by nitrogen fertilization and weed control measures in maize.

Treatment	Leaf area/plant at 50 days (cm^3 /ha)	
	L_1	L_2
N level kg/ha		
0	2140.8	2202.3^{b}
10	2287.2	2594.5^{ab}
20	2465.9	2791.1^{ab}
30	2540.9	2865.5^{a}
LSD (P=0.05)	46.2	51.21
F-test	NS	*
Weed control measures		
W_0	2043.7^{b}	2546.4
W_1	2504.9^{a}	2715.3
W_2	2568.2^{a}	2690.3
W_3	2318^{ab}	2510.5
CV%	21.86	21.06
LSD (P=0.05)	34.39	43.76
F-test	*	NS

** = Significant at P<0.01 using LSD, * = P<0.05 using LSD, NS = Not significant

L_1 = Dera and L_2 = Melkassa. Values in the same column followed by the same letter are not significantly different at the ($P \leq 0.05$) according to protected LSD test.

weed control measures that were at par with each other at Melkassa.

Although atrazine/s-metolachlor at 3.0 kg/ha + 2, 4-D at 1.0 kg/ha recorded the maximum plant height but it was at par with atrazine/s-metolachlor at 3.0 kg/ha + 2, 4-D at 1.0 kg/ha but significantly surpassed the weedy check in Melkassa site. Application of herbicides to plants increased the dry matter yield at all stages of growth significantly in both sites. Maximum increase in grain yield was recorded in atrazine/s-metolachlor at 3.0 kg/ha + 2, 4-D at 1.0 kg/ha which was significantly superior to that obtained under atrazine/s-metolachlor at 3.0 kg/ha, 2, 4-D at 1.0 kg/ha, and non-weeded control.

Application of 30 kg N/ha was found helpful in reducing the dry matter accumulation by weeds probably because nitrogen requirement of weeds and crop was met at this level and crop could compete better with weeds due to increased growth. Leaf area increased with an increase in nitrogen, being maximum (2504.9 and 2865.5) at 30 kg N and minimum (2140.8 and 2202.3 in the non-weeded control at Dera and Melkassa, respectively. Atrazine/s-metolachlor at 3.0 kg/ha + 2, 4-D at 1.0 kg/ha treatment recorded the maximum leaf area as compared with weedy check. As a result of increase in leaf area and yield components, the grain and biomass yield of maize was also significantly enhanced by weed control measures in two sites. Better weed control measures by atrazine/s-metolachlor + 2, 4-D herbicides increased the husked cob weight by 29.9% over the control at Melkassa.

The response of nitrogen fertilizer on most of the parameters was not observed. This might be due to residual effect of fertilizer in the soil. It needs further study in low fertile soil in conjunction with *in situ* moisture conservation practices. The results and information obtained would expedite the development of management strategies to reduce population of weeds and to manage the success ional dynamics of weeds in weed control measures.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the management of Melkassa and Kulumsa Agricultural Research Centers for the technical and logistic support during the execution of this experiment. The study was financed by Oromia Agricultural Research Institute through Agricultural Research and Training Project (ARTP).

LITERATURE CITED

Agarwal, J P., S. Singh, and A. N. Khanna, 1972. Optimum time of sowing and nitrogen dose for dwarf wheat. **Indian J. Agron.** 17: 147-150.

Berkowitz, A. R. 1988. Competition for resources in weed crop mixtures, pp. 89-119. *In* M. A. Alteri and M. Liebman (eds.). **Weed Management in Agro ecosystems: Ecological approaches**. CRC. Press, Boca Raton. F. L.

Cavers, P. B. and D. l. Benoit. 1989. Seed bank in arable land, pp. 309-328 *In* M. A. Leck, V. T. Parker and R. L. Simpson (eds.). **Ecology of Soil seed Banks**. Academic Press, San Deigo.

Gautam, K. C. 1992. Influence of nitrogen level and crop densities on growth of weeds and wheat. Abstract. Annual weed science conference. **Indian Soc. Weed Sci.,** Hissar, 55 p.

Kaushik, S. K. and Gautam. 1984. Weed control studies in Pearl millet under rainfed conditions. **Indian J. Agron**. 29(10) : 31.36.

Kharche, R. M. and V. S. Khuspe. 1970. Effect of graded doses of nitrogen and phosphate supplied through different sources on growth, yield and quality of hybrid maize. **Research J. Mahatama Phule** Agricultural University, Pune 1(2): 85-91.

Minotti, P. L. and R. D. Sweet. 1981. Role of crop competition in limiting losses from weeds, pp. 351-367. *In* M. D. Pimentel (ed.). CRC **Handbook of Pest Management in Agriculture,** Vol. 11. CRC Press, Boca Raton, FL.

Panwar, R. S., R. K. Malik and R. S. Malik 1992. Effect of weedicides on weed control in wheat (*Triticum aestivum*) crop. **Indian J. Agron.** 37 (2): 320-323.

SAS Institute. 1989. SAS/STAT. **User's Guide Version.** 6.4th ed. SAS Institute, Cary. NC.

Singh, R. P. and B. G. Reddy, 1988. Weed growth and wheat response to N levels and weed-control methods. **Indian J. Weed Sci.** 29 (4): 1-6.

Thakur, D.R. and V. Sharma, 1996. Integrated weed management in rain-fed maize. **Indian J. Weed Sci.** 28 (3, 4): 207-208.

Walker, R. H. and G. D. Buchanan. 1982. Crop manipulation in integrated weed management system. **Weed Sci.** 30 {Supply. 1}: 17-24.