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Growth and yield of maize (*Zea mays* L.) in response to herbicide application in the coastal savannah ecozone of Ghana

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ABSTRACT

Field studies were conducted at the University of Ghana, Legon farm from June to September 2005 to investigate the growth and yield of maize (*Zea mays*) in response to herbicide application. Four groups of herbicides; 2,4-D (Bextra and Calliherbe), glyphosate (Kalach 360SL, Fire and Weed Out), Atrazine (Callitraz 500SC and Trazine 500SC) and Paraquat (Gramoxone Super and Benaxone) were used. Each of the named herbicides constituted a treatment, with hand weeding as the control. In all, there were ten treatments and four replicates arranged in a randomized complete block design. Paraquat and gyphosate treatments were applied before sowing; Atrazine and 2,4-D were applied two days after sowing. The compound fertilizer 15-15-15 (N-P-K) at the rate of 250 kg/ha was applied as side dressing 2 WAP. Top dressing with sulphate of ammonia at rate of 125 kg/ha was applied 6 WAP. Analysis of variance (ANOVA) for the data was carried out using (Genstat 5 statistical package, 1997). Significant differences between means were estimated by the Least Significant Difference at 5% level of significance. Results revealed that dry matter accumulation, leaf area were similar in all treatments across the sample period. Glyphosate, Paraquat and Atrazine treatment had dry matter accumulation similar to the control. 2,4-D treatment however had higher dry matter at 2 WAP. Although there was no difference in the number of kernels per plant among the various treatments 2,4-D treatment plots produced 33 to 41% less as compared to the control in yield per hectare.

Keywords: Glyphosate, paraquat, herbicides, maize yield, growth response.

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INTRODUCTION

Maize is one of the most popular food crops on the domestic market and is grown in all the ecological zones of Ghana. It is the basis of many local food preparations and is the main foodstuff for poultry and other livestock (FASDEP, 2002). The main cause of food shortage has been failure of production of food grain to keep pace with the linear increase in population. The feasibility to increase per unit yield is more because yield potential of maize crop has not been realized so far, as there is a large gap between potential and actual yield per acre (Khan et al., 2003). There is a high demand for maize, and opportunity exists to increase production per unit area. The current average yield of 1.5 tonnes per hectare is far below the achievable level of 5 tonnes per hectare (Asenso-Okyere, 2001; FASDEP, 2002). Since maize is an important cereal crop, efforts are being made to narrow the yield gap between potential yield and actual farm yield. The ultimate yields of maize are controlled by a number of genetic and external factors (Ahmed et al., 2001). The yield of maize is greatly affected by weeds in the field. Weeds are a constant source of concern for the successful growth and development of economic crop. They compete with crops for light, moisture, space and nutrients and consequently interfere with the normal growth of crops.

Weed control therefore, is very essential in maize cultivation. The critical period of weed interference in maize is influenced by the competing weed species, the

Table 1. Monthly rainfall, temperature and relative humidity at the experimental area for the period.

Month	Year	Mean total rainfall (mm)	Relative humidity (%)		Temperature (°C)	
			Maximum	Minimum	Maximum	Minimum
June	2005	13.00	97.33	67.33	32.33	27.20
July	2005	12.70	97.83	65.77	31.77	23.81
August	2005	10.30	97.28	62.72	32.00	24.79
September	2005	12.50	97.39	63.23	31.80	27.13

Source: Soil Science Department, University of Ghana.

cultivars, plant density and environmental factors such as light, water, nutrient and allelopathy (Poku and Akobundu, 1985). Yield loss of up to about 39.8% has been reported in maize (Oudejans, 1991). Maize is very susceptible to competition from weeds especially in the early stages of growth; therefore, efficient control at the pre- and early post-emergence stages is essential. Once maize reaches approximately 0.5 m in height, weed control no longer affects yield (Marshall, 2004).

Weed interference not only results in crop losses but also increases insect pest damage, harvesting difficulties and crop contamination (Ohene, 1998). It is generally conceded that the recurrent economic damage to agriculture from weeds far surpasses the more incidental damage inflicted by insect pest, rodents and diseases (Oudejans, 1991). Attention must therefore be focused on weed control measures so as to maintain the competitive ability of the threatened crop by minimizing weed interference during the growth phases of crop. The nature of weed interference influences strongly the choice of weed control measures. The methods of weed control are cultural, biological and chemical. Chemicals are increasingly being used in Ghana and other developing countries for the control of weeds in maize because they offer an effective and relatively inexpensive means for managing cereals weed problems. Several herbicides have been identified for weed control in maize and are applied at various stages of development; hence, they are classified according to their time of application as pre-plant, pre-emergence, or post emergence (G.G.D.P, 1991). Much work has been done on the efficacy of these herbicides on their weed control ability. There is, therefore, the need to evaluate the impact of these herbicides, as an alternative weed control measure, on the growth and yield of maize.

The research work was conducted to investigate into how the growth and yield of maize are affected by the use of some selected herbicides used in controlling weeds.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the University of Ghana Farm Legon, located in the coastal savannah ecozone of Ghana. This area receives a mean annual rainfall of about 800 mm with a range 500 to 1270 mm. The rainfall is highly erratic from the point of view of the time of onset, duration and total from year to year. There are two distinct rainy seasons. The major season begins in March and ends in July while the minor season is from September to November. The mean annual temperature is about 30°C (Table 1).

Experimental design

A randomized complete block design with four replications was used. The treatments involved four categories of herbicides as shown in Table 2.

Cultural practices

The study was carried out from June 2005 to September 2005. Maize variety, Tuxpino, developed by the Grains Development Board of the Crops Research Institute of Ghana was selected for this experiment. Tuxpino is white dent maize, which matures in about 105 days. Seeds were obtained from the Department Crop Science, University of Ghana. Hand weeding was done once to control weeds on untreated plots (control).

All the herbicides were applied using a CP15 knapsack sprayer with a prolijet nozzle. Paraquat and Glyphosate herbicide treatments were applied seven day before sowing but Atrazine was applied two days after sowing and 2,4-D was applied six weeks after germination when plots became infested with weeds. Maize seeds were sown at a spacing of 0.8 m × 0.4 m on 2nd June 2005. Three seeds were sown per hill and the seedlings thinned out to two plants per hill two weeks after emergence. Each plot measured 5.2 m × 5.6 m and the four inner rows of each plots were used for data collection.

Compound fertilizer 15-15-15 (N-P-K) was applied at a rate of 250 kg/ha as side dressing, two weeks after sowing. Top dressing with sulphate of ammonia, at the rate of 125 kg/ha was applied six weeks after emergence. Vegetative growth parameters were measured at two weekly intervals starting from two weeks after planting (WAP) till tenth week when maize had attained full maturity. The maize cobs were harvested 110 days after planting, dehusked and further dried in the sun for three weeks to reduce the moisture level of the grains to 14% before yield records were taken. The data collected was subjected to statistical analysis. Analysis of variance (ANOVA) and correlation, for the data was carried out using (Genstat 5 statistical package, 1997). Significant differences between means were estimated by the Least Significant Difference at 5% level of significance.

RESULTS

Number of leaves per plant

The total number of leaves per plant at 10WAP ranged

Table 2. Treatment, rate of application and time of application of herbicides.

Treatment	Rate of application (a.i) per hectare (kg)	Time of application
Atrazine		
Trazine 500SC	2.0	Pre-emergence
Callitraz 500SC	2.0	Pre-emergence
2,4-D		
Calliherbe	0.54	Pre-emergence
Bextra	0.54	Pre-emergence
Glyphosate		
Kalach 360SL	0.72	Post emergence
Fire	0.72	Post emergence
Weed Out	0.72	Post emergence
Paraquat		
Benaxone	0.3	Post emergence
Gramoxone super	0.3	Post emergence
Control (no herbicide)	-	-

between 12.08 and 13.73 (Table 3). The greatest number of 13.73 leaves was recorded for glyphosate (Weed out) treated plots and lowest of 12.08 was recorded for 2,4-D (Calliherbe) treated plots. This therefore indicates that the herbicide treatments did not significantly influence the growth of leaves of the maize.

Plant height at maturity

Effect of the various herbicides on plant height at maturity is shown in Table 3. The maximum plant height of 146.0 cm was recorded on Glyphosate (Fire) treated plots. The shortest plant height at maturity was recorded for plots treated with 2,4-D (Bextra and Caliliherbe). Plants on the rest of the herbicide treated plots had plant heights between 125.0 and 140.0 cm. There was, however, no significant difference observed for plant height at maturity among the various treatments.

Height of ear above ground

Table 3 shows the effect of the various herbicides on the height of ear above ground level. Herbicide application did not significantly affect the height of ear above ground. The minimum height of 44.8 cm was recorded for control (No herbicide) and maximum for Paraquat (Benaxone).

Dry matter yield (g) at various stages of the maize development as affected by herbicide treatments

Table 4 shows the response of shoot dry matter production of maize to the application of the herbicides. The dry matter yield increased regularly at all developmental stages under all treatments. No significant difference existed in the shoot dry matter at each sampling stage except at 2 weeks after seedling emergence where significant difference was observed between plants on the control, 2,4-D (Calliherbe and Bextra) and Paraquat (Gramoxone Super) treated plots. However, this difference disappeared with time. It is evident from the final dry matter yield obtained 10 weeks after seedling emergence that the application of the herbicides did not significantly affect the accumulation of dry matter by the maize plant.

Grain yield and components of yield of maize as influenced by herbicides

Ear length

Table 5 shows cob length as affected by various herbicide treatments. Cob length was not significantly affected by herbicide application. The maximum length of 11.50 cm was recorded for plants on Glyphosate (Fire and Weed out) treated plots and minimum values of 9.00 cm, was recorded for plants on 2,4-D (Bextra) treated plots.

Number of kernels per ear

The number of kernels per ear is shown in Table 5. Number of kernels per cob was not significantly affected by the various treatments. Maximum number of kernel

Table 3. Maize plant heights, height of ear above ground, leaf area index number of leaves per plant measured at 10 WAP.

Treatment	Plant height at maturity (cm)	Ear height above ground (cm)	Leaf area index	No. of leaves/plant (at maturity)
Atrazine				
Trazine 500SC	125.0	49.0	1.160	13.5
Callitraz 500SC	130.2	46.8	1.123	12.2
2,4-D				
Calliherbe	121.8	47.8	0.980	12.1
Bextra	135.7	51.4	1.410	13.1
Glyphosate				
Kalach 360L	120.1	66.3	1.110	12.7
Fire	143.6	56.7	1.490	13.4
Weed Out	128.5	48.5	1.343	13.7
Paraquat				
Benaxone	140.5	59.9	1.073	13.1
Gramoxone Super	126.1	48.6	1.013	12.8
Control (No herbicide)	126.6	44.8	0.935	13.2
LSD (P = 0.05)	NS	NS	NS	NS

Table 4. Shoot dry weight of maize as influenced by the herbicides at the various sampling stages.

Treatment	Mean total shoot dry weight (g)				
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP
Atrazine					
Trazine 500SC	0.308	4.97	17.2	47.2	77.5
Callitraz 500SC	0.328	3.58	14.4	62.9	80.3
2,4-D					
Calliherbe	0.605	4.19	15.6	55.3	62.4
Bextra	0.555	4.59	15.0	49.9	90.5
Glyphosate					
Fire	0.410	5.53	18.0	58.9	98.4
Weed out	0.360	4.00	14.0	51.7	84.1
Kalach 360SL	0.343	4.16	19.1	46.1	56.5
Paraquat					
Gramoxone super	0.530	5.11	14.3	42.2	60.4
Benaxone	0.255	3.90	17.6	50.7	84.8
Control (No herbicide)	0.305	4.86	11.0	45.0	58.0
LSD (P = 0.05)	0.21	3.52	11.60	21.50	45.60

per ear was (330.70) recorded for plants on glyphosate (Kalach) treated plots and a minimum of (220.90) was recorded for plants on plots treated with 2,4-D (Calliherbe). Except for 2,4-D (Bextra and Calliherbe) grain yield per ear for all the herbicide treated plots was slightly higher than the control. The application of 2,4-D (Bextra) reduced number of kernel per ear by 27%.

Grain weight per ear

Grain weight per ear as influenced by the various

Table 5. Influence of difference herbicides on components of grain yield in maize.

Treatment	Ear length (cm)	Ear diameter (cm)	Number of kernels/ ear	100 seed weight (g)	Grain weight per ear (g)	Grain yield per hectare (kg)
Atrazine Triazine 500SC	10.7± 0.9	3.7 ± 0.1	270.8 ± 11.1	24.6± 2.5	66.9 ± 8.3	4581± 473.5
Callitraz 500SC	10.1 ± 0.5	3.8 ± 0.0	270.2 ± 23.2	22.6± 1.5	60.7 ± 5.5	4273 ± 377.7
2,4-D Calliherbe	9.0 ± 0.4	3.5 ± 0.1	220.9 ± 13.4	19.2 ± 2.2	41.9 ± 3.8	3159 ±183.6
Bextra	10.9 ± 0.5	3.9 ± 0.0	330.7 ± 38.1	25.0 ±3.6	79.7 ± 9.7	3318 ±161.0
Glyphosate Fire	11.5 ±0.9	4.0 ± 0.1	326.3 ± 34.7	23.1 ± 1.5	75.0 ± 7.7	5081± 576.6
Weed out	11.5 ± 0.7	3.9 ± 0.2	306.8 ± 15.7	25.2 ± 2.0	78.0 ± 8.8	4974 ± 531.7
Kalach 360SL	9.4 ± 0.6	3.5 ± 0.2	243.4 ± 25.5	19.4 ± 2.6	47.2 ± 8.7	3913 ± 380.9
Paraquat Gramoxone Super	9.6 ± 0.6	3.7 ± 0.1	285.2 ± 22.4	21.5 ±1.2	61.4 ± 6.8	4960 ± 225.5
Benaxone	10.6 ± 0.4	4.0 ± 0.1	286.3 ± 25.4	24.5 ±2.3	70.7 ± 11.0	4771 ± 503.5
Control	9.2 ± 0.9	3.7 ± 0.2	248.3 ± 33.3	23.8 ± 0.5	58.6 ± 7.1	3682 ± 506.1
LSD (P = 0.05)	N.S.	N.S.	N.S	NS	24.19	1268.8

N.S: Not significant.

herbicide treatments is shown in Table 5. Significant difference occurred among the various treatments in grain weight per ear. Mean values showed a maximum weight of 79.7 g plants on plots treated with Glyphosate (Kalach) and a minimum of 41.9 and 47.2 g for plants treated with 2,4-D (Calliherbe and Bextra), respectively. However, there was no significant difference between the control and other treatments.

100 kernels weight

The hundred seed weight for all the treatments ranged between 19.21 and 25.23 g at 14% moisture level (Table 5). Plants on plot treated with Glyphosate (Weed out) produced the heaviest grains with lightest grain weight recorded for 2,4-D (Calliherbe). Regardless of the herbicide treatments, there was no significant difference observed in hundred seed weight. However, 2,4-D treated plots recorded a reduction in weight of seeds.

Ear diameter (cm)

There were no significant in cob diameter among treatments. Cob diameter, ranged between 3.52 and 4.0 cm recorded for 2,4-D (Calliherbe) and glyphosate(Fire) treated plots respectively (Table 5).

Grain yield per hectare (kg/ha)

Table 5 shows grains yield per hectare as influenced by the various herbicide treatments. Maximum (5081 kg) grain yield was recorded in Glyphosate (Fire) treated plots which was significantly different from the control. The minimum value of 3159 kg was recorded for 2,4-D (Calliherbe), treated plots which was not statistically different from the rest of the treatments except paraquat (Gramoxone Super) and glyphosate (Weed Out) which were also significantly different from yield from the control plots.

DISCUSSION

Effect of herbicides on growth of maize

Though plants on plots treated with herbicides were not significantly different from plants on hand-weeded control plots as regards their shoot dry weight at 2 WAP, there appeared to be small depression in the magnitude of the former. Nevertheless, at maturity the depression had disappeared as was evident from the plant height. These observations support the report by Gill et al. (1988), which showed a depressing effect of triazine herbicides on maize plants at the initial stages. They further reported a complete recovery at maturity.

There was significant difference observed in total dry matter among the treatments at 2 WAP. Total dry weight of maize was greater in 2,4-D (Bextra and Calliherbe) treated plots.

Number of leaves, leaf area and leaf area index

Leaf is the basic photosynthetic machinery for plant food, hence its size would directly affect the yield and yield component of crops. There was no significant difference in leaf area per plant among the herbicide treatments when compared with the control. These results were contrary to findings made by Akhtar et al. (1984) that manual weed control grows greatest in terms of leaf area at tasseling. They observed that using weedy control as checks, the lower leaves of maize are suppressed leading to their early senescence, hence fewer leaves and subsequently lower leaf area. Similar results had been reported by James et al. (2000) on weed competition in maize crop.

Effects of herbicides on grain yield and components of yield

Grain yield of maize increased considerably under all herbicide treatments. The increase in grain yield (grain yield per ear which reflected in yield per hectare) apparently, resulted from better weed control (Table 3) that was provided by the herbicide application as well as the hand weeding at the early stages (4WAP) of development of maize substantiating the findings of other research workers (Rout and Satapathy, 1996; Li, 1999). Grain yield was not significantly different from the control. This indicates that when weeds are controlled at early stages (4 to 6 WAP) of development, competition of weeds with crop plants are reduced (James et al., 2000).

Jughenheimer (1976) reported that the yield of maize is greatly influenced by the number of kernel rows and the hundred seed weight as well as in the length and diameter of the maize ears. These components of yield did not differ significantly among the weed control alternatives, since only a single maize variety was used. This observation revealed that these components of yield might be genetically controlled to a large extent.

2,4-D (Calliherbe and Bextra) caused a significant reduction in grain yield. This seems to agree with Shipinov and Voevodin (1956) who proposed that a possible mechanism contributing to herbicidal action of 2,4-D was to increase respiration that deplete food reserves, when used in the early developmental stages. Wain et al. (1964) reported that 2,4-D caused a greater reduction in carbohydrate content of storage tissue. This may have accounted for the lesser grain yield per ear and hence lower grain weight per cob obtained in the present study.

Conclusions

On the basis of the results obtained from the field experiments, the following conclusions were drawn:

1. Assessment of the effect of the herbicides on maize indicated that the herbicides contributed immensely to the growth and yield of the crop by providing adequate weed control and, hence, reducing the competition offered by dense weed growth.
2. Maize showed differential response in terms of yield to the application of the herbicides while better yields were observed on Glyphosate treated plots, the application of 2,4-D resulted in a significant reduction in yield of maize.

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