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Growth and Yield of Maize as Influenced by Using Lumax 537.5 SE for Weed Control in the Transitional Agro-ecological Zone of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author VYA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors EKA and HKD managed the analyses of the study. Authors VYA and EKA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Two field studies were conducted at the Multipurpose Crop Nursery research field of the University of Education, Winneba, Mampong-Ashanti in the Forest-Savannatransitionzone of Ghana from September-December, 2009 and April-July, 2010, respectively to determine the effects of various rates of Lumax 537.5 SE herbicide on maize growth and yield. The experimental design used was a randomized complete block with four replicates. The treatments were Lumax 537.5 SE at rates 2, 4, 6, and 8l/ha and Hoe-weeded with Unweeded treatment as control. The maize cultivar, Akposoe was used. Differences in percentage of crop establishment among treatments were not significant in both the years. However, 4l, 6l, 8l Lumax/ha and Hoe-weeded treatments produced similarly taller maize plants from 6 to 8 weeks after planting (WAP) with greater leaf area index at 6 WAP and shoot dry matter at 6 WAP and harvest than 2l Lumax/ha and Unweeded control in both years. Differences in 100-seed weight and grain yield of maize among Hoe-weeded and Lumax at 4l/ha, 6l/ha and 8l/ha treatments were not significant during both cropping seasons. The results clearly

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indicated that the use of 4l Lumax 537.5 SE/ha produced similar maize growth and yields as the higher use rates of 6l Lumax/ha and 8l Lumax/ha and therefore can be recommended for adoption across the transitional agro-ecological zone of Ghana.

Keywords: Lumax; maize growth; leaf area index; maize grain yield.

1. INTRODUCTION

Maize is one of the most popular food crops on the domestic market and is grown in all the ecological zones of Ghana [1]. The total maize production in Ghana is done by about 70% of small holder farmers. Maize average yield registered by the Ministry of Agriculture in 2013 was 1.9 Mt/ha against an estimated achievable yield of 6 Mt/ha [2]. One of the biggest constraints to maize production is weed control which is very costly too.The most conventional weed management practices in maize, e.g., hoe-weeding, pulling or slashing, usually involve a substantial input of human labour [3]. However, the high cost and unavailability of labour usually cause delayed and ineffective weeding that often results in substantial crop yield losses [4]. It is, therefore, necessary to develop and adopt more effective and labour-saving weed management strategies to prevent significant crop losses and promote sustainable maize production systems. Chemical control represents a cheaper and more effective alternative to manual weeding, in particular for medium or large-scale maize production in West Africa [4]. The application of proper dose of herbicide is an important consideration for lucrative returns on maize production [5].

In Ghana, the few farmers who apply some herbicides do not apply adequate amounts of the recommended rates, citing the high cost of the input [6]. Lumax 537.5 SE is one of the most recently formulated pre-emergence herbicides with the active ingredients: 2.94% Mesotrione, 29.4% S-metolachlor, 11% Atrazine, and other ingredients (56.66%) that have been introduced into the Ghanaian market for maize production. A pre-emergence application of Lumax consistently provides the opportunity to achieve one-pass weed management and maximum yield results by providing season-long, broad-spectrum weed control [7]. In earlier studies in Nigeria [8], Lumax has been reported to have reduced weed growth at various application rates. [7] recommends that Lumax should be applied at 3.0 qts/A (7l/ha), but in soils with less than three percent organic matter, Lumax should be applied at 2.5 qts/A (5.9l/ha). However, the application of herbicides in each region must be scrupulously examined in the light of the cultivation system in use, the soil, rainfall and existing species of weeds. The aim of this study was to evaluate the growth and yield of maize as influenced by using different application rates of Lumax 537.5 SE for weed control in the transitional agro-ecologicalzone of Ghana.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Multipurpose Crop Nursery research field of the University of Education, Winneba, College of Agriculture Education, Mampong-Ashanti from September-December, 2009 and April-July, 2010. Mampong-Ashanti (7°45'N, 1°24'W) lies at an altitude of 402 m above sea level and in the transitional agro-ecological zone between the rain forest of the south and the Guinea savanna of the north of Ghana. The area experiences bimodal rainfall regime. The major rainy season begins from mid-March and ends in July while the minor season begins in September and ends in mid-November. There is a dry spell of harmattan season from December to March. Details of the rainfall figures at the location during the cropping period are reported in Table 1. The soil belongs to the Bediese series which are sandy loam, well-drained, with a thin layer of organic matter, deep yellowish red, friable and free from stones (CSIR-SRI) and are classified as Chromic Luvisol according to the FAO/UNESCO soil classification [9].

2.2 Field Procedures

The land was cleared with cutlass and the stumps of the few available trees and shrubs were removed with mattock. The land was disc-ploughed and harrowed on1st September, 2009 and 1st April, 2010 for the first and second seasons' experiments, respectively. Seeds of the maize cultivar Akposoe obtained from the Crops Research Institute, Fumesua were sown manually at three seeds per hill spaced at 40cm within rows 75 cm apart, in plots of six rows, 5.6m in length on 15th September, 2009 and 17^{th} April, 2010 for the first and second experiments, respectively. At 2 weeks after planting (WAP), the plants were thinned to two per hill for a final density of 66,666 plants/ha. The experiment was set up as a randomized complete block design with six treatments and four replications. Treatments were four rates of pre-emergence application of Lumax 537.5 SE at 2, 4, 6, 8l/haandHoe-weeded with Unweeded treatment as control. The herbicide was applied the same day as seeds were sown with a CP15 knapsack sprayer calibrated to deliver 300l/ha. The hoe-weeded plots were weeded at 3WAP and 6WAP. A compound fertilizer, NPK (15-15-15) was applied as basal at the rate of 250 kg/ha (i.e. 37.5 kgN:P_2O_5:K_2O/ha) by side placement at 10 days after sowing. Sulphate of ammonia at 125 kg/ha (i.e. 26.25 kgN/ha) was top-dressed at five weeks after sowing.

2.3 Data Collection and Statistical Analysis

Two weeks after sowing, maize seedlings from four middle rows per plot were counted and their percentage establishment per treatment was calculated. Crop injury effect from the various rates of application of Lumax 537.5 SE was observed from seedling emergence to two weeks after treatment (WAT).Maize height was determined at two weeks interval from 2WAP up to tasseling using ten maize plants randomly selected from the four middle rows per plot. Maize height was measured from the ground level of the stem to the crest of uppermost leaf using a graduated pole. Leaf area index (LAI) was taken at tasseling. Five plants were randomly selected from each plot, and measurements of the length and the widest part of each green leaf of each plant taken. The product of the length and width of each leaf was multiplied by 0.75 to give the area for each leaf [10]. The total leaf area per plant was obtained by summing up the leaf area of the record plants and then the mean leaf area of a plant was determined for each treatment. Leaf Area Index was determined using the relation: Leaf Area Index = Total leaf area of plant / inter row spacing x intra row spacing (cm) [11].

Dry matter yield of maize shoot was determined at 6WAP and at harvest in both years. Three plants were sampled at random from plant rows next to the border rows (i.e. the 2^{nd} and 5^{th} rows) per plot, and clipped at ground level. The plants were oven-dried for 48h at 80°C and weighed. The mean weight was calculated to determine the dry matter yield per plant. Days to 50% silking was determined by noting the number of days after planting that 50% of the plants in the middle four rows had produced silk. Maize was harvested from a net plot of 7.8 m^2 on the 12th December, 2009 and 15^{th} July, 2010 during the first and second experiments. Maize grain yields were adjusted to 12% moisture content using a Dickey-John moisture tester (Dickey- John Corporation, AuburnIL, USA, Model 14998). Three sets of one hundred grains were randomly selected per plot, weighed and the average determined for 100-seed weight perplot. The data collected on maize growth and grain yield as affected by the various treatments were subjected to statistical analysis using Analysis of Variance and the SAS Statistical Package [12]. The Least Significant Difference (LSD) test was used to compare all treatments means.

3. RESULTS AND DISCUSSION

3.1 Percentage Crop Establishment

Crop establishment ranged from 96.9 to 100% for both years and did not differ significantly ($P<0.05$) among the treatments (Table 1). The high percentage crop establishment indicated achievement of optimum plant population density. High viability and the healthy nature of the maize seeds used as planting materials possibly contributed significantly to the high percentage crop establishment. High mean monthly rainfall values recorded in the months of August and September, 2009 as well as April and May (Appendix) might also have contributed to such high percentage crop establishment.

The high percentage crop establishment also portrayed the effectiveness of benoxacor, a crop safener in Lumax, in ensuring crop safety from herbicide injury. Crop injury can negatively impact on germination, establishment, growth and yield. This finding confirms the assertion that Lumax provides excellent crop safety [7]. For phyto-toxicity of herbicide on crop, each treatment was observed thoroughly but no such effect was noticed during the study.

Table 1. Maize crop establishment, leaf area index and days to 50% silking as affected by Lumax rates in 2009 and 2010

Treatment	Crop Establishment (%) at 2WAP		Leaf Area Index at Tasseling		Days to 50% Silking	
	2009	2010	2009	2010	2009	2010
Unweeded	98.40	99.55	1.10	1.34	48.50	51.75
2l Lumax/ha	97.80	100.00	1.64	1.41	48.80	51.25
4l Lumax/ha	96.90	100.00	1.98	2.06	48.30	51.25
6l Lumax/ha	97.80	99.10	2.18	2.09	48.80	50.75
8l Lumax/ha	97.10	99.55	2.18	2.00	48.50	51.00
Hoe-weeded	97.30	99.55	2.07	2.02	48.50	50.50
Mean	97.53	99.63	1.86	1.82	48.50	51.08
LSD (0.05)	NS	NS	0.50	0.28	NS	0.97
CV (%)	2.13	0.83	17.97	10.13	1.94	1.26

[13] made similar observations in which pre-emergence herbicides caused no injury to maize. Also, in evaluations made at 7 and 18 days after treatments for numbers of injured plants as well as the amount of the plant expressing the injury, [14] found no injury to any variety when mesotrione (Camix or Lumax) was applied pre-emergence.

3.2 Leaf Area Index

At 6 WAP, the trends in the influence of weed control treatments on leaf area index (LAI) showed that Hoe-weeded treatment and 4l, 6l and 8lLumax/ha treatments had similar LAI values that were higher ($P<0.05$) than those for Unweeded and 2l Lumax/ha treatments (Table 1). The probable indication of these findings was that the LAI for 2l Lumax/ha treatment and Unweeded control reduced as a result of high weed competition for growth factors, especially, for light, nutrients and soil moisture. The findings of the present study supports those of [15] which indicated that since the leaf of a plant is the area where food is manufactured it plays an important function in regulating plant growth and development. Henceforth, grain yield of maize can be predicted based on its leaf area. Also, the leaf area is useful for measuring the photosynthetic efficiency of the maize crop. Thus the wider the leaf area the better it is for the crop to capture energy. An implication for the higher LAI under Hoe-weeded and 4l, 6l and 8l Lumax/ha treatments than 2l Lumax/ha and Unweeded treatments is that, with higher LAI, maize crops that received 4l, 6l, 8l Lumax/ha and Hoe-weeded treatments could have similar efficient interception and utilization of solar radiation for photosynthesis and partitioning of assimilate for better growth and higher grain yield than crops under 2l Lumax/ha and Unweeded treatments.

3.3 Days to 50% Silking

In 2009, the 4lLumax/ha treatment recorded the least number of days to 50% silking, which was not significantly different ($P<0.05$) from days to 50% silking recorded for all other treatments (Table 1). Similarly, [16] reported no statistical differences in days to 50% silking among hoe-weeded, unweeded and herbicide treatments. [16] noted that overall, plots treated with weed control methods took more days to silking than no weeding [16]. In 2010, however, Unweeded control treatment took more days to 50% silking that was significantly higher than those under Hoe-weeded and Lumax treatments. This finding was in contrast with that of [17] which indicated an increased number of days to silking in weed-free plots as compared to check plots.

3.4 Maize Plant Height

Unweeded control treatment produced maize with the least height from 2-8WAP during both cropping years (Figs. 1 and 2). This suggests that the Unweeded might have had a higher weed density that might have competed with maize for nutrients, soil moisture, light and carbon dioxide, and considerably reduced maize height. Earlier researchers, [18] have reported similar trends in shorter maize height in weedy checks than various weed control techniques.

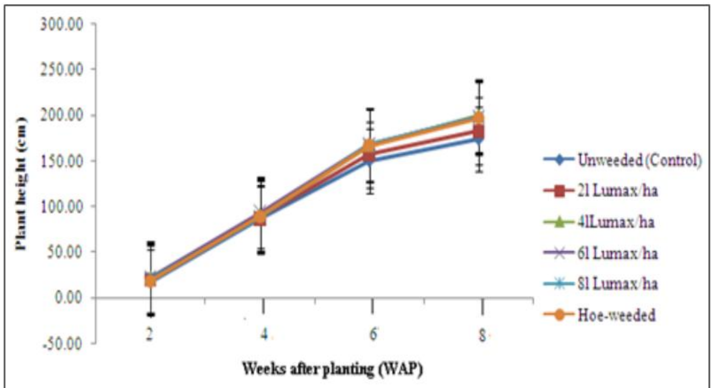

Fig.1. Effect of Lumax rates and Hoe-weeding on maize plant height-2009

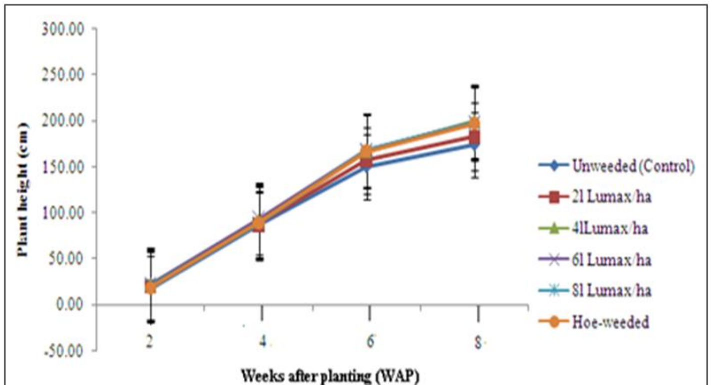

Fig.2. Effect of Lumax rates and Hoe-weeding on maize plant height-2010

Lumax treatments with 4l, 6l and 8l/ha produced taller maize plants than the 2l/ha at 6-8 WAP. Again, this was probably due to a better weed control by the higher rates of Lumax treatment that might have reduced weed densities for competition with maize for resources for maize growth with the higher rates than the lower rate. These results are in agreement with those of [19] which reported that taller maize plants were produced by higher rates ofa herbicide than lower rates. Also, Lumax treatments with 4l, 6l and 8l Lumax/ha probably had higher leaf area index for better interception and utilization of solar radiation that might have contributed to the consistence increase in maize height from these treatments than the 2l Lumax/ha.

3.5 Maize Shoot Dry Matter

Generally, maize plants accumulated more shoot dry matter at both 6WAP and at harvest in 2010 than in 2009 (Table 2). At both 6WAP and at harvest, Hoe-weeded and 4l Lumax/ha, 6lLumax/ha, 8lLumax/ha treatments gave similar maize shoot dry matter that exceeded the dry matter of the 2l Lumax/ha and Unweeded control at harvest in both years. This was possibly due to the better weed control that might result into lesser weed competition with maize, taller maize plants, higher leaf area index of maize, higher efficiency in intercepting and absorbing solar radiation and partitioning of assimilate and inorganic nutrients for enhanced dry matter production in the treatments that received Lumax at 4, 6, 8l /ha, and Hoe-weeded treatment than those of 2l Lumax/ha and Unweeded treatments.

3.6 100-Seed Weight

Generally, 100-seed weight for all treatments was higher in 2010 than 2009 (Table 3).The higher 100-seed weight values obtained in 2010 as compared to those of 2009 could be attributed to availability of higher amount of moisture to the plants as a result of higher amount of rains during the cropping period in 2010 (Appendix).

Table 2. Maize shoot dry matter as affected by Lumax rates in 2009 and 2010

Treatment	Maize shoot dry matter (g/plant)			
	6WAP		Harvest	
	2009	2010	2009	2010
Unweeded	255.69	274.59	425.88	468.75
2l Lumax/ha	325.46	295.93	478.08	620.31
4l Lumax/ha	393.47	394.38	699.89	867.94
6l Lumax/ha	376.87	391.07	699.70	863.94
8l Lumax/ha	389.16	393.45	666.59	868.39
Hoe-weeded	365.26	412.75	639.59	871.96
Mean	350.99	360.36	601.62	760.22
LSD (0.05)	35.04	30.88	61.11	169
CV (%)	9.8	5.7	2.3	14.8

Table 3. 100-Seed weight and grain yield of maize as influenced by Lumax and hoe-weeding in 2009 and 2010

Treatment	100-Seed Weight (g)		Grain Yield (t/ha)		%Mean YieldIncrease	
	2009	2010	2009	2010	Mean	
Unweeded	28.75	36.00	3.07	4.44	3.76	0.00
2l Lumax/ha	29.25	37.25	4.01	5.20	4.61	22.61
4l Lumax/ha	30.35	40.50	5.07	6.50	5.79	54.00
6l Lumax/ha	30.25	40.75	5.10	6.52	5.81	54.52
8l Lumax/ha	30.25	41.25	5.08	6.55	5.82	54.79
Hoe-weeded	30.15	41.00	5.00	6.50	5.75	52.92
Mean	29.83	39.46	4.56	5.95	5.26	39.89
LSD (0.05)	0.40	0.94	0.42	0.86		
CV(%)	0.15	8.43	6.30	9.53		

The Hoe-weeded and all Lumax treatments had significantly heavier ($P<0.05$)100-seed weight than the Unweeded control (Table 3) probably due to the effective control of weeds and reduced competition from weeds. This caused increase in uptake of nutrients and thereby healthy growth and development of crops which resulted in higher grain weight. These results agree with previous findings of [20] which reported that the test weight of maize seeds was recorded with pre-emergence application of a herbicide which was significantly higher than the test weight for weedy check. Hoe-weeded and 4l Lumax/ha, 6l Lumax/ha, 8l Lumax/ha treatments produced similar 100-seed weight that was significantly more ($P<0.05$) than the 100-seed weight for the 2l Lumax/ha and Unweeded control. This suggests that more nutrients had been translocated from the leaves (source) to the seeds (sink) of maize plants which resulted in heavier seeds for the Hoe-weeded and 4l Lumax/ha, 6l Lumax/ha, 8l Lumax/ha treatments than the seeds for 2l Lumax/ha and Unweeded treatmeants.

3.7 Maize Grain Yield

Grain yields of maize were generally higher in 2010 than in 2009 (Table 3).A significant effect of different weed control treatments was observed on grain yield of maize during both years. When pooled, maize grain yield increased by 22.61-54.79% probably because of effective weed control by Lumax treatments at rates 2-8l/ha and Hoe-weeded treatment that might have significantly reduced competition for nutrients, water and solar radiation compared with Unweeded control treatment. Similarly, [8] reported that Lumax at five rates: 1.88-2.96 kg a.i./ha significantly reduced weed density and biomass and increased grain yield by 12-22% while [21] reported that application of selective herbicides provided 65 to 90% weed control and 100 to 150% more maize grain yields than unweeded control.

Among the herbicide treatments, the 2l Lumax/ha treatment produced the least grain yields. Reduced yields under 2l Lumax/ha are due to the lack of adequate suppression or control of weeds (Table 3).

The highest grain yields were in treatments with 4-8l/ha of Lumax and the Hoe-weeded representing increased grain yield of 52.92-54.79% when pooled (Table 3). Higher grain yield under treatments of 4l Lumax/ha, 6l Lumax/ha, 8lLumax/ha and Hoe-weeded control may be due to the fact that their effective control of weeds lead to direct increase in uptake of nutrient and thereby proper growth and development of crop which resulted in increase in 100-seed weight and ultimately resulting into increased grain yield. The similarity in higher yields among the Hoe-weeded and Lumax dosages of 4, 6 and 8l/ha suggests that these treatments are adequate to reduce the weed densities to noncompetitive levels.

Maize grain yield from the Hoe-weeded treatment was among the highest because hoe-weeding provides clean seed bed and loosens the soil. The cut weeds left in the soil may decompose and add organic matter to the soil for enhanced growth and yield of maize. [18] demonstrated that hand weeding and chemical method of weed control in maize gave 32-34% increase in grain yield of maize as compared to weedy check.

4. CONCLUSIONS

Lumax, the mixture of mesotrione, S-metolachlor, and atrazine, at rates ranging from 2l/ha to 8l/ha is effective for the pre-emergence control of weeds in maize in the transitional agro ecological zone of Ghana. There were no significant differences in maize growth and grain yield among 4l Lumax/ha, 6l Lumax/ha, 8l Lumax/ha and Hoe-weeded treatments. This implies that farmers adopting any of these rates of Lumax application and hoe-weeding would have similar results. However, manual weeding which is the predominant method of weed control by small holder farmers in the transitional agro-ecological zone of Ghana is time consuming, laborious and very expensive. The results clearly indicated that the use of 4l Lumax 537.5 SE/ha produced similar maize growth and yields as the higher use rates of 6l Lumax/ha and 8l Lumax/ha and therefore can be recommended for adoption across the transitional agro-ecological zone of Ghana.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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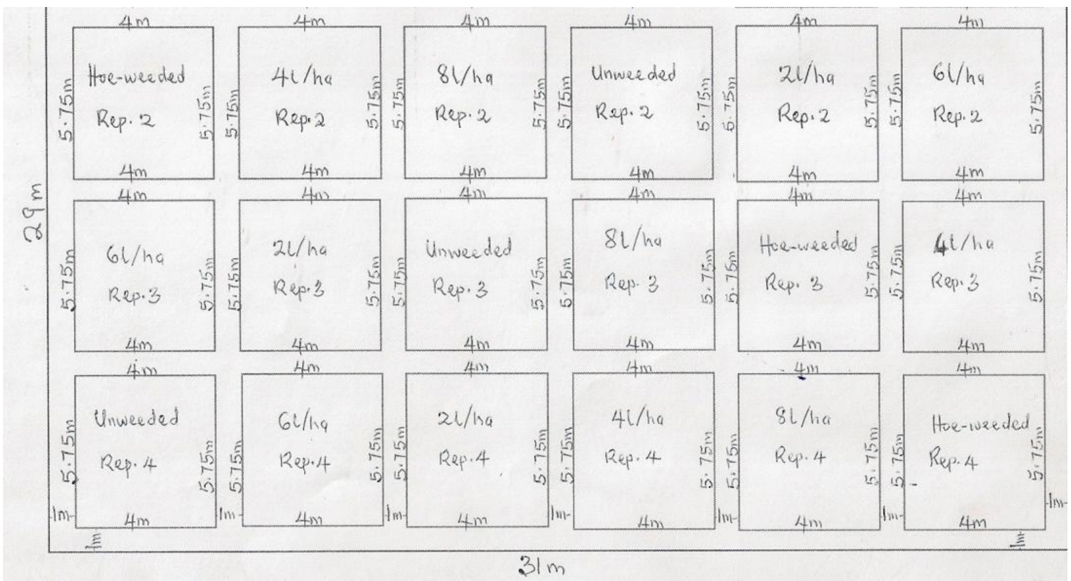
APPENDIX

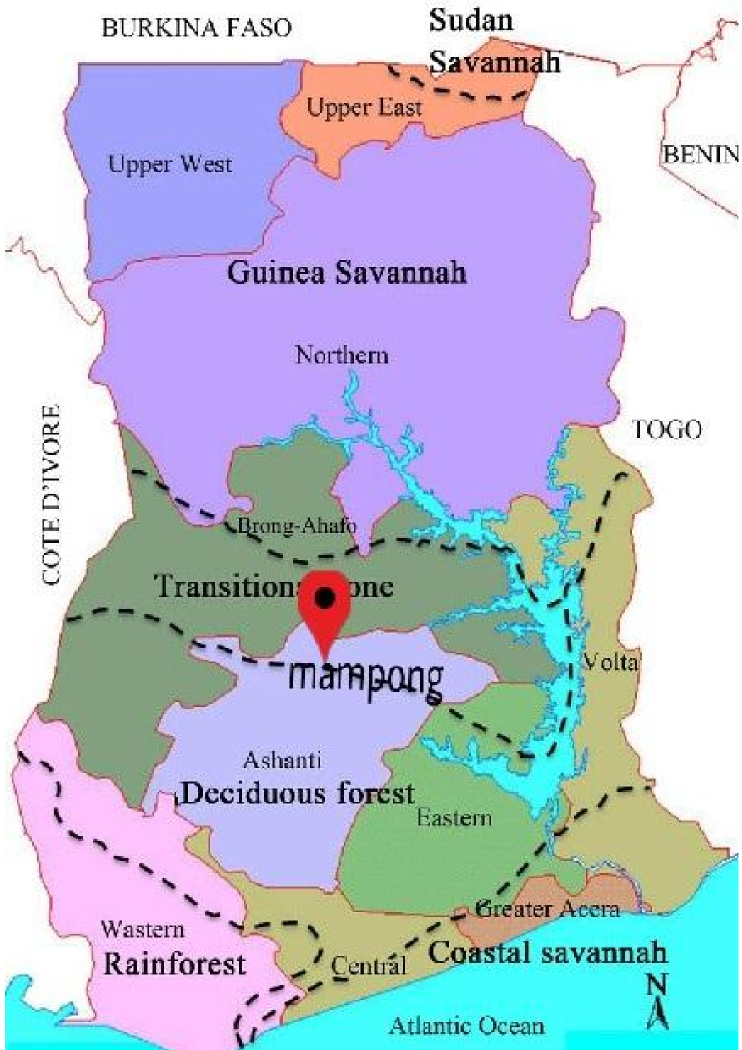
Monthly rainfall at the site during the 2009 and 2010 cropping seasons

1999 cropping season		2000 cropping season	
Month	**Total Monthly Rainfall (mm)**	**Month**	**Total Monthly Rainfall (mm)**
September	99.3	April	77.3
October	138.6	May	108.8
November	45.2	June	225.8
December	33.4	July	83
Total	316.5	Total	494.9
Mean	79.1	Mean	123.7

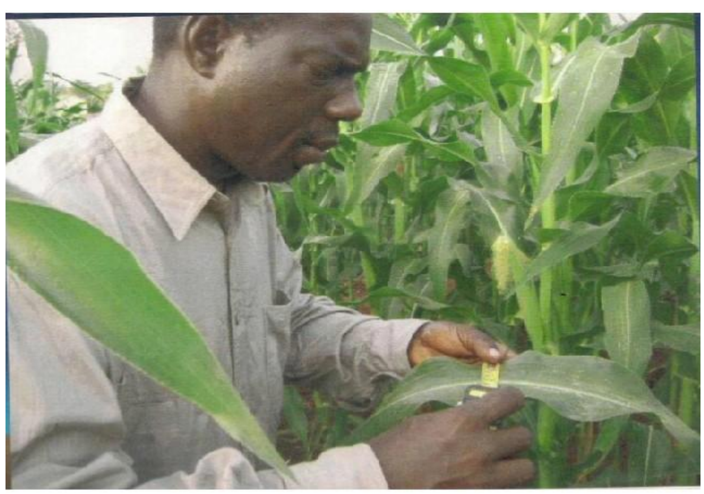
Source: Meteorological Services Department, Ashanti Mampong, Ghana



The field layout of the area studied

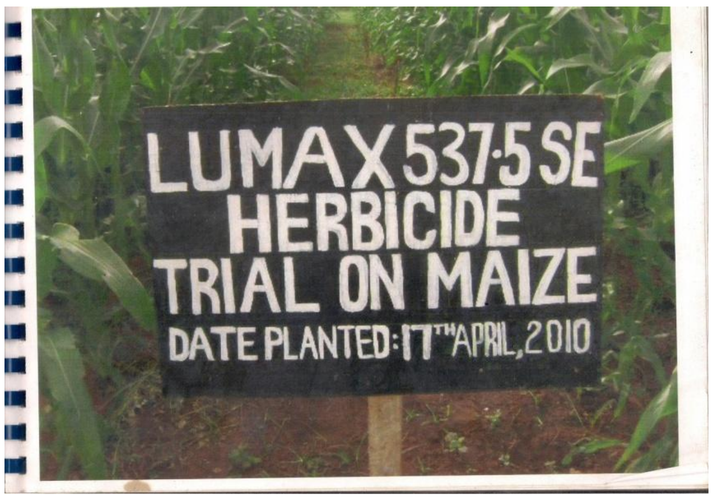


Map of Ghana showing Mampong in the Transitional Zone



Taking Measurement of Maize Leaf Area

Taking Measurement of Maize Crop Height



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