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Effect of Herbicides Application on Soil Physico-chemical Properties and Performance of Maize in Sudan Savanna Zone of Nigeria

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Authors' contributions

This work was carried out in collaboration among both authors. Both authors designed the study, performed the statistical analysis. Author GO wrote the protocol and the first and final draft of the manuscript. Author MBT managed the laboratory analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

A multi-locational field trial was conducted at two locations (Orchard of the Bayero University Gezawa village in Gezawa Local Government area) in the Sudan savanna zone of Nigeria to investigate the effect of applications of paraquat and atrazine herbicides on soil physico-chemical properties and maize performance. Pre-planting and plot-by-plot soil samples was taken 24 hours after herbicides application, vegetative growth period, reproductive stage and at harvest were taken and subjected to routine analyses using standard laboratory methods. Crop growth and yield characters were measured using standard methods. The experiment consisted of 7 treatments laid out in a randomized complete block design replicated 3 times. Results indicated highly significant differences between the locations in the content of the sand, silt and clay separates but no significant differences were observed between the treatments. There were highly significant variations in soil reaction, electrical conductivity, organic carbon, total nitrogen, available phosphorus and all the exchangeable bases, except calcium at both locations. Soil reaction, electrical conductivity, organic carbon, total nitrogen, available phosphorus, calcium, magnesium, potassium, sodium and cation exchange capacity showed no significant differences with all the

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treatments across the locations. Electrical conductivity, organic carbon, total nitrogen, available phosphorus and sodium were low across the locations but were higher at Bayero University Kano. The soils at both locations were generally acid. Thus, the soils at both locations were non-saline and non-sodic. Only the yield varied with the treatments. The highest yield was obtained at Bayero University Kano. Application of the highest treatment (4 kg/ha Atrazine + 4 kg/ha Paraquat was associated with high sand content and strong soil acidity). Combined application of 3 kg/ha Atrazine + 3 kg/a Paraquat was associated with low total nitrogen and exchangeable potassium and with the highest yield of maize. Application of Atrazine at 3 kg/ha corresponded with low organic carbon and low leaf area. Paraquat applied at 4 kg/ha was associated with very low concentration of exchangeable Na and moderate concentration of available P. Combined application of paraquat at 4 kg/ha was associated with low cation exchange capacity. Combined application of 3 kg/ha atrazine and 3 kg/ha paraquat is recommended for higher maize yield. Integrated soil fertility management is recommended in the study areas.

Keywords: Atrazine; paraquat; maize performance; soil properties; Sudan savanna.

1. INTRODUCTION

Tremendous benefits have been derived from the use of herbicides such as Atrazine and Paraquat (a non-selective contact herbicide) in agriculture. Herbicides are often considered a quick, easy, and inexpensive solution for controlling weeds [1]. Warren [2] drew attention to the spectacular increases in crop yields following the use of herbicides. Several researchers stated that "considerable economic losses" would be suffered without pesticide use and quantified the significant increases in yield and economic margin that result from herbicide use. Moreover, in the environment most herbicides undergo photochemical transformation to produce metabolites which are relatively non-toxic to both human beings and the environment [1].

If the credits of herbicides include enhanced economic potential in terms of increased food production their debits have resulted in serious health implications to man and his environment. There is now overwhelming evidence that some of these chemicals do pose a potential risk to humans and other life forms and unwanted side effects to the environment [4,5]. No segment of the population is completely protected against exposure to herbicides and the potentially serious health effects [6]. The world-wide deaths and chronic diseases due to pesticide/herbicide poisoning number about 1 million per year [7]. Herbicides have contaminated almost every part of our environment. Herbicides residues are found in soil and air, and in surface and ground water. Herbicides contamination poses significant risks to the environment and non-target organisms such as beneficial soil microorganisms.

It has been reported that application of herbicides to soils has tremendous influence on soil properties [8]. Soil properties that affect the availability and activity of soil-applied herbicides include soil texture, organic matter level and pH [8,9]. The most influential, however is the organic matter content. The larger the organic matter content, the greater the adsorption of herbicides. The capacity of the soil to hold positively charged ions in an exchangeable form is important with paraquat and other pesticides that are positively charged. Adsorption increases with decreasing soil pH for ionizable herbicides e.g. atrazine [9].

Clay particles are negatively charged and have a large surface area. As a result, soils high in clay content (heavy soils) have the capacity to absorb or tie up herbicides and generally require higher herbicide rates than coarse-textured or light soils. Paraquat adsorption was predominantly related to clay content and the adsorption to clay was so strong that it masked any relationship between adsorption and soil organic matter content [3]. Paraquat adsorption increased linearly as clay content increased with a high correlation coefficient of r^2 = 0.79 [3].

Organic matter content also affects adsorptive capacity of soils [8]. Although un-decomposed plant and animal residues can influence herbicide performance, the well-decayed, fine organic matter particles known as humus are of greatest importance. Like clay particles, humus particles are negatively charged but exhibit an even greater capacity to adsorb or tie up herbicides than clay. Consequently, herbicide rates also have to be adjusted to the soil organic matter level.

Soil pH can also affect the availability of some soil-applied herbicides. This is important for the triazine herbicides (Atrazine and Princep) [8]. These herbicides are most strongly adsorbed (tied up and unavailable for uptake by weeds) on clay and organic matter particles at low pH levels. Although the amount of triazine adsorption increases at all pH levels below 7.0, adsorption is most dramatic at pH levels of 6.0 and below. This is an important consideration for continuous zone/no-tillage fields where the surface inch of the soil profile may have a lower pH than is reflected in the results of a normal soil sample analysis [8].

Based on the negative effects of herbicides on the soil and environment, it becomes pertinent to assess the impact of application of herbicides, particularly Atrazine and Paraquat, on soil physical and chemical properties as well as maize performance for sustainable crop production in the study areas. This research is an attempt in this direction.

2. MATERIALS AND METHODS

2.1 The Study Area

The research was multi-locational conducted at the Orchard of the Bayero University, Kano (latitude 11°97.976'N and longitude 8°41.943'E) (Fig. 1) and lies at an altitude of 452 m above sea level (asl) [10,11] and Gezawa village in Gezawa Local Government area located at latitude 12°00.045'N and longitude 8°65.729'E at about 475 m asl as reported by JARDA [10,11]. The study area lies in the Sudan Savanna zone of Nigeria [11].

Soil in the study area mostly developed from Precambrian basement complex rock to partially sedimentary rock formation. The soil is dominated by sandy to sandy loam texture derived from wind drift materials as reported by [11].

2.2 Soil Sampling, Preparation and Analytical Methods

Five pre-planting surface soil (20 cm depth) samples were taken randomly in a "W" shaped sampling framework and later mixed together. One composite sample was drawn from the mixture and was used for laboratory analysis. Subsequently, plot by plot soil samples were taken at 24 hours after the application of herbicides, vegetative growth period and reproductive stage as well as at harvest. The soil samples were air dried, crushed and passed through a 2 mm sieve for laboratory analysis. The soil samples were analyzed using standard analytical methods. Soil parameters analyzed were; particle size distribution using Boyoucous Hydrometer method [12].

The textural classes were determined using the USDA textural triangle. The soil pH was determined using a glass electrode pH meter at a ratio of 1:2 both in water and in 0.01 M $CaCl_2$. Electrical conductivity of the soil of 1:2 soil to water ratio was determined using a conductivity meter at 25°C. Soil organic carbon was determined by wet oxidation method. Total nitrogen was determined using the Kjeldahl digestion method as described [13].

Available phosphorus was extracted using the Bray 1 method. The exchangeable Ca and Mg were determined using Atomic Absorption Spectrometer while exchangeable K and Na were read on a Flame Photometer (Jenway PFP7). Cation exchange capacity (CEC) was determined using 1 M ammonium acetate buffered at pH 7.0. Exchangeable acidity was determined by titration using 1 M NaOH solution.

2.3 Treatments and Experimental Design

The experiment consisted of seven treatments; Atrazine applied at 3 kg ha^{-1}, Atrazine applied at 4 kg ha^{-1}, Paraquat applied at 3 litres ha^{-1}, Paraquat applied at 4 litres ha^{-1} , Atrazine applied at 3 kg ha^{-1} + Paraquat applied at 3 litres ha^{-1} , Atrazine applied at 4 kg ha^{-1} + Paraquat applied at 4 litres ha^{-1}, Control.

Randomized Complete Block Design (RCBD) was used as the experimental design with 3 replications. Each replication contained seven plots making a total of twenty-one plots per location.

2.4 Cultural Practices

The land was cleared, ploughed, harrowed and ridged (0.75 m apart) before layout. The plots were marked out into the required number of plots (21 per location). The maize seeds were obtained from the Centre for Dry land Agriculture, Bayero University, Kano. The variety used in the experiment was Early Variety Drought Tolerant (EVDT).

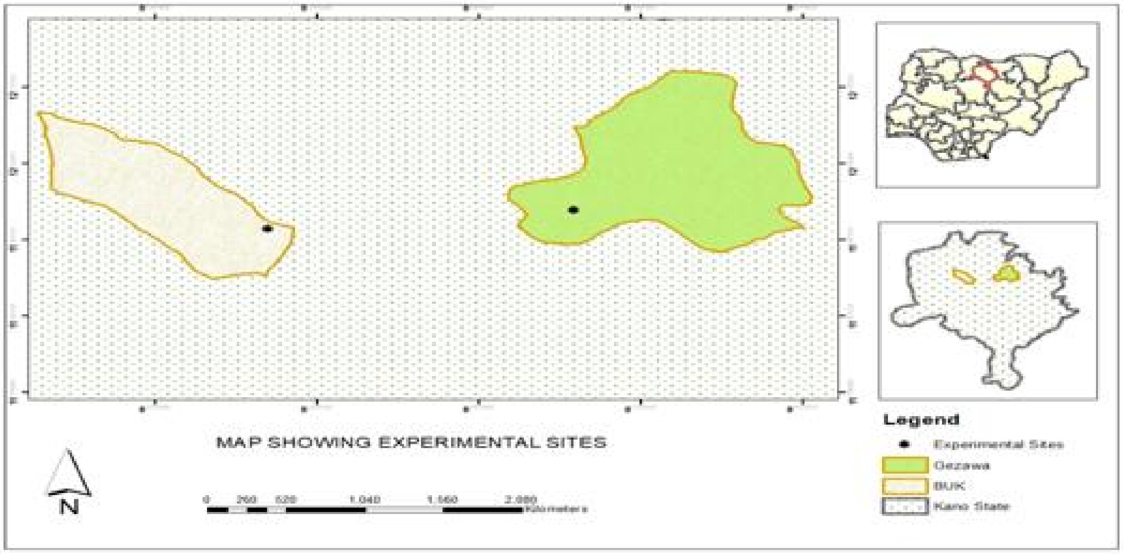

Fig. 1. Experimental sites

Sowing was done on Saturday 30th June 2018. Three seeds were sown manually per hole at a spacing of 75 x 25 cm inter and intra row respectively. The maize was later thinned to one plant per stand at two weeks after sowing. This gave a total plant population of about 53,333 plants per hectare and 60 plants per plot.

Fertilizer was applied at an application rate of 120 kg N, 60 kg P_2O_5 and 60 kg k_2O. Urea was applied as a source of nitrogen at 5.2 bags ha^{-1} (293 g per 11.25 m^2; 16.93 kg per location). Nitrogen fertilizer was applied at planting, at 14 days after emergence (DAE) and at 42 DAE. Triple superphosphate fertilizer was used to supply phosphorus at planting at 6.7 bags per hectare (376 g per 11.25 m^2; 21.81 kg per location). Muriate of potash (MOP) was applied as a source of potassium at planting at a rate of 4 bags per hectare (224.70 g per 11.25 m^2; 13.02 kg per location). Weeding was not carried out because herbicides were applied to take care of weeds. Growth and yield characters were determined using standard methods and procedures as at when due. Atrazine and paraquat were applied according to manufacturer's recommended rate and according to treatments using 2-litre hand sprayer.

2.5 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) as described [14] using Genstat 17th Edition. Significant treatments means were separated using Student Newman-Keul Test (SNK) at 5% level of probability.

3. RESULTS AND DISCUSSION

The pre-planting physico-chemical properties of the experimental soils at the two locations are presented in Table 1. The sand particle dominated over the silt and clay at both BUK (67%) and Gezawa (83%) with sandy loam and loamy sand textural classes, respectively. The EC, OC and EA were low at both locations. The exchangeable bases and ECEC were generally higher at BUK than at Gezawa. Generally, the experimental material will respond to fertilization as expressed by the relatively low values of the soil fertility indicators evaluated.

Table 2 shows the effect of herbicides application (treatments) on soil texture. There were highly significant ($P < 0.01$) differences between the locations in the content of the sand, silt and clay separates with Gezawa showing the highest sand content as observed earlier. The high sand content may be due to the aeolian nature of the parent material in the study area as reported [10]. This may be probably attributed to the fact that the soil was developed on unconsolidated materials.

There were no significant differences between the treatments in terms of the contents of sand, silt and clay across the study area. However, plot that received application of 4 kg of both atrazine and paraquat recorded the highest sand content while plots that received combined applications of atrazine (3 kg/ha) and paraquat (3 L/ha) showed the highest silt fraction. Application of atrazine (4 kg/ha) showed the highest content of clay (Table 2). This may be due to the high surface area and high amount of negative charges of clay which tend to adsorbed more paraquat than the sand and silt particles. This finding is in agreement with the report of researchers that paraquat adsorption increases linearly as clay content increases [3].

Tables 3 and 4 presents the interaction effects between location and sampling time on sand and silt respectively. There were significant ($P < 0.01$) differences in the sand content in both locations with Gezawa recording the highest values at all stages (Table 3). Similarly, variations existed in the silt content at significant ($P < 0.05$) level across the stages with BUK having the highest silt content (Table 4).

There was a high variability ($P < 0.01$) in the distribution of sand and silt at 24 hours after application of the herbicides, during maize vegetative and reproductive growth stages and at harvest (Table 2). However, the clay fraction did not vary significantly at these stages.

Effects of herbicides application on soil chemical properties is presented in Table 5. There were highly significant ($P < 0.01$) variations in soil reaction, EC, OC, TN and available P at both locations. Mean values of all the parameters were higher at BUK than at Gezawa. The higher values may be due to the higher values of these parameters in the preplanting soil samples at the same location (Table 1).

The soil at BUK had the highest clay content (17.51%, Table 2) which may be attributed to higher (14.82%) absorption of atrazine when applied at 4 $kgha^{-1}$ as indicate in Table 2. Similarly, paraquat at the same location was associated with one of the highest clay contents (13.48%). This observation is in agreement with similar finding [3] which showed that Paraquat adsorption increased linearly as clay content increased with a high correlation coefficient of $r^2 = 0.79$.[3].

The treatments did not show variations in the concentrations of the chemical properties measured. Similarly, there was no interaction effect between the location and the treatments (Table 5).

The mean value of soil pH at BUK was observed to be slightly acid (6.30) while being strongly acid at Gezawa (5.20). The soil at BUK is therefore likely to have more nutrients than at Gezawa because the pH fell within 5.5 – 6.5 considered to be ideal for availability of nutrients as reported [15]. This may most probably translate into higher yields at BUK than at Gezawa. The increase in pH at BUK as compared to at Gezawa (Table 5) may be due to the increase in adsorption of the paraquat and atrazine. The combined application of 4 kg/ha atrazine and 4 kg/ha paraquat recorded the highest pH (5.90, rated moderately acid) (Table 5). This may imply that moderate soil pH values are associated with higher (4 kg/ha) atrazine and paraquat applied in combination. However, soil pH has been reported 2004 to increase adsorption of paraquat with decreasing soil pH [9].

Table 1. Preplanting physical and chemical properties of the experimental soils

Soil properties	Buk	Gezawa
Sand (%)	67.36	83.36
Silt (%)	15.28	9.88
Clay (%)	17.36	6.76
Textural Class	Sandy loam	Loamy Sand
Soil pH	7.15	6.40
Electrical Conductivity (dSm^{-1})	0.08	0.05
Organic Carbon (gkg^{-1})	4.13	2.33
Total nitrogen (gkg^{-1})	1.00	0.70
Available Phosphorus (mg/kg)	2.80	2.01
Exchangeable bases (cmol/kg):		
Ca	4.03	1.50
Mg	2.70	1.94
K	0.36	0.16
Na	0.34	0.33
AL^{2+}+H^+ (cmol/kg)	1.50	1.30
ECEC (cmol/kg)	8.93	5.23

Table 2. Effect of herbicides application on soil texture

	% Sand	% Silt	% Clay
Location (L)			
BUK	67.45b	15.03a	17.51a
GEZAWA	80.07a	10.47b	9.46b
SE±	0.76	0.66	0.43
significance	**	**	**
Sampling Time (ST)			
24 Hours	74.86ab	11.73b	13.41
Vegetative growth	72.68bc	12.92b	14.40
Reproductive stage	71.21c	15.42a	13.36
At harvest	76.29a	10.94b	12.77
SE±	1.10	0.93	0.60
Significance	**	**	ns
Treatments (T)			
Control	74.34	12.94	12.72
Paraquat 3 kg ha^{-1}	74.52	12.00	13.48
Atrazine 3 kg ha^{-1}	72.66	13.83	13.51
Paraquat 4 kg ha^{-1}	73.52	12.00	13.29
Atrazine 4 kg ha^{-1}	73.03	13.42	14.82
Atrazine 3 kg ha^{-1} + Paraquat 3 kg ha^{-1}	73.00	13.42	13.59
Atrazine 4 kg ha^{-1} + Paraquat 4 kg ha^{-1}	75.27	11.73	13.00
SE±	1.42	1.23	0.80
Significance	ns	ns	ns
Interaction (I)			
L X ST	**	*	ns
L X T	ns	ns	ns
ST X T	ns	ns	ns
L X ST X T	ns	ns	ns

*Means followed by different letters are significantly different at 0.05 level of significance using Turkey HDS, ns= Not significance at 5% levels of significance; ** = significance at 1% level of significance; * = significance at 5% level of significance*

Table 3. Interaction Effects between Location and Sampling Time on Sand

Location	24 hours	Vegetative growth	Reproductive satage	At harvest
BUK	68.00b	64.51b	66.91b	70.40b
GEZAWA	81.71a	80.85a	75.52a	82.19a
SE±	1.52	1.52	1.52	1.52

Means followed by different letters are significantly different at 0.05 level of significance

Table 4. Interaction effects between location and sampling time on %silt

Location	24 Hours	Vegetative Growth	Reproductive Stage	At Harvest
BUK	14.87a	16.16a	16.02a	13.09a
GEZAWA	8.59b	9.68b	14.82b	8.79b
SE±	1.32	1.32	1.32	1.32

Means followed by different letters are significantly different at 0.05 level of significance

The EC at both locations were low and thus the soils were not saline [16]. Concentrations of OC, TN and Av P were observed to be low at both locations except for Av P at BUK which was moderate (Table 5). Low values of these parameters have been reported for West African soils Jones and Wild, 1975 [17,18,19,20]. The soils are likely to respond to fertilization [21]. However, all the values were higher at BUK.

The distribution of OC did not follow a particular pattern, even though it was higher at BUK, where the clay was higher. The adsorption of paraquat to clay was so strong that it masked any relationship between adsorption and soil organic matter content [22].

There was a highly significant (P < 0.01) difference in the pH of the soil taken at different soil sampling times after the application of the herbicides with the highest pH value of 6.20 at 24 hours after application (Table 5). However, there was a general decline in the pH.

Table 6 shows the interaction effects between location and sampling time on pH. At all the periods, significant (P < 0.01) variations existed in the soil reaction with BUK having the highest values.

The concentrations of all the exchangeable bases, except Ca, varied highly significantly (P < 0.01) in both locations (Table 7). Once again, the concentrations of all the exchangeable bases were higher at BUK than at Gezawa. This may translate into higher yields at BUK probably due to higher soil fertility level as earlier observed.

The concentrations of exchangeable Ca at both locations were moderate. Exchangeable Mg was high at BUK. Exchangeable K and Na was observed to be low at both locations (Table 7). Thus, the soil at both locations were non-sodic.

Table 5. Effect of herbicides application on soil chemical properties

	PH	EC (dSm^{-1})	OC (gkg^{-1})	TN (gkg^{-1})	Av P ($mgkg^{-1}$)
Location (L)					
BUK	6.30a	0.03a	3.74a	1.02a	11.30a
GEZAWA	5.20b	0.01b	2.00b	0.81b	3.60b
SE±	0.05	0.002	0.30	0.15	1.01
Significance	**	**	**	**	**
Sampling Time (ST)					
24 Hours	6.20a	0.018ab	3.00	0.80b	5.50b
Vegetative growth	5.70b	0.02a	2.96	0.81b	5.70b
Reproductive stage	5.50c	0.02	3.20	1.00b	9.10ab
At harvest	5.70b	0.01b	2.50	1.10a	9.60a
SE±	0.07	0.003	0.42	0.08	1.43
Significance	**	**	ns	**	**
Treatments (T)					
Control	5.70	0.01	2.48	0.95	7.32
Pra 3 kg ha^{-1}	5.70	0.02	2.64	0.92	7.11
Atr 3 kg ha^{-1}	5.70	0.02	3.81	0.86	5.00
Pra 4 kg ha^{-1}	5.70	0.02	2.67	0.79	10.50
Atr 4 kg ha^{-1}	3.90	0.02	2.72	0.95	8.00
Atr 3 kg ha^{-1} + Pra 3 kg ha^{-1}	5.80	0.02	2.74	1.05	6.30
Atr 4 kg ha^{-1}+Pra 4 kg ha^{-1}	5.90	0.02	2.82	0.85	7.90
SE±	0.10	0.004	0.60	0.08	1.89
Significance	ns	ns	ns	ns	ns
Interaction (I)					
L X ST	**	ns	ns	ns	ns
L X T	ns	ns	ns	ns	ns
ST X T	ns	ns	ns	ns	ns
L X ST X T	ns	ns	ns	ns	ns

*Means followed by different letters are significantly different at 0.05 level of significance using Turkey HSD; ns=Not significant at 5% level of significance**= Significance at 1% level of significance Pra= paraquat Atr= Atrazine*

Table 6. Interaction effects between location and sampling time on soil pH

Location	24 hours	Vegetative growth	Reproductive stage	At harvest
BUK	6.80a	6.50a	6.10a	6.10a
GEZAWA	5.54b	5.00b	5.00b	5.40b
SE±	0.10	0.10	0.10	0.10

Means followed by different letters are significantly different at 0.05 level of significance using Turkey HDS

Table 7. Effect of herbicide application on exchangeable bases and cation exchange capacity at BUK and Gezawa

	Ca(Cmol/kg)	Mg(Cmol/kg)	K(Cmol/kg)	Na(Cmol/kg)	CEC
Location (L)					
BUK	4.10	2.03a	0.11a	0.08a	6.78a
GEZAWA	3.74	1.30b	0.10b	0.06b	1.83b
SE±	0.37	0.16	0.01	0.005	0.27
Significance	Ns	**	**	**	**
Sampling Time (T)					
24 Hours	4.82a	1.70	0.11	0.10a	4.32
Vegetative growth	2.60b	1.60	0.10	0.07b	3.92
Reproductive stage	4.20a	2.00	0.10	0.05c	4.85
At harvest	4.05a	1.50	0.10	0.06c	4.14
SE±	0.53	0.22	0.01	0.008	0.39
Significance	**	ns	ns	**	ns
Treatments (T)					
Control	5.03	1.80	0.06	0.07	4.71
Paraquat 3 kg ha^{-1}	4.41	1.80	0.07	0.07	4.60
Atrazine 3 kg ha^{-1}	3.32	1.70	0.09	0.07	3.70
Paraquat 4 kg ha^{-1}	3.92	1.60	0.09	0.08	4.71
Atrazine 4 kg ha^{-1}	3.95	1.70	0.09	0.07	4.21
Atrazine 3 kg ha^{-1} + Paraquat 3 kg ha^{-1}	3.50	1.60	0.12	0.07	4.20
Atrazine 4 kg ha^{-1} + Paraquat 4 kg ha^{-1}	3.30	1.30	0.11	0.06	4.01
SE±	0.70	0.30	0.02	0.01	0.51
Significance	Ns	ns	ns	ns	ns
Interaction (I)					
L X ST	*	ns	ns	ns	ns
L X T	Ns	ns	ns	ns	ns
ST X T	Ns	ns	ns	ns	ns
L X ST X T	Ns	ns	ns	ns	ns

*Means followed by different letters are significantly different at 0.05 using Turkey HDS, ns= Not significance at 5% levels of significance; ** = significance at 1% level of significance; * = significance at 5% level of significance*

Table 8. Interaction Effects between Location and Sampling Time on soil Calcium

Location	24 Hours	Vegetative Growth	Reproductive Stage	At Harvest
BUK	4.24b	3.37a	4.78a	3.98b
GEZAWA	5.39a	1.82b	3.62b	4.11a
SE±	0.75	0.75	0.75	0.75

Means followed by different letters are significantly different at 5 % level of significance

The CEC was very much higher at BUK and it was moderate at this location. However, soils with a CEC of less than 16 meq/100 g are considered to be infertile and such soils are highly weathered while fertile soils have a CEC greater than 24 meq/100 g [23]. The higher CEC at BUK may be due to the higher concentrations of OC, exchangeable Ca; K. CEC is highly influenced by organic matter [24].

There were no significant differences in the concentrations of the exchangeable bases as well as the CEC among the treatments including the control as well as the interaction between the location and the treatments (Table 7).

The general non-significant difference observed in the concentrations of the soil properties in response to the treatments imposed may be due to the fact that the experiment covered only one cropping season. It is recommended, therefore, that further field trials over many cropping seasons should be conducted with the hope that variations in the soil properties could be detected.

Table 9. Effect of herbicide application on plant height, number of leaves, leaf area and yield

Parameters	Plant height (cm)	Leaf area (cm)	No. of leaves	Yield (tons ha^{-1})
Location (L)				
BUK	109.70	339.50a	11.00	2.36a
GEZAWA	105.90	280.50b	9.00	1.60b
SE±	4.15	10.33	1.54	0.214
Significance	ns	**	ns	**
Sampling Time (ST)				
Vegetative growth	44.40c	294.10b	7.89b	
Reproductive stage	124.60b	349.00a	12.85a	
At harvest	154.30a	279.40b	9.72a	
SE±	5.10	12.65	1.90	
Significance	**	**	*	
Treatments (T)				
Control	106.70	313.00	15.00	0.62c
Pra 3 kg ha^{-1}	114.60	310.30	9.00	1.51bc
Atr 3 kg ha^{-1}	112.70	315.00	9.00	1.95ab
Pra 4 kg ha^{-1}	100.40	300.10	9.00	2.07ab
Atr 4 kg ha^{-1}	103.20	310.70	9.00	2.25ab
Atr 3 kg ha^{-1} + pra 3 kg ha^{-1}	104.00	305.00	9.00	2.88a
Atr 4 kg ha^{-1}+Pra 4 kg ha^{-1}	112.80	298.40	10.00	2.53ab
SE±	7.80	19.32	2.90	0.40
Significance	Ns	ns	ns	**
Interaction (I)				
L X ST	**	ns	ns	ns
L X T	ns	ns	ns	
ST X T	ns	ns	ns	
L X ST X T	ns	ns	ns	

*Means followed by different letters are significantly different at 0.05 level of significance using Turkey HDS, ns= Not significance at 5% levels of significance; ** = significance at 1% level of significance; * = significance at 5% level of significance*

Only exchangeable Ca and Na showed significant differences with the sampling time (Table 7). The highest Exchangeable Ca and Na were recorded at 24 hours after application.

The interaction between location and sampling time on exchangeable Ca is presented in Table 8. There were significant ($P < 0.05$) differences in the Ca concentrations at all the periods with BUK recording the highest Ca during the vegetative and reproductive stages. The concentration of Ca at Gezawa was higher at 24 hours after the herbicide's application and at harvest.

Table 9 presents the effect of herbicide applications on some maize growth parameters at BUK at Gezawa. Plant height and number of leaves did not show any significant differences across the locations but were respectively higher at BUK. However, leaf area and yield were observed to vary highly significantly ($P < 0.01$).

The higher yield obtained at BUK was due the less sandy nature of the soil (Table 5) and also due to the fact that the soil reaction was more favorable for the release of most nutrients (Table 2) as earlier observed. The higher yield at BUK was likely attributable to the higher values of OC, TN, Av P (Table 3), exchangeable bases and CEC (Table 4) over the corresponding values at Gezawa.

Table 10. Interaction effect between location and sampling time on plant height of maize at BUK and Gezawa

Location	Vegetative growth	Reproductive stage	At harvest
BUK	48.30a	114.60b	166.3a
GEZAWA	40.60b	134.70a	142.30b
SE±	7.19	7.19	7.19

Means followed by different letters are significantly different at 0.05 level of significance

Growth indicators such as plant height, leaf area and number of leaves which may lead to higher yields were observed to be higher at BUK than at Gezawa (Table 9).

Plant height, leaf area and number of leaves showed highly significant ($P < 0.01$) differences at periods of vegetative growth, reproduction and at harvest. Number of leaves also varied ($P < 0.05$) at these periods of growth (Table 9). Plant height, leaf area and number of leaves showed significant differences at the various stages.

The yield was highest (2.88 t/ha) at the combined application of 3 kg/ha atrazine and 3 kg/ha paraquat. This was followed by combined application of 4 kg/ha paraquat and 4 kg/ha atrazine which produced 2.53 tons/ha. The higher yields obtained is most likely to be related to the effect of the herbicides in control of weeds.

The effect of interaction between location and sampling time on maize plant height is presented in Table 10. The plant height showed variations ($P < 0.05$) at all the plant growth stages with BUK showing the highest plant height at vegetative stage and at harvest while Gezawa had the highest plant height at reproductive stage (Table 10).

4. CONCLUSION

Results indicated highly significant differences between the locations in the content of the sand, silt and clay separates but no significant differences were observed between the treatments. Location and sampling time interacted to significantly affect the sand, silt and clay fractions at maize growth stages. Generally, BUK showed higher silt and clay contents.

There were highly significant variations in pH, EC, OC, TN, available P and all the exchangeable bases, except Ca at both locations. There were significant interaction effects on pH, EC, TN, available P, Ca and Na at growth stages. However, OC, Mg and K showed no significant differences at the stages. All the soil parameters evaluated (pH, EC, OC, TN, available P, Ca, Mg, K, Na and CEC) showed no significant differences with all the treatments across the locations.

Electrical conductivity, OC, TN, Av P and Na were low across the locations but were higher at BUK. The soils at both locations was generally acid. Thus, the soils at both locations were non-saline and non-sodic.

Leaf area and yield varied significantly across the locations with only the yield varying with the treatments. Plant height and number of leaves did not show any significant variation across the treatments but were higher at BUK. Interaction between location and sampling time significantly affected plant height. The highest yield was obtained at BUK.

Application of the highest treatment (4 kg/ha Atrazine + 4 kg/ha Paraquat was associated with high sand content and strong soil acidity). Combined application of 3 kg/ha Atrazine + 3 kg/a Paraquat was associated with low TN and Exchangeable K and with the highest yield of maize.

Application of Atrazine at 3 kg/ha corresponded with low OC and low leaf area. Paraquat applied at 4 kg/ha was associated with very low concentration of exchangeable Na and moderate concentration of available P. Combined application of paraquat at 4 kg/ha was associated with low CEC.

5. RECOMMENDATIONS

As a result of the observed non-variability of the soil properties with the treatments, further field trials over many cropping seasons are recommended so as to further assess the non-variability or variability of the soil properties with the treatments.

It is also recommended that combined application of 3 kg/ha atrazine and 3 kg/ha paraquat should be adopted by farmers in order to obtain higher maize yield in the study area.

The application of both organic materials and inorganic fertilizers should be encouraged in the study area. This will not only improve the low soil nutrients but will also improve the physical properties of the sandy soils at both locations for increased and sustainable crop production in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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