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Assessment of Alum (Aluminium Sulphate) Treated Surface-Runoff as Irrigation Water on the Growth and Development of *Zea mays* L

[1]Etukudo, Mbosowo. M., [2]Roberts, Eneni. M. I. and [3]Okereke, Ifeoma. J.
[1&2](Department of Biological Sciences, Federal University Otuoke, P.M.B. 126, Yenagoa, Bayelsa State, Nigeria)
[3](Department of Environmental Resource Management, Abia State University,Uturu, Abia State, Nigeria)

Abstract: *The potency of alum (aluminium sulphate) treated surface- runoff as irrigation water on the growth and development of Zea mays L. was examined in the laboratory. The concentration levels of 10, 20, 30, 40 and 50 % of aluminium sulphate were used alongside a control (0). The percentage germination of the test crop was significantly ($P <0.05$) reduced in treatment containing aluminium sulphate. Surface run-off treated with aluminium sulphate significantly ($P < 0.05$) decreased the shoot length, root length, and moisture content of the crop relative to the control. In addition, chlorophyll a, b and total chlorophyll contents of Zea mays were significantly ($P < 0.05$) decreased with increase in the concentration levels of aluminium sulphate. This study suggests that although aluminium sulphate could be utilized to purify waste water and as inorganic amendment in alkaline soil, inappropriate use of alum in irrigation water treatment without characterization of both the soil medium and waste water may cause damage to Zea mays L.*
Keywords*: Alum, Surface- runoff, Irrigation -water, Zea mays.*

I. Introduction

There are prevalent situations in the utilization of contaminated or impure water such as surface- runoff, wells, e.t.c for irrigation purposes [1]. In most cases, the contaminated water is treated prior to its use for irrigation. Aluminium sulphate (Alum) is commonly used as a coagulating agent in purification of drinking and waste water treatment plant as well as other industrial purposes [1]; [2]. However, the environmental implication of using water treated with high concentration of aluminium sulphate for irrigation in cultivated lands, most especially in strongly acidic soils, evokes serious concern. Again, the level of Aluminium Sulphate used in water treatment by some local farmers may not meet the environmental safety standard. Although, Aluminium Sulphate is sometimes used to reduce the pH of garden soil [3], plant growth and development can be disrupted due to Aluminium (Al) toxicity in most strongly acidic soils [4].

Aluminium sulphate has been shown to clarify water by hydrolysis of aluminium to form a gelatinous precipitate of Aluminium Hydroxide [5]. The addition of aluminium salt to water treatment plant, results in hydrolysis of aluminium ion (Al^{+3}) with water to produce acid (H^+) [5]. Thus, Aluminium Hydroxide [Al(OH)] and the resulting Hydrogen ions (H^+), which produce Sulphuric acid (H_2SO_4) result when Aluminium Sulphate $Al_2(SO_4)_3$) is added to water [6];[7]. Aluminium sulphate tends to neutralize water acidity to form alum sludge, a gelatinous precipitate of Aluminium Hydroxide [$Al(OH_3)$] in water containing dissolved bicarbonate or other sources of alkalinity (OH) [6]; [7]. Although, Aluminium toxicity is considered as one the growth limiting factors in strongly acidic soils, Aluminium Sulphate (Alum) has the potential as soil amendment to increase plant growth, most especially in alkaline soils [8]. However, appropriate soil nutrient and pH interaction with Aluminium sulphate must be considered under field conditions.

Surface runoff is the flow of water that occurs when excess water from rain or other sources flows over the earth's surface. This occurs when soils are saturated to full capacity, or rain enters the soil more quickly than the soil can absorb it. During heavy rainfall, runoff flows along the ground and can pick up soil contaminants such as grease, bacteria, petroleum, pesticides, fertilizers, plant debris, animal wastes and heavy metals [9]; [10].

Zea mays L. belongs to the family Poaceae. It is utilized as a stable food crop and constitutes a major component to many confectionery dishes, as well as a basal medium and raw material for industries [11]. In view of the environmental consequence of improper use of aluminium sulphate in treatment of waste water for use in irrigation purposes, this study was conducted to examine the effects of aluminium sulphate treated surface-runoff on the growth and development of Zea *mays* L.

II. Materials and Methods

1.1. Collection and Analysis of Surface Run-off: Surface run-off used for this study was obtained from road side gutters in Abak, Akwa Ibom State, Nigeria and was analyzed for physico- chemical characteristics using standard procedures [12]. Physico-chemical characteristics (pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, Total dissolved solids, total suspended solids, total nitrogen, phosphorus, calcium, magnesium, potassium, sodium, zinc, copper, iron, manganese and lead) of the surface run-off were examined. The surface run-off was adjusted to 0 (control-distilled water),10%, 20%, 30%, 40%, and 50 % levels of concentration by adding appropriate quantity of Aluminium sulphate- Alum ($Al_2(SO_4)_3$).

1.2. Germination and Growth Studies: Seeds of *Zea mays* used for this research were obtained from Akwa Ibom Agricultural Development Programme (AKADEP), Uyo, Akwa Ibom State, Nigeria. Healthy seeds were sorted out and surface sterilized with 5% sodium hypochloride solution for 5 minutes and washed several times with sterile distilled water. Air-dried seeds (10 seeds) of the crop were sown in sterilized Petri dishes containing two sterile What-Man's filter paper per treatment. Each level of treatment was replicated five (5) times. The experimental set up was maintained under light condition (28 ± 1^0C) for 20 days [13]. The percentage germination and coefficient of velocity of germination at 24, 48, 72, and 96 hours after sowing of the seeds were determined [14] thus:

$$\text{Germination Percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times \frac{100}{1}$$

$$\text{Coefficient of Velocity of Germination} = \frac{\text{Total number of seedlings}}{A_1T_I + A_2T_2 \text{ ----- } A_XT_X}$$

Where A = the number of seedling emerging on a particular number of days- (T)

Growth parameters such as shoot length, root length, fresh weight, dry weight, moisture content, and chlorophyll content of the seedlings were examined at the end of the study (20 days).

1.3. Determination of Fresh Weight, Dry Weight, and Moisture Content: Harvested seedlings were washed with sterile-distilled water using a sieve. The fresh weight of the seedlings was measured using mettler-p-165 weighing balance. Gallen Kamp oven was used to dry the fresh seedlings at 65^oC for 2 days for determination of dry weight [15]. The percentage moisture content of the seedlings was measured by determining the difference between the fresh weight and dry weight of the plantlets multiplied by 100 over the fresh weight [14].

1.4. Determination of Chlorophyll Content: Chlorophyll content in the leaves was determined [16]; [17]. 2g of leaf tissue was macerated in a mortar and appropriate quantity of 80% acetone was added to homogenize the tissue. A filter paper was used to extract the supernatant into a 100ml volumetric flask. Addition of acetone to the residue in the mortar and the extraction process was conducted repeatedly. 100ml mark of the volumetric flask was attained by using additional acetone to wash off the chlorophyll. The solution obtained was thoroughly shaken, 5ml measured into a 50ml flask and 80% acetone was used to make up to the required volume. Determination of chlorophyll a, b, and ab contents was achieved by measurement of absorbance of the extract at 645, 663, and 652nm wavelengths with model 690 spectrophotometer, using 80% acetone as blank. The concentrations of chlorophyll a, b, and ab were calculated and expressed in mg/g fresh leaf weight.

1.5. Statistical Analysis: Values of mean data obtained from the replicate readings were used to calculate standard error and data were subjected to analysis of variance (ANOVA). The differences in the means were tested using Least Significant Difference (LSD) at 0.05 level of probability [18]

III. Results and Discussions

The surface- runoff had an acidic pH value of 4.86 with a temperature of 26.9^oC. Other Physico-chemical characteristics of the surface- runoff assessed are also presented (Table 1).

The percentage germination of *Zea mays* decreased significantly ($P < 0.05$) from 82.46% in the control treatment to 59.92% at 50% level of aluminium sulphate treatment (Table 2). The coefficient of velocity of germination of the crop decreased from 0.23 at the control treatment to 0.17 at 50% level of aluminium sulphate treatment (Table 2). The shoot length of the crop significantly ($P < 0.05$) decreased with increase in the concentration of aluminium sulphate treatment with a highest value of 15.40cm at the control (0%) and lowest value of 2.30cm at 50% level of aluminium sulphate (Table 3).

Table 1: Physico- Chemical Characteristics of Surface-Runoff

Parameters	Content
pH	4.86
Temperature	26.9°C
Dissolved Oxygen	5.07 mg/l
Biological Oxygen Demand	3.60 mg/l
Chemical Oxygen Demand	3.17 mg/l
Total Dissolved Solids	52.65 mg/l
Total Suspended Solids	10.42 mg/l
Total Nitrogen	0.41%
Phosphorus	3.42mg/l
Calcium	4.21 mg/l
Magnesium	2.02 mg/l
Potassium	3.47 mg/l
Sodium	0.65 mg/l
Zinc	0.16 mg/l
Copper	0.07 mg/l
Iron	0.04 mg/l
Manganese	0.21 mg/l
Lead	0.18 mg/l

The root length of the crop decreased significantly ($P < 0.05$) from 6.50cm in the control treatment to 2.30cm at 50% level of aluminium sulphate treatment (Table 3). The fresh weight and dry weight of the crop decreased with increase in the concentration of aluminium sulphate treatment with highest values of 2.93g for fresh weight and 0.56g for dry weight at the control (0%) and lowest values of 1.20g for fresh weight and 0.41g for dry weight at 50% level of aluminium sulphate (Table 3). The percentage moisture content of the crop decreased significantly ($P < 0.05$) from 80.89% in the control treatment to 65.83% at 50% level of aluminium sulphate treatment (Table 3). The contents of chlorophyll a, b and total chlorophyll in the crop decreased in treatments with aluminium sulphate comparable with the control. The total chlorophyll contents decreased from 5.107mg/g (control- 0%) to 0.461mg/g at 50 % level of aluminium sulphate (Table 4).

Table 2: Germination Percentage and Coefficient of Velocity of Germination of *Zea Mays* L. Irrigated with Surface -Runoff Treated with Aluminium Sulphate.

Concentration of Alum (%)	0	10	20	30	40	50	Mean	LSD
Germination Percentage (%)	82.48 ± 0.62	80.43 ± 0.54	79.25 ± 0.23	65.82 ± 0.55	63.07 ± 0.42	59.92 ± 0.35	71.83	1.78
Coefficient of Velocity Of Germination	0.23 ± 0.02	0.21 ± 0.07	0.19 ± 0.09	0.18 ± 0.05	0.17 ± 0.09	0.17 ± 0.02	0.19	0.20

Mean value ± Standard error of 5 replicates

The reduction in percentage germination and coefficient of velocity of germination of *Zea mays* in aluminium sulphate treated water may be due to the surface runoff- aluminium sulphate pH interaction in the growth medium. Soil amendment with aluminium sludge has been shown to reduce soil pH, increase Al activity in the soil solution with an overall effect on growth retardation [19]; [20]. Aluminium sulphate is an important stress factor for plants in acidic environment, which causes toxicity to plant and germination problems at high rate of aluminium sulphate application [19]; [4].

Table 3: Growth Parameters Of *Zea Mays* L. Irrigated With Surface-Runoff Treated With Aluminium Sulphate

Concentration of Alum (%)	0	10	20	30	40	50	Mean	LSD
Shoot Length (cm)	15.40 ± 0.27	14.30 ± 0.45	12.10 ± 0.62	10.20 ± 0.72	9.50 ± 0.34	8.40 ± 0.43	11.65	1.20
Root Length (cm)	6.50 ± 0.44	5.20 ± 0.14	4.20 ± 0.96	3.80 ± 0.31	3.40 ± 0.15	2.30 ± 0.28	4.23	1.02
Fresh Weight (g)	2.93 ± 0.16	2.02 ± 0.11	1.98 ± 0.35	1.83 ± 0.47	1.50 ± 0.39	1.20 ± 0.52	1.91	2.04
Dry Weight (g)	0.56 ± 0.02	0.42 ± 0.05	0.50 ± 0.03	0.50 ± 0.09	0.44 ± 0.02	0.41 ± 0.03	0.47	0.41
Moisture Content (%)	80.89 ± 0.32	79.21 ± 0.45	74.75 ± 0.64	72.68 ± 0.43	70.67 ± 0. 57	65.83 ± 0.43	74.01	1.22

Mean value ± Standard error of 5 replicates

Similarly, the pH of water determines the solubility, biological availability of chemical constituents such as mineral nutrients for plant growth [21]; [22].

In this study, the crop growth parameters such as shoot length, root length, fresh weight, dry weight and moisture content were reduced with increase in the concentration of aluminium sulphate. Plant growth reduction in aluminium sulphate treatment may be attributed to nutrient imbalance and disruption of root metabolism. The availability of ions in the soil solution is profoundly affected by the hydrogen ions concentration such that a pH value outside the physiological range as found in soils with aluminium toxicity, causes damage to the plant tissue and carriers resulting in inhibition of nutrient absorption and growth retardation [4]; [23].

Table 4: Chlorophyll Contents Of *Zea Mays* L. Irrigated With Surface-Runoff Treated With Aluminium Sulphate.

Concentration of Alum (%)	0	10	20	30	40	50	Mean	LSD
Chlorophyll a (Mg/g)	2.726 ± 0.02	2.312 ± 0.01	1.526 ± 0.05	1.263 ± 0.02	0.947 ± 0.02	0.328 ± 0.01	1.52	0.17
Chlorophyll b (Mg/g)	2.430 ± 0.01	2.107 ± 0.34	1.319 ± 0.14	1.121 ± 0.16	0.632 ± 0.02	0.154 ± 0.02	1.29	0.12
Chlorophyll ab (Mg/g)	5.107 ± 0.24	4.302 ± 0.35	2.820 ± 0.32	2.343 ± 0.42	1.556 ± 0.04	0.461 ± 0.04	2.77	0.10

Mean value ± Standard error of 5 replicates

Similarly, plant growth has been restricted due to aluminium toxicity by phosphorus deficiencies induced by the ability of alum to adsorb phosphorus in soil medium and convert it into forms unavailable for plant growth [22]; [6]. In addition, root cells show sensitivity to Al^{3+} toxicity by a reduction in lateral root size [24]; [3]. This reduction in the activity of the root cells may be due to reduction in both new cell formation and cell elongation in the extension region of the root [25].

The reductions in the chlorophyll contents of the crop in aluminium sulphate treatments may be attributed to disruption in metabolic processes. Aluminium toxicity is one of the major factors that can limit the growth and development of plants in acidic growth medium, such that root cells and plasma membrane are seriously affected [26]; [27]. Strong interaction of Al which is the main Al toxic form with oxygen donor ligand results in the inhibition of cell division, cell extension and transport [3]. In addition, at the cellular and molecular level, many cells components are implicated in Al toxicity including DNA in nucleus, numerous cytoplasmic components and mitochondria [27]; [28].

IV. Conclusion

Aluminium sulphate (Alum) has the potential as a coagulant and flocculant in the treatment of waste water for use in irrigation purposes. Similarly, it could be utilized as an inorganic amendment in alkaline soils. However, under field conditions, higher rates of application and inappropriate use of aluminium sulphate in irrigation water treatment without prior analysis of both the soil medium and waste water for physiological properties may cause retardation of plant growth and development.

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