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Assessment of Nutrient Availability and Competition Between Striga Hermonthica and Maize Plant

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Abstract: One of the major challenges in maize production across the globe is that of infestation by striga, a parasitic plant resulting in intense competition for mineral resources. And eventual decline in overall maize yield. This study assesses the extent of competition for nutrients by maize plant inter-planted with *Striga hermonthica* under green-house conditions using the variables: Maize planted alone (M), maize inter-planted with striga (M/S), maize planted alone with fertilizer application (MF), maize inter-planted with striga and fertilizer applied (M/SF), striga only (S) and striga with fertilizer (SF). The growth profile obtained was in the order: MF > M > M/SF > M/S > SF > S implying a significant effect on maize growth by striga. However, the distribution of proximate constituents' showed that moisture, ash, crude protein, lipid, and fibre content is more in striga root compared to the shoot likewise, the moisture, ash, and lipid content of the root supersede the shoot in maize plant inter-planted with striga. Then, the moisture, ash, and carbohydrate content of striga root and shoot surpass that of the maize inter-planted with striga. Soil to plant Bio-Concentration Factor of phosphorus was in the order: S > M > M/S, for potassium, was S > M /S > M, while magnesium: S > M > M/S then manganese: S = M = M/S. Based on the highest value of regression coefficient R^2 of the linearized plot of the diverse kinetic models, the pseudo second order kinetics model dominates the uptake rate of K, Mg and Mn by maize plant while the uptake of P, K, and Mg by striga conforms to elovic kinetic model. The mean sorption capacity K of minerals based on Freundlich-like equation reveals higher uptake capacity by striga plant when compared to maize plant which supports the reason why striga competes favorably with maize for mineral with a significant effect in lowering maize yield. Given the higher sorption capacity of *Striga hermonthica*, further studies are suggested on fortifying maize to compete favorably with striga plant.

Keywords: *Striga hermonthica*, Proximate Compositions, Mineral Elements, Uptake Capacity and Kinetics

1. Introduction

All growing plants need nutrients, light, and water. The requirements for weeds and parasites may be similar to those for crop plants and when the two overlap in space they compete for one or more of these resources either aboveground and/or belowground. Competition for these resources leads to reduced crop yield and quality especially when the weed competes better [2, 5].

Maize (Zea mays L.), also known as corn, is a versatile cereal crop grown in a variety of agro-ecological environments around the world. Because of its adaptability, maize grows well in a variety of agro-ecologies. It has emerged as a crop of global importance owing to its multiple end uses as food for humans and livestock feed. It serves as an important component for varied industrial products. Maize is also used as a model organism in biological research around the world. Globally, about 1016.73 million metric tonnes of maize is produced every year being the highest among major staple cereals [10].

Production and utilization of maize have increased in Nigeria and other parts of the world in recent years as a result of the introduction of high-yielding, drought tolerant, early and extra early maturing varieties nevertheless improved maize hybrids with substantial increase in production per unit area are still required to meet up the demand of the ever-growing population. Furthermore, with the changing climatic conditions, several new biotic stresses have emerged, minor diseases, parasites such as striga, insects and pests have become more prevalent, inflicting more damages. Drought, heat, and water logging are the most common abiotic stresses, and their occurrence is now more common than ever. Malnutrition caused by deficiency of minerals has been identified as one of the important problems of maize production [4, 9].

Parasitic plants pose a significant threat to agriculture, and plant parasitism has progressed at least 12 times independently, resulting in over 4000 parasitic dicotyledonous plant species [20]. For instance, *Striga hermonthica* a parasitic weed is popularly called ‘witch weed’ attacking a wide range of crops including maize plants [15], thereby reducing the value of grain crops, particularly in Africa. *Striga hermonthica* is an obligate parasite, drawing moisture, nutrients, and photosynthetic products from its host plants such as wheat, corn (maize), sorghum, rice, and sugarcane. *Striga* is typically found in dry, infertile soils in semi-arid tropical grasslands and savannahs [17]. Thus, its effects are most felt by poorer farmers on marginal lands. *Striga* species are prolific seed producers which are fine dust-like, lasting more than 15 years.

Striga hermonthica reduces crop yields by extracting water, nutrients (particularly nitrogen), and photosynthetic from the root system of its host plant, resulting in stunting and yield reduction. Other adverse effects on crops may include a reduction in the ear size, plant height, stem diameter, weight of the whole plant, blotching, scorching, wilting, loss of vigour, and even death of the plant. In addition, severe root damage and stem lodging may be observed. Chlorosis, wilting, and stunting of susceptible hosts, causing yield and economic losses [28].

Striga species exhibit variation in their mode of reproduction, while *S. hermonthica* is allogamous, which means it observes cross-pollination and typically relies on pollinators such as bees and other pollinators for pollen transfer [6]. Other species such as *Striga asiatica* is autogamous that is it observes self-pollination and so no vectors are needed for pollination instead, pollens are picked up by the lengthening of the style, and fertilization occurs [17].

This study unveils the effect of *Striga hermonthica* on the nutrient sorption capacity of maize plant, growth, proximate composition as well as the most probable nutrient uptake kinetics.

2. Materials and Method

2.1. Experiment

Striga hermonthica was inter-planted with maize plant in a pot under greenhouse conditions displayed in Figure 1. To assess the effect of competition for mineral resources by the two plants, changes in growth (height) were evaluated at varying conditions such as Maize planted alone (M), maize inter-planted with striga (M/S), maize planted alone with fertilizer application (MF), maize inter-planted with striga and fertilizer applied (M/SF), striga only (S) and striga with fertilizer (SF) planted in the soil adopting methodology described in striga research methods manual [3, 26].

At harvest, the plants were washed with water and rinsed with distilled water, to get rid of dirt. After which each plant was separated into root and shoot, and dried at room temperature for three weeks before it was pulverized and passed through a 2 mm sieve and preserved for digestion and onward determination of bioaccumulation of mineral and heavy metals within them.

Figure 1. *Visual of striga hermonthica inter-planted with maize.*

2.2. Determination of Proximate Composition

The proximate constituents: moisture, ash, crude fat, crude fibre, crude protein, and carbohydrate contents were determined on maize plant tissues (root and shoot) inter-planted with *Striga hermonthica*, the maize plant planted alone (root and shoot) and *Striga hermonthica* (root and shoot) using the methods of [1]. Crude protein was determined by the method developed by Kjeldahl and adopted by the Association of Official Analytical Chemists [1, 24].

2.3. Determination of Mineral Element

Digestion of soil and the plant tissue samples were digested to release the analytes into solution using 1: 1 HNO_3 and 30% H_2O_2 with the aid of microwave digestion system (Milestone connect) as described by [25].

The digests were then allowed to cool and filtered before being diluted again to 50 mL with deionized water. Total P, K, Mg, and Mn content in the samples were determined using Micro Plasma Atomic Emission Spectrophotometer (4210 MP-AES Agilent technologies) [24].

2.4. Data Processing and Statistical Analysis

The soil-plant transfer coefficient (f) of minerals was determined using equations (1) and (2) while the root-shoot transfers coefficient using equation (3) where C is mineral concentrations [29, 23, 26].

$$\text{BCF} = [\text{C}]_{\text{root}} / [\text{C}]_{\text{soil}} \quad (1)$$

$$\text{BCF} = [\text{C}]_{\text{shoot}} / [\text{C}]_{\text{soil}} \quad (2)$$

$$\text{TF} = [\text{C}]_{\text{shoot}} / [\text{C}]_{\text{root}} \quad (3)$$

The mineral concentrations of the plants at day 10, 20, 30, 40, and 50 of maturity were subjected to pseudo first-order kinetics (4), second-order kinetic model (5) elovich equation (6) and intraparticle diffusion kinetic model (7) to ascertain the kinetics of the mineral uptake process.

Pseudo-first order kinetic model:

$$\log(q_m - q_t) = \log q_m - \frac{k_1}{2.303}t \quad (4)$$

Second order kinetic model:

$$\frac{t}{q_t} = \frac{1}{k_2 q_m^2} + \frac{1}{q_m}t \quad (5)$$

Where K_1 and q_m can be obtained from the plot of $\log(q_m - q_t)$ versus (t) which gives $\frac{k_1}{2.303}$ as slope and $\log q_e$ as intercept for the pseudo-first order kinetic model similarly, for second order kinetics, K_2 and q_m is obtained from the plot of $(\frac{t}{q_t})$ versus (t).

Elovich equation:

$$\text{q} = \frac{1}{\beta}\ln \alpha\beta + \frac{1}{\beta}\ln \text{t} \quad (6)$$

where q is the amount of sorbate per unit mass of sorbent at time t and α, β are constants. A plot of q versus $\ln t$ gives a linear relationship if the elovich equation is applicable with a slope of $(\frac{1}{\beta})$ and an intercept of $\frac{1}{\beta}\ln \alpha\beta$ [22].

Intraparticle diffusion equation: $\text{q}_\text{t} = \text{k}_{\text{id}}\text{t}^{1/2} + \text{C} \quad (7)$

where, q_t is the amount of pollutant adsorbed at time (t), ($\mu g.g^{-1}.min^{-1}$), (k_{id}) is the intra-particle rate constant and C the intercept [11].

The sorption capacity (K) of minerals by maize plant and *Striga hermonthica* was estimated using the Freundlich-like equations (8) and (9)

$$\text{q} = \text{KC}^{\frac{\text{i}}{\text{n}}} \quad (8)$$

$$\log \text{q} = \log \text{k} + \frac{1}{\text{n}}\log \text{C} \quad (9)$$

However, in this case, q is the mineral concentration in plants (mg/kg) and C is the mineral concentration in the soil (mg/kg). K is the sorption capacity where a larger K indicates a larger capacity. And the value of 1/n is indicative of the sorption strength [14].

The data were further subjected to a one-way analysis of variance (ANOVA) using the Statistical Package (IBM SPSS Statistics 20) and the means were separated by using Duncan's multiple range test (DMRT) ($P < 0.05$).

3. Results and Discussion

3.1. Growth Profile

The growth profile of maize and striga plant is presented in Figure 2 for maize planted alone (M), maize and striga (M/S), maize plant only with amendment (MF), maize planted with striga and fertilizer applied (M/SF), striga alone (S) and striga with amendment (SF) revealed the growth curve of maize and striga to be sigmoid (S-shape).

The growth rate within the first 20 days was slow, followed by a rapid increase in growth over a period of about 50 days then a relatively slower growth and constant height about the 70^{th} day and beyond. The rapid growth phase is probably due to rapid adsorption and translocation of minerals while the second phase is due to the diffusion of the solute within internal mesopores and micropores [12, 16]

There was statistical variation in the height of maize inter-planted with striga and maize planted without striga ($P < 0.05$). The maximum growth of striga and maize plant and biomass obtained in soils was in the order: MF > M > M/SF > M/S > SF > S.

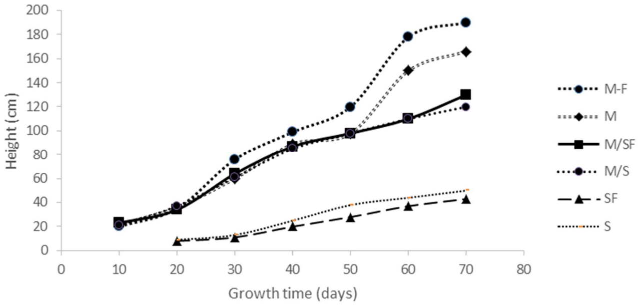

Figure 2. Growth Profile of Maize and Striga Inter-planted.

3.2. Proximate Composition of Maize and Striga Plants

The proximate composition of maize plant tissues (root and shoot) inter-planted with *Striga hermonthica*, the maize plant planted without *Striga hermonthica* (root and shoot) and *Striga hermonthica* is presented in Table 1 revealed the mean moisture content of maize plant root inter-planted with striga, maize plant root planted without *Striga hermonthica* and *Striga hermonthica* root were 4.70%, 3.82%, and 5.42%. Where *Striga hermonthica* has the highest moisture content (5.42%) while the least moisture content (3.82%) was recorded in maize plant root planted without *Striga hermonthica.*

The moisture content of maize plant shoots inter-planted with striga, maize plant shoot planted without *Striga hermonthica* and *Striga hermonthica* shoot were 4.06%, 3.10%, and 4.53% where *Striga hermonthica* has the highest moisture content (4.53%) while the least moisture content (3.10%) was recorded in maize plant shoot planted without

Striga hermonthica.

There is a positive correlation between the moisture content of the root and shoot respectively ($P < 0.05$). However, the relatively low moisture content recorded in the root and shoot of the maize planted without striga implies better stability of the product from microbial action [8].

The mean ash content of maize plant root inter-planted with striga, maize plant root planted without *Striga hermonthica* and *Striga hermonthica* root were 3.48%, 4.90,% and 4.21%, where *Striga hermonthica* has the highest ash content (4.21%) while the least ash content (3.48%) was found in maize plant root inter-planted with *Striga hermonthica.* The values were generally less than the 13.0% ash content recorded in the roots of *B. aegyptiaca* [19].

The ash content of maize plant shoot inter-planted with striga, maize plant shoot planted without *Striga hermonthica* and *Striga hermonthica* shoot were 0.560%, 1.45%, and 2.64% where *Striga hermonthica* has the highest ash content (6.64%) while the least ash content (0.560%) was recorded in maize plant shoot inter-planted with *Striga hermonthica.* The values were generally less than the 7.50% and 13.0% recorded in the stem and leaves of *B. aegyptiaca* [19]. The relatively high values of percentage ash content in root and shoot of *Striga hermonthica* and maize plant unaffected by striga, implies high mass and better competition for minerals needed for building a healthy body and proper functioning of body tissues.

Table 1. *Proximate Composition of Maize and Striga Plant.*

Sample	Moisture Content (%)	Ash Content (%)	Crude protein (%)	Crude Lipid Content (%)	Crude Fiber Content (%)	Carbohydrate Content (%)
R-M/S	4.70±0.81	3.48±0.76	10.80±2.93	14.4±1.73	14.0±1.95	53.4±1.82
R-M	3.82±2.51	4.90±1.05	12.30 ±0.82	14.7±3.54	16.1±1.75	52.1 ± 1.91
R-S	5.42±0.21	4.21±0.01	7.11±0.12	14.7±0.88	10.5±1.33	58.7±0.09
S-M/S	4.06±1.45	0.56±0.99	11.50 ±1.69	11.3±2.49	16.6±10.76	59.1 ± 2.86
S-M	3.10±1.01	1.45±0.93	12.10±0.95	13.2±1.80	15.7±1.10	58.4±1.16
S-S	4.53±1.20	2.64±1.30	5.34±1.11	10.5±1.03	9.8 ± 0.22	67.3± 0.01

Key: R-M/S= root of maize affected or inter-planted with striga, R-M= root of maize unaffected, R-S= root striga, S-M/S= shoot of maize affected or inter-planted with striga, S-M = shoot of maize unaffected, S-S= shoot striga

The mean crude protein content of maize plant root inter-planted with striga, maize plant root planted without *Striga hermonthica* and *Striga hermonthica* root were 10.8%, 12.3% and 7.11% where maize plant root planted without *Striga hermonthica* has the highest crude protein content (12.3%) while the least crude protein content (7.11%) was recorded in the root *Striga hermonthica.* The values were generally less than the 12.8% recorded in the root of *B. aegyptiaca* [19].

The crude protein content of maize plant shoot inter-planted with striga, maize plant shoot planted without *Striga hermonthica* and *Striga hermonthica* shoot were 11.5%, 12.1% and 5.34% where maize plant shoot planted without *Striga hermonthica* had the highest crude protein content (12.1%) while the least crude protein content (5.35%) was recorded in *Striga hermonthica.* The values were generally within the 6.94% and 22.9% recorded in the stem and leaves of *B. aegyptiaca* except for the 5.35% crude protein content recorded in the shoot of *Striga hermonthica* [19].

The mean fat content of maize plant root inter-planted with striga, maize plant root planted without *Striga hermonthica* and *Striga hermonthica* root were 14.5%, 14.8% and 14.7% as presented in Table 1, where maize plant root planted without *Striga hermonthica* has the highest fat content (14.8%) while the least fat content (14.5%) was recorded in the root of maize plant inter-planted with striga. These values of crude lipid in all the samples were generally higher than the 3.49% found in guinea corn silage treated with molasses and urea [24].

The fat content of maize plant shoot inter-planted with striga, maize plant shoot planted without *Striga hermonthica* and *Striga hermonthica* shoot were 11.3%, 13.2% and 10.5% where maize plant shoot planted without *Striga hermonthica* had the highest crude fat content (13.2%) while the least fat content (10.5%) was recorded in *Striga hermonthica.*

The mean crude fibre content of maize plant root inter-planted with striga, maize plant root planted without *Striga hermonthica* and *Striga hermonthica* root were 14.0%, 16.1% and 10.5% where maize plant root planted without *Striga hermonthica* has the highest crude fibre content (11.1%) while the least crude fibre content (10.5%) was recorded in the root *Striga hermonthica.* The values were generally less than the 16.8% crude fibre content recorded in the roots of *B. aegyptiaca* [19].

The crude fibre content of maize plant shoot inter-planted with striga, maize plant shoot planted without *Striga hermonthica* and *Striga hermonthica* shoot were 11.6%, 13.8% and 10.9% where maize plant shoot not inter-planted with *Striga hermonthica* has the highest crude fibre content (13.8%) while the least crude fibre content (10.9%) was recorded in *Striga hermonthica.* The values were generally less than the 34.8% and 12.0% crude fibre content recorded in the stem and leaves of *B. aegyptiaca* [19].

The mean carbohydrate content of maize plant root inter-planted with striga, maize plant root planted without *Striga hermonthica* and *Striga hermonthica* root were 53.4%, 52.1% and 58.7%, where the root of *Striga hermonthica* has the highest carbohydrate content (58.7%) while the least carbohydrate content (52.1%) was recorded in the root of maize plant planted without *Striga hermonthica.* The values were generally greater than the 50.0% carbohydrate content recorded in the roots of *B. aegyptiaca* [19].

The carbohydrate content of maize plant shoot inter-planted with striga, maize plant shoot planted without *Striga hermonthica* and *Striga hermonthica* shoot were 59.1%, 58.4% and 67.3% where maize plant shoot inter-planted with *Striga hermonthica* had the highest carbohydrate content (59.1%) while the least carbohydrate content (58.4%) was recorded in the shoot of maize plant planted without *Striga hermonthica.* The values were generally greater than the 42.9% and 44.5% carbohydrate content recorded in the stem and leaves of *B. aegyptiaca* [19].

3.3. Bio-Concentration of Mineral Elements in Plant Tissues

Plant's ability to accumulate minerals from soils was estimated using the BCF, which is defined as the ratio of mineral element concentration in the plant's root to that in the soil. The plant's ability to translocate mineral elements from the roots to the shoots is measured using the TF, which is defined as the ratio of metal concentration in the shoots to the roots were presented in Table 2. Enrichment occurs when contaminants taken up by a plant are not rapidly degraded, resulting in a buildup in the plant [18].

The soil to root bio-concentration factors (BCF) of phosphorus, potassium, and magnesium of striga plant were 3, 5 and 1 while that of maize plant inter-planted with striga were 1, 4 and 1 respectively suggesting enrichment of the said mineral in their root tissues however this was a contrast to the BCF of maize planted without striga (control) for potassium and magnesium. This may be due to less sorption stress as in the former imposed by striga on the maize plant. The soil to root BCF of manganese and zinc were all less than 1.

The soil to shoot bio-concentration factors (BCF) of phosphorus and potassium in striga plant were approximately 2 indicating enrichment. The shoot of maize plant inter-planted with striga recorded BCF of 3 with respect to potassium.

The hyperaccumulation demonstrated by striga may be due to the efficient abstracting of minerals from the xylem of maize plant by striga which is underpinned by direct luminal continuity between the striga and maize plant vessels [13].

The root to shoot translocation factor (TF) of phosphorus and potassium in striga plant was greater than 1, while the TF of manganese in maize plant planted with striga was approximately 1. The control (maize plant planted without striga) records root to shoot TF of potassium, magnesium and manganese to be greater than 1. These suggest shoot as the most probable storage site of the listed mineral with respect to the plants.

Table 2. *Mean Mineral Content (mg/kg) and Bioaccumulation Factor.*

Mineral/Sample		Phosphorus	Potassium	Magnesium	Manganese
Striga	Soil	208.01±64	542.72±292	450.83±87	103.21±39
	Root	723.25±47	2733.05±324	531.11±56	13.07±0.5
	Shoot	446.50±6.7	1543.40±6	279.66±3.6	10.02±0.02
	Root/Soil	3	5	1	0
	Shoot/Soil	2	2	0	0
	Shoot/Root	2	2	0	0
Maize inter-planted With Striga	Soil	208.01±64	542.72±292	450.83±87	103.21±39
	Root	222.61±23	2431.97±129	542.77±173	18.75±11
	Shoot	156.90±40	1856.55±120	412.81±126	33.81±13
	Root/Soil	1	4	1	0
	Shoot/Soil	0	3	0	0
	Shoot/Root	0	0	0	1
Maize planted without Striga (Control)	Soil	180.55±59	484.53±102	396.34±105	144.61±14
	Root	417.15±25	12.11±6	0.52±0.5	0.98±0.0
	Shoot	48.792.1	346.60±26	210.44±13	28.85±1.9
	Root/Soil	2	0	0	0
	Shoot/Soil	0	0	0	0
	Shoot/Root	0	28	404	29

3.4. Kinetic Parameters for Mineral Uptake in Plant Tissues

The uptake of P, K, Mg and Mn with time (10-days interval) into striga plant (S), maize inter-planted with striga (M/S) and maize plant alone (M) were fitted into pseudo first order, second order, elovic and intra-particle diffusion kinetic models respectively. The kinetic data generated from the various models are presented in Table 3.

Based on the highest value of regression coefficients (R^2) obtained the uptake of phosphorus, potassium and magnesium by striga plant conforms best to the elovic kinetic model while manganese uptake fits intra-particle diffusion kinetic model implying the rate of adsorption of the minerals decreases exponentially as the amount of adsorbed mineral increases [21].

While for the maize plant inter-planted with striga, the uptake of phosphorus fits best to the pseudo first order kinetics, potassium fits intra-particle diffusion kinetic model, magnesium and manganese is best explained using 2nd order kinetics.

Then for the maize planted alone, the uptake of minerals almost correlate with that of maize planted with striga where phosphorus up fits best to the pseudo first order kinetics, potassium, magnesium and manganese is best explained using 2nd order kinetics implying chemical sorption [7].

Table 3. *Kinetic Parameter of Mineral Elements Uptake.*

		First Order	Second Order	Elovic	Intraparticle Diffusion
Phosphorus	S	$R^2 = 0.5682$	$R^2 = 0.773$	$R^2 = 0.8749$	$R^2 = 0.86645$
		$K_1 = 1.06 \times 10^{-4}$	$K_2 = 1.02 \times 10^{-7}$	$\alpha = 0.0464$	$K_{id} = 8.685$
		$Q_m = 5937.65$	$Q_m = -541.66$	$\beta = 0.00359$	$C = -922.1$
	M/S	$R^2 = 0.69945$	$R^2 = 0.5135$	$R^2 = 0.5422$	$R^2 = 0.62295$
		$K_1 = 6.9 \times 10^{-5}$	$K_2 = -2.2 \times 10^{-6}$	$\alpha = 0.005085$	$K_{id} = 0.593$
		$Q_m = 236.785$	$Q_m = 48.96$	$\beta = 0.01685$	$C = -42.9$
	M	$R^2 = 0.93305$	$R^2 = 0.787$	$R^2 = 0.857$	$R^2 = 0.88605$
		$K_1 = 9.2 \times 10^{-5}$	$K_2 = 3.32 \times 10^{-7}$	$\alpha = 0.00887$	$K_{id} = 0.477$
		$Q_m = 121.67$	$Q_m = 111.51$	$\beta = 0.02105$	$C = -20.22$
Potassium	S	$R^2 = 0.8432$	$R^2 = 0.62685$	$R^2 = 0.9492$	$R^2 = 0.9347$
		$K_1 = 1.3 \times 10^{-4}$	$K_2 = 1.83 \times 10^{-6}$	$\alpha = 0.226$	$K_{id} = 35.4$
		$Q_m = 25509$	$Q_m = -13.32$	$\beta = 3.12 \times 10^{-4}$	$C = -4075$
	M/S	$R^2 = 0.6821$	$R^2 = 0.75105$	$R^2 = 0.8027$	$R^2 = 0.8283$
		$K_1 = 1.2 \times 10^{-4}$	$K_2 = -5.1 \times 10^{-8}$	$\alpha = 0.2541$	$K_{id} = 11.05$
		$Q_m = 8538.05$	$Q_m = 2750$	$\beta = 10.4 \times 10^{-4}$	$C = -293.05$
	M	$R^2 = 0.2218$	$R^2 = 0.81515$	$R^2 = 0.7411$	$R^2 = 0.721$
		$K_1 = 4.15 \times 10^{-5}$	$K_2 = -1.3 \times 10^{-7}$	$\alpha = 0.22736$	$K_{id} = 2.41$
		$Q_m = 1675.32$	$Q_m = 692.3$	$\beta = -2.54 \times 10^{-4}$	$C = 1478.4$
Magnesium	S	$R^2 = 0.70175$	$R^2 = 0.61245$	$R^2 = 0.9975$	$R^2 = 0.9095$
		$K_1 = 6.91 \times 10^{-5}$	$K_2 = 3.14 \times 10^{-4}$	$\alpha = 0.0304$	$K_{id} = 4.2$
		$Q_m = 1226.3$	$Q_m = -2.2750$	23.2×10^{-4}	$C = -16.75$
	M/S	$R^2 = 0.7223$	$R^2 = 0.90085$	$R^2 = 0.8124$	$R^2 = 0.6519$
		$K_1 = 9.21 \times 10^{-5}$	$K_2 = 3.39 \times 10^{-6}$	$\alpha = 0.0633$	$K_{id} = 1.66$
		$Q_m = 868.41$	$Q_m = 254.65$	$\beta = 71.6 \times 10^{-4}$	$C = -19.625$
	M	$R^2 = 0.62695$	$R^2 = 0.94015$	$R^2 = 0.5611$	$R^2 = 0.65585$
		$K_1 = 5.3 \times 10^{-5}$	$K_2 = 1.11 \times 10^{-6}$	$\alpha = 0.0487$	$K_{id} = 0.4713$
		$Q_m = 614.12$	$Q_m = 331.05$	$\beta = 0.0120$	$C = 38.258$
Manganese	S	$R^2 = 0.7276$	$R^2 = 0.803$	$R^2 = 0.7026$	$R^2 = 0.8223$
		$K_1 = 5.76 \times 10^{-5}$	$K_2 = 8.19 \times 10^{-5}$	$\alpha = 9.71 \times 10^{-4}$	$K_{id} = 0.214$
		$Q_m = 49.685$	$Q_m = -0.2194$	$\beta = 0.0609$	$C = -27.215$
	M/S	$R^2 = 0.65265$	$R^2 = 0.86255$	$R^2 = 0.7924$	$R^2 = 0.74725$
		$K_1 = 3.46 \times 10^{-5}$	$K_2 = -2.6 \times 10^{-5}$	$\alpha = 16.3 \times 10^{-4}$	$K_{id} = -0.04345$
		$Q_m = 7.92$	$Q_m = 4.145$	$\beta = 0.253$	$C = 18.09$
	M	$R^2 = 0.89185$	$R^2 = 0.90485$	$R^2 = 0.7844$	$R^2 = 0.80695$
		$K_1 = 2.6 \times 10^{-5}$	$K_2 = 3.34 \times 10^{-5}$	$\alpha = 6.74 \times 10^{-4}$	$K_{id} = 0.1413$
		$Q_m = 24.49$	$Q_m = 9.86$	$\beta = 0.152$	$C = -16.117$

R = Regression coefficient, K_{id} = intraparticle diffusion rate constant (g/mg $\text{min}^{0.5}$), α = initial sorption rate constant ($\text{mg.g}^{-1}.\text{min}^{-1}$), β = desorption constant (g.mg^{-1}), C = intercept

3.5. Sorption Capacity of Mineral Element by Striga and Maize Plant

The transfer of P, K, Mg and Mn from soil to striga plant (S), maize plant inter-plant with striga (M/S) and control, maize plant only (M) presented in Tables 4 base on the relationship between plant uptake and their concentration in soil and was interpreted base on Freundlich-like equation: where q is the contaminant concentration in plants (mg/kg) and C is the concentration of contaminants in the soil (mg/kg), K was considered as the sorption capacity whereas the value of 1/n is indicative of the strength of sorption [14].

Table 4. *Sorption Kinetics for Mineral Elements Uptake.*

Macro Element	Sample	log K	1/n	R^2	K
P	M	2.499	-0.1539	0.00120	315.8
	S	3.049	-0.1278	0.0137	1119
	M/S	- 2.038	1.826	0.321	9.160×10^{-3}
K	M	- 23.20	9.207	0.427	6.250×10^{-24}
	S	3.585	-0.1011	0.0196	3845
	M/S	1.947	0.4739	0.0714	88.57
Mg	M	- 5.638	2.532	0.0215	2.300×10^{-6}
	S	3.385	-0.3016	0.0167	2424
	M/S	2.562	0.03870	0.000400	364.6
Mn	M	0.6654	0.0299	0.000100	4.628
	S	1.172	-0.0573	0.0142	14.89
	M/S	- 0.7536	1.02	0.126	0.1730

The transfer of phosphorus from soil to maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S) in soil. Revealed that the sorption capacity K, of maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S) was 315.8, 1119 and 9.160×10^{-3}, respectively. Indicating a significant variation in sorption capacities ($p < 0.05$), where the sorption capacity of striga is 122265 times the capacity of maize inter-planted with striga.

The transfer of potassium from soil to maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S). Reveals that the sorption capacity K, of maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S) was 6.250×10^{-24}, 3845 and 88.57, respectively. Indicating a significant variation in sorption capacities ($p < 0.05$), where the sorption capacity of striga is 43.41 times the capacity of maize inter-planted with striga.

While the transfer of magnesium from soil to maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S). Reveals that the sorption capacity K, of maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S) was 2.300×10^{-6}, 2424 and 364.6, respectively. Indicating a significant variation in sorption capacities ($p < 0.05$), where the sorption capacity of striga is 6.65 times the capacity of maize inter-planted with striga.

Then the transfer of manganese from soil to maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S) in soil. Reveals that the sorption capacity K, of maize plant (M), striga plant (S) and maize plant inter-plant with striga (M/S) was 4.628, 14.89 and 0.1730, respectively. Indicating a significant variation in sorption capacities ($p < 0.05$), where the sorption capacity of striga is 86 times the capacity of maize inter-planted with striga.

4. Conclusion

One of the major challenges in maize production across the globe is that of infestation by striga, a parasitic plant resulting in an intense competition for mineral resources, then eventual decline in maize growth, biomass and overall maize yield. The growth profile obtained was in the order: MF > M > M/SF > M/S > SF > S implying a significant effect on maize growth by striga. However, the striga, maize planted with striga and maize planted alone were all rich in proximate compositions such as moisture, ash, crude protein, lipid and fibre content. Soil-plant BCF of minerals been highest in striga and least in maize planted with striga. The mineral uptake mechanism by maize plant was best explained using the pseudo second order kinetics model while that of striga conforms more to the elovic kinetic model. The mean sorption capacity K of minerals based on Freundlich-like equation reveals higher uptake capacity by striga plant when compared to maize plant which supports the reason why striga competes favorably with maize for mineral with significant effect in lowering maize yield. Given the higher sorption capacity of *Striga hermonthica*, further studies are suggested on fortifying maize to compete favorably with striga plant.

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