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SIMPLE CORRELATION BETWEEN STRIGA VIGOR AND GROWTH CHARACTERS OF SORGHUM TAKEN DURING THE 2018, 2019 AND 2020 RAINY SEASONS IN BAUCHI, BAUCHI STATE, NIGERIA

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ABSTRACT
Field experiment was conducted for three (3) years during the rainy seasons of 2018, 2019 and 2020 to study the productivity of sorghum as influenced by transplanted age and nitrogen rate on striga (*Striga hermonthica* L. Benth) infestation in Bauchi. The research was conducted at the Teaching and Research Farm of the Faculty of Agriculture and Agricultural Technology, Abubakar Tafawa Balewa University, Bauchi (10° 22' N and 9°47′ E) in the northern Guinea savanna ecological zone of Nigeria. The treatments consisted of transplanted age; 2, 3, 4 and 5 weeks after emergence in the nursery (WAE) with a control (direct seeded on the field) and five nitrogen levels; 0, 30, 60, 90 and 120 kg N/ha). The treatments were factorially combined and laid out in a Randomized Complete Block Design with three replications. In all the three seasons, sorghum seedlings were first raised in the nursery before being transplanted out to the field. Characters measured were plant height, number of leaves, stem girth, leaf area, leaf area index, crop growth rate, net assimilation rate and flag leaf area. Striga vigor was carried out based on visual observation using Striga vigor chart and Striga vigor score classes. Simple correlation between striga vigor and growth characters of sorghum indicated that significant and negative correlations exist.

Keywords: Striga, Sorghum, Transplanting, Correlation, Nitrogen.

INTRODUCTION
Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop grown for human consumption, surpassed only by rice, wheat, barley and maize. World production of sorghum is between 55 and 70 million times of grains per annum cultivated from between 40 and 45 million hectares, with an average yield of 1412 kg ha. In 2010, the USA was the world's largest producer of sorghum (8.8) metric tons annually), followed by India (7.0), Mexico (6.9), Nigeria (4.8) and Argentina (3.6).

Sorghum is one of the leading food crops of Nigeria. The national estimated and expected average crop productivity of sorghum is 2137 kg ha^{-1} (Samual *et al*., 2013). Sorghum is cultivated across the world in the warmer climatic areas. It is unique in its adaptation to environmental extremes of abiotic and biotic stresses and an essential crop to diets of poor people in the semi-arid tropics where droughts have caused frequent failures of other crops. Sorghum is produced in virtually all the northern states in Nigeria, though some states produce more than others. Kano, Kaduna, Sokoto, Gombe, Bauchi, Zamfara, Benue, Kogi, Nasavawa, Taraba and Plateau are major sorghum producing States.

In Nigeria, sorghum is used in various ways. The grain is used for human food such as poridge, *"Kunu", "Fura", "Tuwo", "Dambu"*, infant food, syrup, and local beverage known as "*Kunuzaki*" and "*Burukutu*". Also, the stalk is used for animal feed, for construction of houses and fences, and as fuel wood. Its importance is ever increasing as a source of food for rural populace, as animal feed and raw materials, for the industries.

Sorghum suffers from a lot of pests among which, the witch weed *Striga* is the most important. The genus *Striga* belongs to the family *Scrophulariaceae* and thought to include 35 species. *Striga* is generally native to semi-arid tropical areas of Africa but have been recorded in more than 40 countries. *Striga* possibly originates from a region between Semien Mountains of Ethiopia and the Nubian Hills of Sudan. This region is also the birthplace of the domesticated sorghum. It has long been recognized as the greatest biological constraint to food production in Africa, where nearly 100 million ha of the African savannah are infested annually with *Striga*. Although these parasites attack several crops, the brunt of the ravage has fallen on the staple crops of the poor in the African savanna, namely maize (*Zea mays*), sorghum (*Sorghum bicolor* (L), pearl millet (*Pennisetumglaucum* [L.] Gartn), upland rice (*Oryza sativa*) and cowpeas (*Vigna unguiculata*) (Ejeta and Gressel, 2007).

Most important species of *Striga* are *S. asiatica, S. hermonthica and S. forbgesi* which are mainly found in cereals such as maize, sorghum, pearl millet and rice. *S. hermonthica* is thought to be the most important parasitic weed specie worldwide. *Striga* species have become the most common parasitic weeds in sorghum-producing areas or eastern Ethiopia, causing crop losses of 50 to 80% and sometimes of even 100%. *S. hermonthica* is the most common specie, damaging sorghum (*Sorghum bicolor*), maize (*Zea mays*), finger millet (*Pennisetum glaucum*), tef [(*Eragrostis tef* (Zucc.) Trotter], barley (*Hordeum vulgare*) and wheat (*Triticum spp*.) in many parts of the world. As a menace to most cereal crops, its seeds mode of dispersal in nature is usually attributed to wind and rain, facilitated by the distinct sculpturing on the seed (Abdul *et al*., 2012).

Striga seeds can remain dormant for several months before they respond to chemicals exuded by the host; this period is referred to as “after ripening”. Conditioning occurs when two environmental factors are present: suitable temperatures in the range of 25-35°C and adequate moisture (Parker, 1991).

Research on striga control has been carried out for a long time and a wide range of technologies have been developed such as cultural and mechanical methods which includes hand weeding and sanitation, crop rotation, trap and catch crops, intercropping, soil fertility, ‘push-pull’ technology. Biological control method involves biological control using insects and biological control using pathogens. Chemical control method includes using pre-emergence herbicides, post-emergence herbicides, and host plant resistance. Integrated striga management is another control method that is managed through using two or more different control methods.

Striga hermonthica could be controlled by using resistant variety, fertilizer on farms which had long been abandoned due to *Striga* infestation, whereas the local cultivars had severe infestation. The application of high nitrogen (N) increases the performance of cereal crops under *Striga* infestation. This is due to the fact that N reduced the severity of *Striga* attack while simultaneously increasingly the host performance (Lagoke and Isah, 2010). Also, other advantageous effects of fertilizers include increasing soil N and other nutrients, replenishing the soil organic matter and increasing soil moisture holding capacity.

Sorghum productivity in the world in general and in Nigeria in particular is by far below its potential. The major factors that account for this low yield is moisture stress, low soil fertility, pest damage and possibly agronomic practices like use of transplanted seedlings, transplanting. Among the pests, the root parasitic weed *Striga* has long been recognized as the greatest biological constraint to sorghum production (Gebrelibanos and Dereje, 2015). *Striga* spreads rapidly in areas of low fertility and decreasing plant diversity, conditions often experienced by poor farmers in dry land zones. This problem is also common in the semi-and area which is one of the most sorghum producing areas of the country.

Striga has a high fecundity with seed production of 10,000 to 100,000 seed per plant and the seed is asynchronous with seed dormancy of twenty years. This makes the weed difficult to control. It is difficult to control effectively because most of its damages made to the host plant occurs underground before the striga plant emerges. Although the level of striga infestations and damages is increasing, farmers rarely adopt control methods duo to limitation and lack of information about available technology options (Hearne, 2008). Application of high dosage of nitrogen fertilizer is generally beneficial in delaying striga emergence and obtaining stronger crop growth (Lagoke and Isah, 2010).

Oswald *et al* (2001) and Oswald (2005) recommended transplanting as a striga control method. Furthermore, available options when applied individually are not effective. Integration of high urea application and profile agronomic practices like transplanting will further enhance the long-time control of striga, Experiment shows that the best solution in the control of striga is an integrated approach that include a combination of methods that are available and acceptable by farmers (Workineh, 2019).

Controlling *Striga spp*. becomes an enormous task. There is a need to solve the *Striga* problem in order to achieve sustainable food production and N fertilizer is an essential element for reversing this effect. Therefore, adequate application of N fertilizer increases plant vigor and dry matter weight and good plant vigor and high dry matter weight are important criteria for selecting sorghum that are resistant/tolerant to *Striga* threat.

Correlation analysis was performed to study the relationship that exist between Striga vigor and growth characters of sorghum in a Striga infested field.

MATERIALS AND METHODS

Field trial was conducted during the rainy seasons of 2018, 2019 and 2020 at the teaching and research farm of the Faculty of Agriculture and Agricultural Technology, Abubakar Tafawa Balewa University Bauchi, (10° 22' N and 9° 47' E) in the northern Guinea savanna ecological zone of Nigeria. The site of the research has been known to be endemic to striga due to continuous cereal crop monoculture over years. Moreover, aside the endemic nature of the site, the parasite was also inoculated in the field.

The treatments consisted of four transplanted ages 2, 3, 4, 5 weeks after emergence in the nursery and a control (directly seeded in the field) and also, five nitrogen levels of 0, 30, 60, 90 and 120kgN/ha applied as urea (46%N). Experimental area of 1200 m^2, the gross plot size was 3m x 4m (12m^2) with 1m between plots and 2m between replicates to serve as a walk way. Using a spacing of 75cm x 75cm, 120 number of plants with two stands per plant were obtained from 3m x 4m plot size.

The field was ploughed once and harrowed twice to a fine tilth during the first year using tractor drawn implement. However, manual tillage using hand hoe was carried out in the subsequent years so as to maintain plots and their treatments. The treatments were factorially combined to give 25 treatment combinations which were laid out in randomized complete block design (RCBD) replicated three times. Spacing of 75cm and 25cm (inter and intra-row) was used.

The experimental land has been known over the years to be endemic to *striga hermonthica* due to continuous cropping of maize and sorghum for over ten years. However, artificial striga inoculation was also carried out, before sowing sorghum (directly seeded treatment plot), holes of 10 cm deep were made at spacing of 75cm by 25 cm. A mixture of 30g of *Striga hermontica* seed with 2kg of sieved sand (with a 212-micron sieve was used).

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Sticks were placed on each hole for identification of planting hills for sorghum. The striga seeds were then poured inside the holes using spoon and allowed to be conditioned for two weeks following the procedure of Berner (1997) before sorghum was sown.

Two nurseries were established close to the field. Nursery one with the application of nitrogen constructed to a size of 6m x 3m (18m^2) and nursery two without nitrogen application of 2m x 3m (6m^2) size. Seeds were sown in the nursery using broadcast method at the establishment of the rains in each year of the study.

The direct seeded plots were sown on the same day with the seeds in the nursery. Sowing was carried out manually with hand. However, the emerged seedlings were later thinned to two plants per stand, three weeks after emergence. Intra and inter row spacing was maintained at 25cm x 75cm respectively.

The first dose NPK 15:15:15 was applied in nursery one by broadcasting at planting and on the directly seeded plot by side placement. Then the second application of NPK 15:15:15 was applied two weeks after transplanting of each transplanted age and two weeks after the first application on the directly seeded plot. The balance of 30, 60 and 90kgN/ha were applied to 60, 90 and 120kgN/ha treatment plot four weeks after the second application using urea (46%N) by side placement. The 0kgN/ha treatment 0:30:30 was applied using single phosphate (18% P_2O_5) and muriate of potash (60% K_2O) into two split application halves at planting in nursery two by broadcasting and at directly seeded plot by side placement. The remaining half at two weeks after the first application in the directly seeded plot and two weeks after transplanting of each transplanted age.

No herbicide was applied during the three (3) years trial. Weeding was carried out using hoe at two weeks interval before striga emergence. After striga emergence, weeds were controlled by hand puling to prevent the destruction of emerging striga plants on the plot.

Assessment of Growth Characters

Data on growth characters for the three years was collected periodically on five randomly tagged plants in each plot and taken at 8, 10 and 12 weeks after emergence (WAE). All the sampled plants were tagged at their bases with a twine rope (white in colour) for easy identification before the commencement of data collection and after that, the following data were collected:

1. **Plant Height (cm):** Height of five tagged plants in each plot was measured using a measuring tape at 8, 10 and 12 WAE. This was taken from the ground level of each sampled plant to the tip of the apical bud. The mean height was then taken and the average recorded on per plant basis.
2. **Number of Leaves per Plant:** Number of leaves per plant was determined by counting from five randomly selected plants from each plot and recorded at 8, 10 and 12 WAE. The average was then taken on per plant basis.
3. **Stem Girth (cm):** Stem girth was measured from the five randomly selected plants at 8, 10 and 12 WAE. Vernier caliper was placed on the stem at the bottom of the leaves.
4. **Leaf Area (cm^2):** Leaf area was taken from the randomly selected five plants by measuring the area of the leaf (length x breath) from 2 bottom, middle and upper leaves using measuring tape. The average was then multiplied by a factor of 0.723 following the procedure of Duncan (1968). Leaf area was also carried out at 8, 10 and 12 WAE.
5. **Leaf Area Index (LAI):** Leaf area index (LAI) is the ratio of leaf area to the area of ground cover. It was obtained by dividing the plant leaf area obtained in 3.7.2.4 above by the land area covered by the plant as suggested by Duncan (1968). This was also taken at 8, 10 and 12 WAE. The LAI was then worked out and recorded as follows:

$$LAI = \frac{A}{P} = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)} \quad \ldots(1)$$

where;
A = leaf area of plant leaf (cm^2)
P = Ground area covered by the plant (cm^2)

6. **Flag Leaf Area (cm^2):** Flag leaf area was taken by measuring the area of the flag leaf (length x breadth) using measuring tape and multiplied by a factor of 0.723 as suggested by Duncan (1968). The flag leaf area was however, only taken at 14 WAE when the plants were headed.
7. **Crop Growth Rate (CGR):** Crop growth rate (CGR) is the gain in dry matter production per unit of land area per unit of time. Total dry weight was obtained each year from the mean of five plants per plot by uprooting the plants from the two border rows. These plants were then oven-dried at a temperature of 70°C to a constant weight and the mean weight recorded. The data was taken at 8, 10 and 12 WAE. After the total dry weight per unit time was obtained, the result was used for the computation of CGR at 8 and 10 WAE. The CGR expresses the dry matter increment of the plant material per unit ground area covered by the plant. CGR was computed using the formula by Watson (1958) and Little and Hills (1978) as follows:

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} x \, \frac{1}{P} \, (gcm^2 \, wk^{-1}) \quad \ldots(2)$$

where;
W_1 = Dry weight at first sampling period
W_2 = Dry weight at the second sampling period
T_1 = Time at which W_1 was taken
T_2 = Time at which W_2 was taken
P = Land area covered by the plant

8. **Net Assimilation Rate (NAR):** Net assimilation rate (NAR) or unit leaf rate is the net gain of the assimilate per unit of leaf area per unit of time, After the leaf area of each sampled plant from 3.8.2.4 above was taken and their dry weights from 3.8.2.7 were determined, the plants NAR was calculated at 10 and 12 WAE, using the formula suggested by Watson (1958) as follows:

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} x \, \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1} \, (gcm^2 \, wk^{-1}) \quad \ldots(3)$$

where;
W_1 = Dry weight at first sampling period
W_2 = Dry weight at the second sampling period
T_1 = Time at which W_1 was taken
T_2 = Time at which W_2 was taken
A_1 = Leaf area value for T_1
A_2 = Leaf area value for T_2
$\log_e$ = Natural logarithm

9. **Striga Vigor:** The Striga vigor was carried out based on visual observation using striga vigor chart and striga vigor score classes as presented in Figure 1 and Table 1.

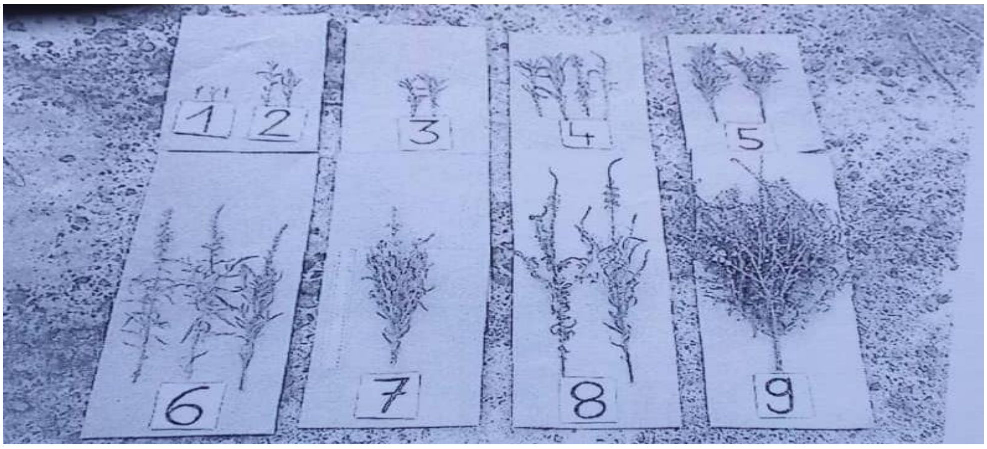

Figure 1: *Striga*

Table 1: Striga Vigor Score classes

Score	*Striga* plant height (cm)	Number of Striga branches
1	≤ 5	None
2	6 – 20	None
3	6 – 20	≥ 1
4	21 – 30	≤ 5
5	21 – 30	> 5
6	31 – 40	≤ 10
7	31 – 40	> 10
8	>40	≤ 10
9	>40	> 10
0	Zero emerged *Striga* plants	

RESULTS AND DISCUSSION

Simple correlation between growth characters of sorghum and striga vigor during the 2018, 2019 and 2020 rainy seasons in Bauchi, Bauchi State, Nigeria is presented in Table 2. The result shows that there was highly significant (P≤0.001) and negative relationship between striga vigor and all the growth characters studied except plant height with significant and negative relationship at (P≤0.05).

Simple correlation between striga vigor and growth characters of sorghum during the 2018, 2019 and 2020 rainy seasons in Bauchi, Bauchi State, Nigeria. The significant and negative correlation existed between Striga vigor with plant height, number of leaves, stem girth, leaf area, leaf is index, crop growth rate, net assimilation rate and flag leaf area. This revealed that, the lesser the striga vigor, the taller the plant, the higher the number of leaves, the thicker the stem, the wider the leaf area, the higher the leaf area index, the higher the crop growth rate, the higher the net assimilation rate and the wider the flag leaf area.

Severity of infestation of *Striga* is reported to correlate negatively with soil fertility. Nitrogen proved to be an essential element for reducing *Striga* infestation and mitigation of its adverse effects on crops. The suppressive effects of N on *Striga* infestation were attributed to

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delayed germination, reduced radical elongation, reduced stimulants production and reduction of seeds response to the stimulants (Hassan *et al*., 2009).

Fertilizer application had significant effect on height, vigor score, reaction score of sorghum as well as shoot count, days to emergence, dry matter of production and dry weight of *Striga*. The application of high nitrogen (N) increases the performance of cereal crops under *Striga* infestation. This is due to the fact of that nitrogen reduced the severity of *Striga* attack while simultaneously increasingly the host performance (Lagoke and lsah, 2010). This study agrees with that of Gebrelibanos and Dereje (2015) who reported that nitrogen fertilizer significantly reduced the number of Striga branches per plant and Striga plant height. Zerihun (2016) also reported a decrease in Striga plant height and dry weight with the application of nitrogen fertilizer. Clottey *et al.* (2015) reported significant reduction of striga population and growth in transplanted sorghum through seedlings with well-developed roots in nursery which unlike direct sowing, did not release exudates to stimulate striga germination. As a result, transplanted maize seedlings have the ability to suppress weed population in the field by greater coverage of resources (Miguel-chavez and Larque-Saavedra (1996).

Table 2: Simple correlation between striga vigor and growth characters of sorghum taken during the 2018, 2019 and 2020 rainy seasons in Bauchi, Bauchi State, Nigeria

Characters	Correlation coefficient (λ)	Mean	Standard Deviation
Striga vigor	-	-	-
Plant height	- 0.65*	170.61	1.08
Number of leaves	- 0.190**	11.22	0.11
Stem girth	- 0.198**	6.84	0.10
Leaf area	- 0.205**	515.36	8.88
Leaf area index	- 0.196**	0.27	0.004
Crop growth rate	- 0.193**	3.73	0.14
Net assimilation rate	- 0.238**	3.14	0.18
Flag leaf area	- 0.190**	200.93	4.56

*Significant at 5% level of probability; **significant at 1% level of probability

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