Journal of Plant Development **ISSN 2065-3158 print / e-ISSN 2066-9917**
Vol. **28**, Dec **2021**: 97-108 Available online: www.plant-journal.uaic.ro
doi: 10.47743/jpd.2021.28.1.876

INTERCROPPING AND N FERTILIZATION EFFECTS ON *STRIGA* INFESTATION, SOIL C AND N AND GRAIN YIELD OF MAIZE IN THE SOUTHERN GUINEA SAVANNA OF NIGERIA

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Abstract: Millions of hectares devoted to cereal production in Africa were affected by *Striga* infestation across locations and time. A study was conducted in 2012 and 2013 rainy seasons at the Teaching and Research Farms of Niger State College of Agriculture, Mokwa and the Teaching and Research Farms of Federal University of Technology, Minna, in the Southern Guinea Savanna ecology of Nigeria to determine cereal / legume intercropping and N fertilization effects on *Striga* infestation, Soil C and N and grain yield of maize. The treatments consisted of four inorganic N fertilizer levels (0, 60, 90, 120 kg ha^{-1}), alternate hill and same hill intercropping of *Aeschynomene histrix*. Intercropping maize with *A. histrix* has the potential of reducing *Striga* parasitism with about 33-47% with respect to *Striga* shoots per m^{-2} and *Striga* shoots per plot thus, enhancing maize grain yield. The use of herbaceous legumes in intercropping contributed about 58% SOC and 52-57% reduction in number of *S. hermonthica* due to application of N using urea, thereby helping to control *Striga* infestation. Intercropping maize with *A. histrix* improved the soil organic matter and hence, the physical, chemical and biological properties of the soil for good crop growth. Incorporation of the *A. histrix* residues substantially increased the soil N content. There was response to inorganic N fertilizer application, suggesting the need for N application to maize for optimum grain yield. Nitrogen rate of 60 kg ha^{-1} was optimum for maize yield in the study area.

Keywords: Grain yield, intercropping, legume, Maize, *Striga* infestation.

Introduction

Maize (*Zea mays* L.) ranks third globally after wheat and rice, provide 35% of food requirement in most countries and belongs to family Poaceae [BASSEY & al. 2019a]. More than 50% of the total maize production is being used as a food in developing countries [ARUN-KUMAR & al. 2008]. Nigeria's corn (maize) production in 2019 (October-September) is about 10.5 MMT, two percent less than 10.7 million metric tons in 2018 estimates [AATF, 2011]. The phenomenal increase in maize production in Nigeria over the past few years was attributed to increase in its utilization for various food items, livestock feed and industrial materials, as well as research activities [FAO, 2009].

Intercropping (IC) is an ancient multiple-cropping system that is popular with smallholder farmers in developing countries today, due to its higher land and nutrient use efficiency [LI & al. 2007], better economic returns [VAN ASTEN & al. 2011], and lower pest and disease incidence [ZHU & al. 2000] as compared to sole crops [HUANG & al. 2019]. Numerous studies have been conducted on cereal / legume IC systems based on field experiments

Received: 29 December 2020 / ***Revised***: 10 December 2021 / ***Accepted***: 13 December 2021

in Africa, Asia, Europe and Latin America [YU & al. 2015; LI & al. 2016; MARTIN-GUAY & al. 2018]. These studies have shown that IC has yield advantages generated by the mechanisms of interspecific facilitation (or complementarity) and/or competitive production principles [ZHANG & LI, 2003]. Due to facilitation and complementarity between species, cereal/legume IC has been widely practiced and promoted for sustainable agriculture development [ZHANG & LI, 2003]. The use of intercropping of host crops with legume crops is to serve as trap crop. Leguminous trap- crops stimulate suicidal germination of *Striga* seeds and, therefore reduce the seed bank and improve soil fertility [SCHULTZ & al. 2003]. KOLO & LAWAL (2009) observed that sorghum interplanted with jointvetch (*A. histrix*) delayed *Striga* shoot emergence by about two weeks and reduced its density thus, increased the grain yield of the crop. DUGJE & al. (2003) found that interplanting sorghum and millet with groundnut, respectively, reduced *Striga* infestation compared with sole cropping. Improved soil fertility conditions especially N is likely to lead to reduced *Striga* infestation. The use of herbaceous legumes can contribute to soil N, thereby helping to control *Striga* infestation. The yields benefit have been attributed to increased soil N availability following the legume through biological N fixation [YUSUF & al. 2009a], mineralization of their residues and release of N from the breakdown of roots and nodules after harvest and higher soil organic carbon [YUSUF & al. 2009b].

Striga hermonthica (Delile) Benth. (family Orobanchaceae)-is a debilitating root parasite and possesses an ominous obstacle to the African continent that is struggling with food security as it affects the livelihood of more than 300 million people [BABIKER, 2007]. Prodigious seed production, prolonged viability of the seeds and the subterranean nature of the early stages of parasitism make the control of the parasite by conventional methods difficult if not impossible. The increasing incidence of *Striga* has been attributed to poor soil fertility and structure, low soil moisture, intensification of land use through continuous cultivation and an expansion of cereal production [BERHANE, 2016]. Many potentially successful approaches developed to control this weed include using resistant/tolerant varieties, sowing clean seeds that are not contaminated with *Striga* seeds, rotating cereal hosts with trap crops that induce abortive germination of *Striga* seeds, intercropping, applying organic and inorganic soil amendments such as fertilizer or manure, fumigating soil with ethylene, applying post emergence herbicides, push-pull technology and using biological control agents [ABDALLAH & al. 2015]. Based on some studies, the interaction of tied-ridging with N fertilizer and resistant varieties; cereal-legume intercropping and its interaction with N fertilizer revealed low *Striga* infestation. No single management option has been found effective across locations and time. AATF (2011) stated that *Striga* infests 40% of arable land in the African Savannah region and two – thirds of the 73 million hectares devoted to cereal production in Africa were affected by *Striga*. The hectarage of land under maize production infested by *Striga* was put at four million [ANON, 2011]. Nearly 100 m ha of the African Savanna is infested annually with the witchweed and more than half of African farmers recognize that *Striga* infestation is on the increase on their farms [EJETA, 2011]. Over US $1billion losses per year was estimated for *Striga* infested maize alone in Africa [AATF, 2011]; a major cause of food insecurity in the region. In Nigeria based on an average grain loss of 39% caused by *S. hermonthica* on sorghum, an estimated annual loss of US $93.6 million was incurred [AATF, 2011].

The control of *Striga* has proved exceptionally difficult. In Nigeria, the use of inorganic fertilizers to increase the N content in the soil is not feasible for the peasant farmers due to lack of resources, inaccessibility, low industrial technology and poor road network, among others. One alternative to inorganic fertilizer to increase soil N is by intercropping with herbaceous legumes especially *A. histrix* or similar ones. Not many studies on the use of *A. histrix* which grows widely in Niger State, Nigeria, in the southern Guinea savanna have been done. Hence, the objectives of the study were to evaluate the effect of *A. histrix* on *Striga* infestation, soil organic carbon and nitrogen content, and maize yields.

Materials and Methods

Field experiments were conducted on a *Striga* infested field in 2012 and 2013 rainy seasons at the Teaching and Research Farms of Niger State College of Agriculture, Mokwa (09°18'N; 05°50'E) and the Teaching and Research Farms of Federal University of Technology, GidanKwano, Minna (9°31.860'N; 6°27.244'E; 254 m), situated in the Southern Guinea savanna agro ecological zone of Nigeria. Rainfall pattern of both sites is monomodal with the rainy season in Minna starting in April or May and ending in October, while that of Mokwa start in March or April and end in October or November. Monthly rainfall during the period of study at both sites are shown in Table 1. The soil of the Minna site is with loamy sand surface soil texture, slightly acidic, low organic carbon, N, and medium phosphorus. Selected soil physical and chemical properties of both sites before land preparation in 2012 are shown in Table 2. The two fields were heavily infested with *Striga hermonthica* which makes them to be sparingly cultivated with maize and sorghum over the years with no fertilizer.

Table 1. Monthly rainfall of the two experimental sites during the period of study

Months	Rainfall (mm)			
	Mokwa	Minna	Mokwa	Minna
	2012		2013	
January	0.0	0.0	0.0	0.0
February	58.0	1.5	0.0	0.0
March	0.0	0.0	20.1	0.0
April	88.0	258.0	43.4	34.2
May	235.4	140.4	165.0	204.5
June	123.0	67.3	174.0	96.5
July	268.2	194.7	346.0	333.1
August	132.0	160.4	423.2	376.9
September	111.4	301.8	487.0	337.2
October	38.0	100.3	76.3	158.0
November	0.0	0.0	12.1	0.0
December	0.0	0.0	0.0	0.0
Total annual rainfall	1054	1224.4	1747.1	1540.4

Source: College of Agriculture metrological station

Table 2. Some soil physical and chemical properties of both sites before planting in 2012

	Values	
Properties	**Mokwa**	**Minna**
Sand (g kg^{-1})	795	860
Silt (g kg^{-1})	116	93
Clay (g kg^{-1})	89	47
Textural class	Loamy sand	Loamy sand
pH (H_2O) (g kg^{-1})	6.7	6.8
Organic Carbon (g kg^{-1})	3.30	2.39
Total Nitrogen (g kg^{-1})	1.80	0.15
Available Phosphorus(mg kg^{-1})	18	12
Na+ (cmol kg^{-1})	0.09	0.23
K+ (cmol kg^{-1})	0.19	0.36
Mg++ (cmol kg^{-1})	0.98	1.65
Ca++ (cmol kg^{-1})	4.96	2.77
Exchangeable acidity(cmol kg^{-1})	0.11	0.04
ECEC (cmol kg^{-1})	6.32	5.05

Treatments and experimental design

The two sites had the same treatments, experimental designs and plot sizes. The treatments were four inorganic N fertilizer levels (0, 60, 90, 120 kg ha^{-1}), alternate hill and same hill intercropping of *A. histrix*. The treatments were laid out in a randomized complete block design with three replicates. There were 18 experimental plots, such that gross plot size was 8 m × 4 m (32 m^2) and the net plot size was 18 m^2, separated by 1 m alley. The number of ridges in the plot was five while the length of ridge was 8 m.

Both sites have the same crop establishment and management. The fields were manually cleared and ridged using hoe at 75 cm apart in 2012 and 2013. The maize variety, SUWAN 1, obtained from premier seeds, highly susceptible to *Striga* was manually planted at 3 seeds per hill, spaced 50 cm within rows. The seedlings were thinned to two plants per hill at two weeks after sowing (WAS) to give a plant population of 53, 3333 plants ha^{-1}. Basal application of 30 kg P ha^{-1} as single superphosphate and 30 kg K ha^{-1} as muriate of potash were carried out at 2 WAS after thinning. Inorganic N fertilizer as urea was split – applied to plots that were to receive N fertilizer. At 2 WAS, one-third of the N was applied, while the remaining two-third were applied at 6 WAS. Fertilizers were applied by side banding at about 5 cm away from the seedlings and at about 5 cm deep along the ridge. The first hoe – weeding was carried out at 3 WAS while the second weeding was at 5 WAS followed by careful hand-pulling of weeds other than *Striga*.

Data collection

The data collected from both sites were the same. The number of *Striga* shoots per maize plant was taken by counting each *Striga* shoot present per maize plant stand starting from 6 WAS. The number of *Striga* shoots flowering was taken by counting closely the number that flowered in each plot. The number of *Striga* shoots per meter squared was taken by counting closely the number of *Striga* present in each plot per m^2. Days to 50% *Striga* shoot flowering was carried out by counting the number of days from the day the first *Striga* shoot emerged to the day that 50% of

Striga shoots flowered. The *Striga* reaction score was taken on the scale of 0-9 using visual observation to measure mild, severe and very severe or death infestation of *Striga* on maize plant.

Ten maize plants from each of the net plot were randomly tagged for periodic observation at 3, 6 and 9 WAS. The following observations made were: The maize plant population was carried out by counting individual plants at 3, 6 and 9 WAS. This is also known as plant population count and expressed in hectare. The maize plant height was observed by tagging ten plants from the inner rows at random which were used throughout for taking the measurements. The plant height was measured using meter rule from the top of the uppermost leaf to the base of the plant at 3 and 6 WAS but from the base to the tip of the tassel at 9 WAS and expressed in centimeters. Days to 50% maize tasseling was taken through observation by counting the number of days from the sowing date to the day when about 50% of all the maize plants in each plot has tasseled and expressed in percentage. The average cob length of 10 harvested tagged maize plant from the inner row of each plot were taken and measured using meter rule and expressed in centimeters. The number of maize cobs from the inner rows of each plot was counted and estimated per hectare. This was done when the plant attains physiological maturity. The number of maize grain per cob was also obtained by weighing those harvested from the inner rows and shelled at harvest time. This was done by counting. 100 maize grain weights was taken from the ten harvested cobs from each plot, shelled and weighed using a weighing balance, expressed in grams. The maize grain yield analysis was carried out by harvesting maize ears in the two central rows leaving out the border plants at both ends (net plot of 18 m^2). These were shelled, air- dried and weighed. The grain yield was adjusted to 12% moisture content for each plot and weighed.

Soil samples were taken at harvest from each treatment plot and subjected to routine analyses. Particle size analysis was done by the hydrometer method [KLUTE, 1986], organic matter was determined by the procedure of Walkley and Black using the dichromate wet oxidation method [NELSON & SOMMERS, 1982]. Total N was determined by the micro – Kjeldahl digestion method [BREMNER & MULVANEY, 1982] and available P was by Bray – 1extraction followed by molybdenum blue colourimetry [BREMNER & MULVANEY, 1982]. Exchangeable K, Ca and Mg was extracted by EDTA titration method [THOMAS, 1982]. Soil pH was determined in 1:2 soil-water ratio using digital electronic pH meter.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) and means were separated using Duncan Multiple Range Test at 5% level of probability. The statistical package used was Statistical Analysis System (SAS), version 9.2 (2002).

Results

The effect of intercropping and N fertilization on *Striga* shoot m^{-2} was significant (Table 3). In 2012 at Mokwa site, AH intercropping had the least *Striga* shoot at 9 WAS while the zero N application had the highest. However, the effect of 60-120 kg N ha^{-1} fertilizer application and SH intercropping on *Striga* shoot were similar. Also, at 12 WAS in Mokwa site, SH and AH intercropping had the least *Striga* shoot which were similar, and the effects of 60-120 kg N ha^{-1} fertilizer application and intercropping treatments on *Striga* shoot were not significantly different. In 2013, AH intercropping had the least *Striga* shoot at both sites at 9 WAS while zero N application had the highest. However, the effect of 0-90 kg N ha^{-1} application on *Striga* shoot were similar at both sites. In the same year at 12 WAS, at Minna site, AH had the least *Striga* shoot while zero N application had the highest. However, application of 0-120 kg N ha^{-1} fertilizer on *Striga* shoot were similar at Mokwa, while at Minna site, application of 60-120 kg ha^{-1} fertilizer and SH intercropping had similar effects on number of *Striga* hoots.

Table 3. Effect of intercropping and N fertilization on *Striga* shoot m^{-2} at 9 and 12 WAS in 2012 and 2013 cropping seasons

Treatment	*Striga* shoot m^{-2}							
	Mokwa	Minna	Mokwa	Minna	Mokwa	Minna	Mokwa	Minna
	9 WAS 2012		12 WAS 2012		9 WAS 2013		12 WAS 2013	
0 kg N ha^{-1}	3a	17a	6a	11a	6a	14a	12a	44a
60 kg N ha^{-1}	2ab	16a	5ab	11a	2ab	10a	11a	30b
90 kg N ha^{-1}	1b	11a	2ab	11a	2ab	8a	8ab	30b
120 kg N ha^{-1}	1b	9a	2ab	10a	1b	8a	8ab	29b
SH	1b	8a	1b	10a	1b	5b	6b	29b
AH	0c	8a	1b	8a	0c	0c	4b	22c
SE±	0.30	1.01	0.70	1.03	0.50	1.02	1.20	3.03

Means in the column with different letter(s) are significantly different from each other at $P<0.05$ using Duncan Multiple Range Test (DMRT). WAS – Weeks after planting, SH – Same hill, AH – Alternate hill, SE – Standard error.

The effect of intercropping and N fertilization on *Striga* shoot growing with maize was significant (Table 4). In 2012 at Mokwa site, SH and AH intercropping had the least number of *Striga* shoot growing with maize while zero N fertilizer had the highest number of shoots. However, the effect of 60-120 kg N ha^{-1}fertilizer application, and SH and AH intercropping on *Striga* shoot were similar. Zero N fertilization had the highest *Striga* shoot at 12 WAS while 60 to 120 kg N ha^{-1} and intercropping treatments had the lowest. In 2013, AH intercropping had the least *Striga* shoot at Mokwa site at 9 WAS which were similar to 120 kg N ha^{-1} and SH intercropping. In the same year, at 12 WAS, AH had the least *Striga* shoot at Minna site while zero N fertilizer had the highest number of shoots.

Table 4. Effect of intercropping and N fertilization on *Striga* shoots growing with maize plant at 9 and 12 WAS in 2012 and 2013 cropping seasons

Treatment	*Striga* shoot per maize plant							
	Mokwa	Minna	Mokwa	Minna	Mokwa	Minna	Mokwa	Minna
	9 WAS 2012		12 WAS 2012		9 WAS 2013		12 WAS 2013	
0 kg N ha^{-1}	7a	20a	15a	29a	3a	29a	4a	124a
60 kg N ha^{-1}	3ab	19a	3b	28a	2ab	27a	4a	93a
90 kg N ha^{-1}	2b	19a	2b	26a	2ab	25a	3a	74a
120 kg N ha^{-1}	1b	18a	1b	25a	1bc	22a	3a	66a
SH	0b	13a	1b	22a	1bc	22a	3a	60b
AH	0b	12a	1b	20a	0c	19a	3a	45c
SE±	0.81	3.00	1.88	2.01	0.33	2.03	0.25	7.04

Means in the column with different letter(s) are significantly different from each other at $P<0.05$ using Duncan Multiple Range Test (DMRT). WAS – Weeks after planting, SH – Same hill, AH – Alternate hill, SE – Standard error.

The effect of intercropping and N fertilization on Soil C and N was significant (Table 5). In 2012 at both sites, AH intercropping had the highest Soil C while zero N application had the lowest. However, the effects of SH intercropping and N fertilization treatments at Minna site, and 60-90 kg N ha^{-1} fertilizer application and AH intercropping were similar in Soil C. In the same manner, SH intercropping had the highest soil C at both sites in 2013 while zero N application had the lowest. Soil N was significantly higher in AH intercropping than the N fertilization treatments in 2012. However, the effects of SH intercropping and N fertilization treatments were similar in Soil N.

Table 5. Effect of intercropping and N fertilization on Soil C and N at physiological maturity of maize in 2012 and 2013 cropping seasons

	Soil C (g kg^{-1})				**Soil N (g kg^{-1})**			
Treatment	**Mokwa**	**Minna**	**Mokwa**	**Minna**	**Mokwa**	**Minna**	**Mokwa**	**Minna**
	2012		**2013**		**2012**		**2013**	
0 kg N ha^{-1}	3.18b	2.39b	5.80ab	3.21b	1.08b	0.15b	1.12a	0.12a
60 kg N ha^{-1}	3.73ab	2.41b	6.23ab	3.23b	1.05b	0.17b	1.16a	0.16a
90 kg N ha^{-1}	3.63ab	2.44b	5.13b	3.36b	1.08b	0.19b	1.12a	0.12a
120 kg N ha^{-1}	2.97b	2.45b	4.97b	3.37b	1.07b	0.18b	1.19a	0.19a
SH	3.05b	2.47b	6.67a	3.45a	1.11b	0.19b	1.12a	0.12a
AH	4.78a	2.53a	5.27b	3.39b	1.85a	0.24a	1.15a	0.15a
SE±	0.20	0.02	0.02	0.01	0.01	0.02	0.01	0.01

Means in the column with different letter(s) are significantly different from each other at $P<0.05$ using Duncan Multiple Range Test (DMRT). SH – Same hill, AH – Alternate hill, SE – Standard error.

The effect of intercropping and N fertilization on grain yield was significant (Table 6). In 2012 and 2013 at both sites, application of 60 kg N ha^{-1} produced the highest maize grain yield than the higher rates of N fertilization and intercropping treatments. However, in 2012 at Mokwa site, the effect of 60-120 kg N ha^{-1} fertilizer application and AH intercropping on maize grain yield were similar. In the same manner, at Minna site in 2013, the effect of 60 kg N ha^{-1} fertilizer application and AH intercropping on maize grain yield were similar.

Table 6. Effect of intercropping and N fertilization on Grain yield of maize in 2012 and 2013 cropping seasons

	Grain yield (kg ha^{-1})			
Treatment	**Mokwa**	**Minna**	**Mokwa**	**Minna**
	2012		**2013**	
0 kg N ha^{-1}	1306c	1207e	2222d	1804e
60 kg N ha^{-1}	1757a	1590a	3505a	3034a
90 kg N ha^{-1}	1628ab	1436b	3131bc	2567b
120 kg N ha^{-1}	1539ab	1442b	2587cd	1890d
SH	1412bc	1385c	2616c	2117c
AH	1552ab	1368d	3295b	3010ab
SE±	5.10	4.2	1.60	1.42

Means in the column with different letter(s) are significantly different from each other at $P<0.05$ using Duncan Multiple Range Test (DMRT). SH – Same hill, AH – Alternate hill, SE – Standard error.

Discussion

Striga shoots per m^{-2} and *Striga* shoot per maize plant were generally reduced by and varied between N fertilization and *A. histrix* intercropping with maize in this study. This clearly demonstrated that alternate plants of *A. histrix* could cause a reduction in *Striga* emergence, similar to application of N at 60-120 kg N ha^{-1}. Furthermore, same hill intercropping of *A. histrix* also produced a reduction in *Striga* shoots in this study. These might be attributed to *A. histrix* acting as a trap or catch crop and the shading effect from *A. histrix* canopy. In addition to shading out *Striga* in intercropping systems, the *A. histrix* has also shown to stimulate the germination of *Striga* without acting as host, just like cowpea and soybean. Our findings is in agreement with various studies that shown that intercropping cereals, mainly with legumes such as cowpea (*Vigna unguiculata*), peanut (*Arachis hypogaea*) and green gram (*Vigna radiata*) can reduce the number of *Striga* plants [CARSKY & al. 2000; BASSEY & al. 2019a]. Potentially, they might be acting as traps crops, stimulating suicidal *Striga* germination or the microclimate under the crop canopy may be altered and interfere with *Striga* germination and development [KUREH & al. 2000]. It is also hypothesized that nitrogen fixed by the legumes might interact with *Striga* growth, as increasing the amount of available nitrogen can reduce *Striga* densities [KUCHINDA & al. 2003; BASSEY & al. 2019b]. Our findings in this studies show that 52-57% reduction in number of *S. hermonthica* recorded was due to application of N using urea. This is because the nitrogenous compound fertilizer which contains urea considerably suppressed germination of *S. hermonthica* when applied during conditioning. It could also be because the germination of *S. hermonthica* seed is associated with the secretion of germination stimulants by host plants. The secretion ultimately depends upon the nutrient status of the soil. Our findings is in agreement with [BASSEY & al. 2019c], who reported 55-82% reduction in number and weight of *S. hermonthica* due to application of N using urea in Niger. BERHANE (2016) also reported that N fertilizers altered assimilate partitioning in favour of the ear and increased maize grain yield and reduced *Striga* count by 64%. Similarly, the study of ABDALLAH & al. (2015) conducted in North east Nigeria showed a reduction in *Striga* infestation and damage with the application of N fertilizer on maize varieties.

The soil organic carbon (SOC) and soil total nitrogen (STN) were increased by intercropping. The findings of this experiment indicated that *A. histrix* fixed about 5% SOC. This can be attributed to the high C/N ratio of the *A. histrix* residue which ensure a slow rate of mineralization of the residue, with consequent increase in SOC. There was also significant effect of intercropping and N fertilization on soil total nitrogen (STN), although there was a slight decrease across all the treatment. This scenario might be due to high STN in the organic form, which was not immediately available for crop use. The significant effects of intercropping and N fertilization on SOC and STN at physiological maturity might be due to dead leaves and roots added to the soil. The immobilization of N as a result of the high C/N ratio of the residues could be responsible for the high STN. Intercropping and N fertilization had positive effects on SOC and STN at physiological maturity of maize. Our finding was in agreement with those of CRICK (2007) and BASSEY & al. (2019b), who noted an appreciable increase in soil fertility in crop mixture, involving certain tropical legumes after cropping. They adduced the increase in soil fertility to the ability of legumes to fix large quantities of nitrogen into the soil. The inclusion of legumes in many crop mixtures had been reported to include improvement in N status of the soil through nitrogen fixation, its short lifespan, as well as its ability to cover the ground, with resultant decreases in the incidence of weed infestation and soil erosion [AYA, 2004; GERH, 2007]. The inclusion of certain tropical legumes in crop mixture has been reported to increase soil organic carbon, total nitrogen, available phosphorus and exchangeable potassium. In addition to the above, the inclusion of legumes in crop associations minimizes the risk of crop failure and brings about higher total returns per unit area of land which allows larger financial gains for farmers [BEADER, 2004]. Significant effects of increasing maize planting density in a cowpea/maize mixture on soil nutrients and cowpea yield have been demonstrated by many studies [EZEMADU, 2007; VINE, 2007].

Maize grain yield was increased but varied between N fertilizer levels and *A. histrix* intercropping with maize in this study. The positive response (increase) observed in this study for grain yield due to N application and intercropping with *A. histrix* could probably be due to incorporation of residues resulting in high SOC and legume root system turnover. Increase in soil organic matter level might have resulted in increase in soil fertility, nutrient supply, porosity, permeability and thus, soil productivity [GRAY & MORANT, 2003; BASSEY & al. 2019b]. Our findings obtained are consistent with that of other workers in the same savanna agroecological zone of Nigeria [YUSUF & al. 2009a]. FRANKOW-LINDBERG & DAHLIN (2013) have suggested that a major part of the legume root system turnover occurs in the uppermost part of the soil profile. In a study in coastal lowland Kenya, SAHA (2015) observed the highest maize root length density in the top 30 cm of the soil profile. Therefore, intercropped maize is likely to benefit from the root system turnover of cowpea planted within the same row. Grain yield without inorganic N fertilizer was significantly lower than that of the other inorganic N levels. Similar response to inorganic N fertilizer has been reported in the study area by ADEBOYE & al. (2009) and AFOLABI & al. (2017). The high yield obtained in the study area might also be attributed to reduced temperature and moisture conservation effected by the overlapping maize and legume canopies. Nutrient uptake is known to increase with improved soil moisture. Maize intercropped with legume within the row probably responded to soil moisture conservation by increasing its nutrient uptake, leading to increased yields [TENEBE & PETU-IBIKUNLE, 2012].

Conclusion

From the results of this study, it can be concluded that intercropping maize with *A. histrix* has the potential of reducing *Striga* parasitism with respect to *Striga* shoots per m^{-2} and *Striga* shoots per plot thus, enhancing maize grain yield. The use of herbaceous legumes in intercropping contributed to soil N, thereby helping to control *Striga* infestation. *Striga* infestation is frequently associated with low soil fertility. Intercropping maize with *A. histrix* improved the soil organic matter and hence, the physical, chemical and biological properties of the soil for good crop growth. Incorporation of the *A. histrix* residues substantially increased the soil N content. There was response to inorganic N fertilizer application, suggesting the need for N application to maize for optimum grain yield. Nitrogen rate of 60 kg ha^{-1} was optimum for maize yield.

Notes on contributors

Moses Samuel BASSEY is a plant protectionist with special interest in weed science and agronomy. His focus is on the *Striga* management practices and Maize productivity. Joy Ekaette ETOPOBONG is a soil scientist with special interest in soil fertility. Bigun PONMAN Ishaku is a crop scientist with special interest in crop agronomy. Sheriff Adam BADOM is a research extension scientist with special interest in result dissemination. Aliyu USMAN is a crop scientist with special interest in crop agronomy. Abubakar Kutigi MOHAMMED is a plant breeder with special interest in crop improvement. Opeyemi Ruth IBRAHIM is a research scientist at National Biotechnology Development Agency.

Acknowledgement

We want to use this medium to acknowledge and to thank the management of National Cereals Research Institute for the support in providing all that was needed for the execution of this work.

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How to cite this article:
BASSEY M. S., ETOPOBONG J. E., PONMAN B. I., BADOM S. A., USMAN A., MOHAMMED A. K. & IBRAHIM O. R. 2021. Intercropping and N fertilization effects on *Striga* infestation, soil C and N and grain yield of maize in the Southern Guinea Savanna of Nigeria. *J. Plant Develop*. **28**: 97-108. https://doi.org/10.47743/jpd.2021.28.1.876