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MANAGEMENT OF SPEARGRASS [*IMPERATA CYLINDRICA (L.) RAEUSCHEL*]IN OF SOUTHERN AGRO-ECOLOGIES OF NIGERIA

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ABSTRACT
Speargrass [Imperata cylindrica (L.) Raeuschel] infestation limits crop growth and yield. The effects of tillage methods, kenaf genotypes, and plant spacing patterns were studied for speargrass suppression at Eruwa (Derived Savanna) and Kishi (Southern Guinea Savanna) in 2015 and 2016. These were randomized in a Split-split plot design with three replicates. Agronomic data collected were analyzed, and the means were separated at $P \leq 0.05$. Results showed that tillage enhanced weed control efficiency (10%), improved I. cylindrica suppression, and kenaf performance, relative to plant sown in no-till plots at both locations. The bast-fibre yield was higher in Ifeken DI 400 than in Ifeken 400 at Eruwa, but genotypes had similar bast-fibre yield at Kishi. Also, both genotypes had comparable I. cylindrica biomass and weed control efficiency at Kishi, while Ifeken 400 had higher weed control efficiency than Ifeken DI 400 at Eruwa, due to better suppression of I. cylindrica. The agronomic traits measured and weed control efficiency (WCE %) had a substantial inverse relationship with I. cylindrical growth at both locations. Tillage improved bast fibre yield (26 – 32%), core fibre yield (20 – 28%), and seed yield (26 – 59 %) relative to no-tilled plots. Ifeken 400 showed superior weed-suppressive traits and optimum fibre yield to Ifeken DI 400 at both locations. Tilling speargrass-infested land, with kenaf plant spacing of 50 cm × 10 cm and 50 cm × 15 cm with early canopy formation and better weed suppression are considered for an integratedspeargrass management scheme.
Keywords: Kenaf genotypes, tillage, spacing, suppression

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INTRODUCTION

Speargrass [*Imperata cylindrica (L.)* Raeuschel]is a problematic weed among the farmers in the southern agroecologies of Nigeria (Aluko, Smith, and Omodele, 2018). This limits cropping activities, and yield is critically reduced. It affects 73 countries and has been reported as a major inhibitory force in the cultivation of 35 annual and perennial crops with significant yield reduction (Brook, 1989; Chikoye and Ekeleme, 2001). Speargrass is undesirable because it reduces crop yield and quality, limits farm size, causes injury to the skin, increases labour requirements, and increases the presence of pathogens and insects in economic crops (Chikoye, Manyong, and Ekeleme, 2000). Farmers reported that tuber crops especially yam, cassava, and sweet potatoes are perforated by *I. cylindrica* rhizomes, and are subsequently infested by termites thereby reducing yield quality and return on investment. Endemic *I. cylindrica* infestation can lead to total crop failure with its attendant financial loss. Due to the high cost of control, and mechanical injuries to the skin caused by rhizome ramets, the efficiency of cultural practices is reduced, often resulting in the abandonment of farmlands (Holm *et al.,* 1977; Terry *et al.,* 1997). This, in turn, hurts the food security. Generally, *I. cylindrica* management usually increases the cost of crop production and reduces the revenue generated from harvested crops. This cost will increase as weed species distribution changes in response to future changes in the climate (Hilbert *et al.,* 2007).

The persistence of *I. cylindrica* is established through the perennation of underground rhizomes. Hence, tillage of infested fields is considered, however, this may lead to fragmentation of rhizomes with the spread and sprouting of buried fragmented rhizomes. However, crop production is slowed down without conventional tillage operations. The burning and slashing practices among resource-limited farmers during the dry season, lead to spontaneous bud sprouting from the nodes in cultivated and uncultivated land making way for the proliferation of *I. cylindrica* (Holm *et al.,* 1977). *I. cylindrica* also produces viable seeds that enhance its persistence.

Several herbicides have been tested, viz, paraquat, fluazifop-butyl, glufosinate-ammonium, dalapon, imazapyr, glyphosate, sulfometuron, nicosulfuron, and rimsulfuron; for the control of *I. cylindrica* (Udensi, Akobundu, Ayeni, and Chikoye 1999; Terry *et al.,* 1997; Shilling and Gaffney, 1995; Avav, 2000). A few of these herbicides have shown poor-to-good control, depending on the rate of application, climate, and soil type. The use of herbicides is undermined by its persistent use in *I. cylindrica* endemic farmland thereby snowballing to risks in the environment. The environmental impact of herbicide application induces health hazards in both livestock and humans. There may also be a shift in weed flora composition as a result of the continuous application of herbicides.

Speargrass is susceptible to shading (Aluko, Chikoye, and Smith, 2012). Cultivation of a fast-growing crop to shade *I. cylindrica* has been used as an intervention option in its control (MacDicken, Hairiah, Otsamo, Duguma, and Majid 1997; Akobundu, Udensi, and Chikoye, 2000; Chikoye and Ekeleme,2001; Aluko *et al*., 2012). The use of crop plant interference for the control of weeds minimizes loads of herbicides in the environment and reduces the cost of production while promoting healthy cropping systems. Kenaf is a fast-growing, multi-commodity crop that may replace *Mucuna* that is noted for suppression of *I. cylindrica*, however with no return on investment (Udensi *et al*., 1999; Aluko *et al*., 2012). Cultivation of kenaf is gaining the interest of the farmers in Oyo state as a commodity crop, especially in the southern guinea savanna and derived savanna. However, infestation of *i. cylindrica* is endemic in arable farmland in these agroecologies (Aluko *et al*., 2018). This limits cropping activities and reduces fibre production.

The study aimed to control Speargrass infestation in endemic zones. The integrated approach was used to reduce speargrass infestation and retrieve cropping land, with appreciable income generation from commodity crops.

MATERIALS AND METHODS

The experiment was established in two *I. cylindrica*-endemic agro-ecologies of southwestern Nigeria viz. Derived savanna (Ibarapa North local government area) and southern Guinea savanna northern fringe (Irepo local government area). Two land preparation methods (tillage) were used, viz. tilled (conventional tillage) and no-till (slashed field, followed by treatment of regrowth and volunteer weeds with Gramozone®), and these served as the main plot treatments in the study. Two kenaf varieties (Ifeken 400, and Ifeken DI 400) served as the subplot treatments. Four plant spacing patterns viz. 50 cm × 25 cm, 50 cm × 20 cm, 50 cm × 15 cm, and 50 cm × 10 cm, were assigned as the sub-sub plot treatments, while weedy control (50 × 10 cm) and weed-free control (50 cm × 10 cm) were assigned as the control plots. All the treatments were arranged in a 2 × 2 × 4 factorial using an RCBD with three replicates. The plot size was 5 m × 5 m. Data were collected on kenaf agronomic traits using five randomly tagged plants and on *I. cylindrica* biomass. The experiment was carried out during the rainy seasons of 2015 and 2016.

I. cylindrica biomass (shoot and rhizome) before planting was determined by random placement of 1m × 1m quadrat on the field. *I. cylindrica* shoots were harvested and the soil was dug to 30 cm to obtain the rhizomes. These were oven-dried at 80˚C for 48 hours and weighed to determine the dry weight. Plant height was measured from the stem butt to the peak of the plant with a graduated meter rule at 4, 6, 8, and 10 weeks after planting (WAP). Stem diameter (butt and mid) was measured with Venier's caliper at the butt and mid-stem at 4, 6, 8, and 10 WAP. Kenaf canopy width (6, 8, and 10 WAP) was measured with a graduated ruler by measuring the breadth of the plant canopy. Kenaf bast and core fibre yield at 10 WAP were determined by weighing the dry fibre after retting on a sensitive digital scale. The number of capsules/plant at harvest were counted on the five tagged sample plants and recorded. The number of seeds/capsules at harvest was determined from the sample plant after threshing and the average from threshed capsules was determined. Seed yield (kg/ha) at harvest was determined from the threshed mid-portion of the plot (2 m × 2 m). This was extrapolated to kg/hectare. 100-seed weight at harvest was determined by counting 100 seeds from the threshed samples in each plot. This was weighed with a digitally sensitive scale. *I. cylindrica* biomass (shoot; rhizome) at kenaf maturity was taken from each plot after harvest by using a quadrat (1 m × 1 m) placed in the plot. The shoots and rhizomes were harvested, oven-dried at 80^{o} C, and weighed to determine the weight.

Data collected were subjected to summary statistics (Mean, Variance, and covariance), factorial analysis of variance using split plot design, with tillage as the main factor and kenaf varieties as the subplot, separation of the mean of significantly different variables into significant classes using the Duncans multiple range test (DMRT), and different variables were analyzed using General linear mode (GLM).

RESULTS AND DISCUSSION

Table 1 shows the cumulative effects of land preparation methods, kenaf genotypes, and plant spacing on kenaf agronomic traits in Eruwa and Kishi. The number of leaves/plant varied with the treatments applied. Kenaf plants sown in weed-free plots had the highest number of leaves (Table 1). This was similar to leaves/plant in 50 cm × 25 cm and 50 cm × 20 cm at Eruwa and 50 cm × 25 cm at Kishi. However, weedy control recorded the lowest leaves/plant in both locations. Kenaf plants in the tilled plot were leafier than no-till plots and Ifeken DI 400 produced more leaves than Ifeken 400 in both locations.

Weed-free plots recorded the kenaf plant with the thickest mid-stem and butt-stem girth in both locations (Table 1). Other plots with spacing patterns recorded comparable mid-stem and butt-stem girth, while the thinnest mid-stem and butt-stem were recorded in weedy control plots. Tilled plots had thicker mid-stem and butt-stem than no-till plots at both locations. Kenaf genotypes had similar mid-stem and butt-stem girth across locations.

Kenaf plants sown into weed-free plots had the highest number of seeds/capsule across treatments (Table 1). This was not quite different from the average number of seeds/capsule in plots sown at 50 cm × 25 cm, 50 cm × 20 cm, and 50 cm × 15 cm plant spacing at Eruwa. Other plots with different spacing patterns had similar seeds/capsules in Kishi except for the weedy control which had the lowest number of seeds/capsules at both locations. The tilled plot had more seeds/capsule than the no-till plot. Ifeken 400 gave more seeds/capsule in Eruwa than Ifeken DI 400. However, both genotypes had a similar number of seeds/capsule at Kishi. At both locations of the study, the interactions of genotypes × spacing ($p = 0.05$; 0.05) had similar levels of significance on the number of leaves/plant. At Eruwa, genotypes x spacing interaction effects on the number of seeds/capsule and mid-stem girth were comparable at $p = 0.05$ significance level. The effects of the interaction of tillage × genotype × spacing ($p = 0.001$) were only significant on kenaf mid-stem girth at 10 WAP at Eruwa.

Kenaf had a similar 100-seed weight across treatments at Eruwa (Table 2). Plot sown with 50 cm × 25 cm spacing had the heaviest 100-seed at Kishi. This was similar to other treatments applied except 50 cm × 10 cm plot. Tilled plots and no-till had similar 100-seed weights. There was a comparable 100-seed weight between kenaf genotypes at both locations.

The weed-free control plot recorded the highest number of capsules/plant (Table 2). This was similar to capsules/plant in 50 cm × 25 cm and 50 cm × 20 cm in Eruwa and 50 cm × 25 cm, 50 cm × 20 cm, and 50 cm × 15 cm at Kishi (southern Guinea savanna). The tilled plot had more capsules/plant than the no-till plot at both locations. There was a similarity in the number of capsules/plant between kenaf genotypes at Eruwa. Ifeken 400 had more capsules/plant than Ifeken DI 400 at Kishi. At both locations of the study, the interaction of genotype × spacing ($p = 0.05$) was significant on the kenaf number of capsules/plant at seed harvest.

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Weed-free control plots had the highest seed yield/ha; the lowest seed yield/ha was recorded in weedy control plots at both locations (Table 2). Plant spacing of 50 cm × 10 cm, 50 cm × 15 cm, and 50 cm × 20 cm had comparable seed yield/ha at Eruwa, while 50 cm × 25 cm, 50 cm × 15 cm, and 50 cm × 10 cm plots had similar seed yield/ha at Kishi. The tilled plot had more seed yield/ha at both locations than the no-till plot. Kenaf genotypes were comparable in seed yield at both locations.

Maximum core-fibre yield/ha was recorded in the weed-free control plot, and the minimum was recorded in the weedy control plot. Core-fibre yield increased with a decrease in plant spacing. The tilled plot had more core-fibre yield/ha than the no-till plot at both locations (Table 2). The interaction between genotype × spacing (p = 0.001) was significant on kenaf core yield at fibre harvest.

Weed-free control plots had the highest bast-fibre yield, while the minimum was recorded in the weedy control plot at both locations (Table 2). Bast-fibre yield seemed to decrease with an increase in spacing as recorded. Tilled plots gave more bast-fibre yield/ha than no-till plots at both locations. Ifeken DI 400 had more bast-fibre than Ifeken 400 at Eruwa, while genotypes had comparable bast-fibre yield/ha at Kishi.

Weedy control had the highest *I. cylindrica* dry weight at the kenaf seed harvest, while the lowest *I.cylindrica* dry weight was recorded in weed-free control plots at both locations (Table 3). *I. cylindrica* shoot dry weight increased with plant spacing. No-till plot had a higher *I. cylindrica* dry weight than the tilled plot at both locations, while kenaf genotypes had similar *I. cylindrica* shoot weight at harvest. The effects of interactions of tillage methods × spacing (p = 0.05), and tillage methods × genotypes × spacing (p = 0.05) were comparable and significant on *I. cylindrica* shoot dry weight at kenaf seed harvest. Hence, the No-till plot had more *I. cylindrica* rhizome weight than the tilled plot. Ifeken DI 400 had more rhizome dry weight than Ifeken 400 at Eruwa, while genotypes had comparable rhizome dry weight in Kishi. At both locations, the interactions of tillage methods × genotypes × spacing (p = 0.05; 0.001) had significant effects on *I. cylindrica* rhizome dry weight at kenaf seed harvest.

Relative yield loss was higher in the no-till plot than in the tilled plot at both locations. Kenaf genotypes had comparable relative yields at both locations (Table 3). At Eruwa and Kishi, the interactions of tillage methods x spacing (ns; p = 0.01) and tillage methods x genotypes x spacing (p = 0.05; 0.05) were significant on relative yield loss at kenaf seed harvest.

In Table 3, the weed-free control plot had the highest weed control efficiency at both locations, this was followed by kenaf plots sown with a plant spacing of 50 cm × 10 cm and 50 cm × 15 cm, while weedy control plots recorded the lowest weed control efficiency at both locations. The tilled plot consistently had higher weed control efficiency than the no-till plot at both locations. In Eruwa, Ifeken 400 had higher weed control efficiency than Ifeken DI 400, but there was a similarity in weed control efficiency in genotypes at Kishi. The interactions of tillage methods ×

spacing (p = 0.001) and genotypes × spacing (p = 0.001) had significant effects on weed control efficiency at kenaf seed harvest.

Table 4 shows Relationship between kenaf traits and *I. cylindrica* growth at Eruwa and Kishi. The plant height at 10 weeks after sowing (WAS) and *I. cylindrica* biomass had a significant negative relationship with rhizome dry weight (- 0.59 p≤001 and – 0.51 p≤001) and shoot dry weight (- 0.61 p≤001 and - 0.56 p≤001) and relative yield loss (– 0.63 p≤001 and – 0.53 p≤001) in Eruwa and Kishi respectively.

The plant canopy width at 10 weeks after planting had a significant negative correlation with relative yield loss (- 0.65 p≤001 and - 0.61 p≤001), rhizome dry weight (- 0. 58 p≤001 and - 0.52 p≤001), and shoot dry weight (- 0. 62 p≤001 and - 0.60 p≤001) at Eruwa and Kishi respectively (Table 5). Equally, the bast-fibre yield had a significant negative correlation with relative yield loss (- 0.77 p≤001 and - 0.63 p≤001) at both locations. Speargrass rhizome dry weight (-0. 73 p≤001 and - 0.65 p≤001) and *I. cylindrica* shoot dry weight (- 0.74 p≤001 and -0.67 p≤001) had a negative relationship with bast-fibre in Eruwa and Kishi respectively.

Table 6 shows the correlation between seed yield, and weed control efficiency (0.60 p≤001 and 0.57 p≤001) in Eruwa and Kishi correspondingly, However, seed yield had a significant negative correlation with relative yield loss (-0.91 p≤001 and - 0.76 p≤001), rhizome dry weight (-0.57 p≤001 and - 0.52 p≤001) and shoot dry weight (- 0.62 p≤001 and - 0.56 p≤001) in Eruwa and Kishi respectively. Furthermore, weed control efficiency had a significant negative correlation with relative yield loss (- 0.62 p≤001 and - 0.56 p≤001), rhizome dry weight (-0.72 p≤001 and - 0.67 p≤001), and shoot dry weight (- 0.85 p≤001 and - 0.81 p≤001) at Eruwa and Kishi in that order.

The effect of tillage increased plant height significantly at both locations, as taller plants were found in tilled plots relative to no-till plots. The cutting and fragmentation of *I. cylindrica* shoot and rhizomes might have exposed a fraction of *I. cylindrica* biomass to desiccation and decomposition. This reduced the *I. cylindrica* competition with Kenaf in the tilled plots. Initial land ploughing and harrowing gave a better seedbed for kenaf germination and establishment. Srivastava *et al*., (2006) showed that tillage enhances suitable seedbeds and is crucial for crop establishment, growth, and ultimately yield. Similar results were obtained when maize and cowpea were sown in tilled and no-till soils (Kayode and Ademiluyi, 2004; Aikins and Afuakwa, 2010; Ojeniyi and Adekayode, 1999). Tillage retarded *I. cylindrica* growth and the initial competition with kenaf plants. Conversely, slashing induced sprouting of *I. cylindrica* at the nodes through the breaking of apical dominance in the no-till plot, thereby increasing the population of *I. cylindrica* in competition with kenaf plant. This critical kenaf-*I. cylindrica* competition might have resulted in the stunting of kenaf plants in no-till plots. This corroborated the findings of Aluko and Olasoji (2017) that weed competition reduced kenaf plant growth.

Kenaf plant height was significantly influenced by plant spacing and *I. cylindrica* interference at both locations of the study. This is in line with the work of Amaducci *et al*. (2008) that higher

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plant density in hemp (*Cannabis sativa*) lowers plant height as a result of intra-specific competition between plants. The competition from *I. cylindrica* occurred at different densities of both kenaf and *I. cylindrica.* This might have equally influenced differences in growth parameters during kenaf-*I. cylindrica* interactions which were observed at all the sampling dates. The highest plant height recorded in weed-free control plots arising from little or no *I. cylindrica* competition with narrow (50 × 10 cm) might have influenced the plant height. Closely-spaced plants appeared to grow taller than widely-spaced plants at the early stage of kenaf growth. This might be due to intra-specific competition for space and soil nutrients. However, plant stem-girth may be compromised during this competition. Burczyk, Grabowska, Strybe, and Konczewicz (2009), explained that the shade-avoidance syndrome causing stem elongation under light competition is greatest at plant density or close plant spacing. This trend was consistent at all the Kenaf sampling dates at both locations. However, widely spaced kenaf plants (50 cm × 20 cm, 50 cm × 25 cm) might have experienced more intensive *I. cylindrica* interference due to the higher density of *I. cylindrica* hence, critical competition with kenaf might have influenced lower plant height in widely-spaced kenaf plots.

Taller Ifeken 400 plants than Ifeken DI 400 across sampling dates and locations, might be due to the differences in genotypic traits, better adaptation to location, and tolerance/resistance to weed incursion. The genotypic differences might be implicated in the differences found. This is in line with the previous study that kenaf genotypes varied in their morphology under weed pressure (Aluko and Anjorin, 2019). Tillage created less weed pressure and a better seedbed for the establishment and growth of the kenaf plant compared to the untilled plots. Ifeken 400 had better utilization of growth factors than Ifeken DI 400. This might be due to their genetic variations.

Higher kenaf canopy width in tilled plots than in no-till plots might have been influenced by better plant growth conditions created by soil tillage. Tillage created a seedbed for better plant establishment and growth resulting in decimated *I. cylindrica* growth and competition. Tillage suppressed *I. cylindrica* through rhizome fragmentation, burying of the shoot, and decomposition of *I. cylindrica* as green manure into the soil. This further confirms the advantages of tillage in crop establishment, growth, and yield (Atkinson, Sparkes, and Mooney, 2007). According to Agbaje, Saka, Adegbite, and Adeyeye, (2008), the anticipation of good and timely cultural practices enhanced kenaf plant growth and yield. This gave a head-start to kenaf plants sown in the tilled plot for early canopy coverage as competition with *I. cylindrica* was minimized. Conversely, the dense *I. cylindrica* population in the no-till plots had a competitive advantage over kenaf plants, and this retarded kenaf establishment and growth. It is, therefore, safe to conclude that tillage of *I. cylindrica*-infested field will enhance kenaf growth and canopy formation for weed suppression. Aluko *et al*., (2012), reported similar results when the growth of soybean genotypes sown to both tilled and no-till *I. cylindrica*-infested plots was compared; soybean genotypes sown to tilled plots had superior growth than those sown into no-till plots.

In *I. cylindrica*-endemic plots, canopy coverage from crop plants may have a complementary suppressive effect on *I. cylindrica*. However, in the current study, kenaf genotypes were not

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distinctly different in canopy coverage across sampling dates and locations. Thus, canopy width in kenaf genotypes might be influenced by comparative competitive stress from kenaf genotypes and *I. cylindrica.* Kenaf canopy width was influenced by plant spacing and *I. cylindrica* infestation. *I. cylindrica* competition with kenaf plant for soil nutrients and space might have reduced the nutrients available for optimum kenaf plant growth. However, the relatively high plant population in closely spaced kenaf plots enhanced canopy closure, thus resulting in dense canopy coverage.

Most studies have shown the benefits of reducing crop row spacing in early canopy closure which increases the capability of crops to compete with weeds for sunlight, nutrients, and water (Aldrich, 1987; Lauriel, Maja, Ngobeni, and Plooy, 2015). Although Kenaf and *I. cylindrica* are fast-growing plant species, intense crop-weed competition under high *I. cylindrica* density may cause a considerable reduction in kenaf plant growth and population.

The influence of land preparation on kenaf leaf area showed that tilled plots had distinctly higher plant leaf area than no-till plots. The higher *I. cylindrica* density in the no-till plot compared to tilled plots might have increased *I. cylindrica* competition for soil nutrients with the kenaf plant in the tilled plots. This confirmed the inverse relation of leaf area to weed density recorded. Tilling the soil invariably influenced kenaf-*I. cylindrica* competition due to favourable seedbeds for seed establishment and growth (Ojeniyi and Adekayode, 1999). Atkinson *et al*., (2007) reported the positive effect of tillage on crop establishment and growth. Das (2011) and Akobundu (1987) extensively enumerated the weed control advantage of tillage on crop plants. The initial weed control through weeding enhanced the establishment and growth of kenaf especially in respect of wider leaf area.

Kenaf leaf area was influenced by row spacing and weed interference. The weed-free plot had the highest leaf area at all the sampling dates, contrasting the lower leaf area recorded across the weedy plots. The competition between kenaf and *I. cylindrica* might have influenced the reduction in kenaf leaf area. Where weed control is anticipated, leaf area tends to increase significantly as recorded in weed-free plots. However, large plant spacing may influence leaf area. However, this was not almost consistent with the leaf area recorded in 50 cm × 25cm spacing that had comparable value with the highest leaf area in weed-free plots. The relatively lower intra-specific competition among kenaf plants in wide row spacing might have enhanced leaf area compared to those in closer row spacing. These results strongly indicate that plant proximity plays a significant role in leaf area development.

Das (2011) and Akobundu (1987) reported that in crop-weed competition, the population or density of either crop or weed is of importance to the survival and dominance of either, although, weeds tend to occupy empty spaces in sparsely populated crop fields. However, this effect depends on weed density, growth level, soil nutrient availability and requirements of both crop plant and weed, and weed growth pattern or virulence. The interference of highly competitive weeds in the crop-weed competition will adversely affect the leaf area development of crop plants. However, in the current study, both kenaf genotypes produced similar leaf areas, and this may be due to close genetic properties and similarity in their tolerance to *I. cylindrica* competition.

Compared to tilled plots, the marked reduction in kenaf leaf production in no-till plots can be primarily attributed to the higher *I. cylindrica* density and associated competitive stress effects on plants in the no-till plots. The high population of both kenaf plants at different spacing and the high density of *I. cylindrica* might be exerting on soil nutrients and competition for space was keen in no-till plots. This in turn might have given rise to fewer leaves in kenaf plants in no-till plots. Reduction in the number of leaves in the no-till plot might have influenced the canopy width negatively as the plant number of leaves was recorded to be positively correlated with canopy coverage in this study.

The highest leaf number was recorded in weed-free due to insignificant or zero interference of *I. cylindrica* with kenaf plants. However, this value was statistically different from the number of leaves recorded on kenaf plants sown to 50 cm × 25 cm and 50 cm × 20 cm plots at Eruwa (Derived Savanna) and 50 cm × 25 cm in Kishi (southern Guinea savanna). This might be due to the wide plant space that further reduced intra-specific competition between kenaf plants and minimized cumulative competition between *I. cylindrica* and kenaf. Amaducci, Zalta, Pelatti, and Venturi (2008) reported that closely-spaced hemp plants showed a reduction in agronomic traits measured when compared with those sown with wide space as a result of intra-specific competition. Wider spacing invariably increases the cumulative competition in crop-weed interactions when space is not well manipulated to suppress weeds. Closely sown kenaf plants may induce intra-specific competition and this may reduce the expression of competitive traits such as the number of leaves/plant and leaf area.

However, the varietal differences in the number of kenaf leaves produced at 10 WAP may be due to genetic expression under weed pressure. The ability of crop type to produce more leaves under weed interference may be an adaptive or tolerant strategy to combat weed competition and give compensatory yield. The reduction in the plant height photosynthetic productivity of a crop may impact negatively the yield. Where kenaf fibre or seed is the target harvest, plant height is a function of fibre and seed yield as both were positively correlated (Aluko and Olasoji, 2017).

In this study, tilling the soil has been shown to minimize the effect of *I. cylindrica* interference in kenaf as thicker butt-stem girth was reported in tilled plots than in no-till plots. This reflected the comparative advantage of the tillage over the no-till cropping system under speargrass infestation.

Kenaf butt-stem girth was improved through continuous weeding in weed-free plots as the higher thickness of the butt was recorded. However, similarity in other treatments applied, apart from weedy control might have resulted from self-thinning in kenaf plant stands (Webber and Bledsoe, 1993) and *I. cylindrica* interference. The noticeable reduction in kenaf stem girth by about 50% in weedy control relative to weed-free kenaf plants could be attributed to *I. cylindrica* interference. Aluko and Olasoji (2017) reported that weedy control plots had the thinnest kenaf butt-stem girth and gave about46% and 52% reduction in bast-fiber in both years of the trial. Thus, *I. cylindrica* competition can cause a significant reduction in kenaf stem girth and fibre yield.

This explains the significant differences in fibre yield (Bast and Core) in tilled plots and no-till plots. The initial land preparation in tilled plots significantly reduces *I. cylindrica* biomass and produces a more favourable seedbed for crop seed germination and subsequent growth, in contrast to no-till plots. The constitution of the cumulative effect of these on the variations in kenaf fibre yields is strongly indicated. These observations were in agreement with Agbaje *et al.* (2008), who demonstrated the significant influence of cultural practices on kenaf component yield.

The influence of row spacing on crop fibre yield cannot be underestimated. In this study, variation in plant spacing influenced plant density and other interactions among kenaf stands and *I. cylindrica*–kenaf competition. Wide plant spacing reduced the number of crop stands in competition with *I. cylindrica*. Thus, influencing kenaf canopy width, the number of *I. cylindrica* involved in the competition with kenaf, and the number of kenaf plants harvested. Agbaje, Aluko, and Olasoji, (2011) recommended 50 cm × 10 cm and 50 cm × 15cm plant spacing for fiber yield in kenaf. This spacing influenced kenaf plant density and the optimum fibre yield to varying degrees. However, they might not appreciably interfere with, and suppress noxious weeds such as *I. cylindrica*. Despite the potential of the plant population to suppress weed growth. High crop plant density influences crop canopy formation and weed smothering (Akobundu, 1987). Thus, the current study strongly implicated the adverse effect of intra-specific and inter-specific competition (weed–crop) on kenaf growth and yield. A high *I. cylindrica* population arising from wide crop spacing might influence the number of *I. cylindrica* in competition with the kenaf plant, with the competition shifting in favour of *I. cylindrica* and ultimately reducing the kenaf fibre yield.

I. cylindrica interference reduced kenaf plant height, and stem girth and had a significant negative correlation with the number of capsules per kenaf plant. Reduction in kenaf plant height thus reduced the number of kenaf capsules/kenaf plant as both are significantly and positively correlated. Hence, a significant reduction in capsule/kenaf plant was recorded in weedy control plots and no-till plots. Poor seed-filling resulted in scanty and light-weight seeds recorded in the weedy control plots. A similar reason accounts for the higher number of seeds/capsule in tilled plots than in no-till plots. Although Ifeken 400 had more seeds/capsule than Ifeken DI 400 at Eruwa, this contrasted with the similarity in seeds/capsules between the genotypes at Kishi.

The cumulative effect of *I. cylindrica* interference in kenaf is more pronounced on seed yield. Kenaf seed yields as influenced by spacing were found to be below the kenaf seed yield reported in the previous studies (Agbaje, Aluko, and Olasoji,2011; Olasoji *et al.*, 2014; Aluko and Olasoji, 2017). According to Agbaje *et al*., (2011), planting kenaf in 50 × 20 cm gave an average

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yield of 1200kg/ha, about four times higher than the seed yield in plots infested with *I. cylindrica* in the current study. However, the devastating effect of *I. cylindrica* infestation was more evident in weedy control plots where the average kenaf seed yield was 150 kg/ha at both locations. This was similar to a four-fold reduction in seed yield when compared with the average kenaf seed yield from the weed-free plot. Hence, Agbaje *et al*.,(2008) projected early culture management practices in Kenaf. Aluko, Ayodele, and Ajijola,(2017) and Aluko and Olasoji (2017) affirmed this projection that weed interference in kenaf must be anticipated early with appropriate integrated weed management techniques for season-long weed suppression and profitable kenaf production, as delayed weed control may lead to critical yield loss. This study further confirmed the effect of tillage on weed suppression under noxious weed infestation. Aluko *et al.,* (2012) reported the advantage of conventional tillage in *I. cylindrica* suppression in the Savanna agroecology of Nigeria. This study further showed that the kenaf plant is sown into *I. cylindrica*-infested land can be given a head-start and enhanced performance with soil tillage, judging from the reduction in relative yield loss (RYL %), enhanced weed control efficiency (10 %), lower cumulative dry weight of *I. cylindrica* at kenaf maturity and better crop performance.

I. cylindrica dry weight had a significant negative relationship with WCE. Conversely, *I. cylindrica* growth was positively correlated with RYL %. Therefore, an increase in *I. cylindrica* growth will significantly reduce yield. These were influenced by cultural practices (tillage and plant spacing), crop competitive ability (CA), and crop tolerance ability CTA (Agbaje *et al*. 2008; Das, 2011).

Vegetative traits such as plant height, leaf area, and stem girth had a significant positive relationship with kenaf yield components recorded. This is in line with the findings that leaf area and plant height guarantee plant success in competition with weeds, and the impact of canopy structure on the absorption of radiation, evaporation and transpiration, dry matter accumulation, and yield (Rahman, Hampton, and Hill, 2005; Vazin, Mudani, and Hassanadeh, 2010; Rezvani, Zaefarian, and Joveini, 2013). The significant inverse relationship of plant height and canopy width with *I. cylindrica* indicated the suppressive traits in kenaf for weed management.

The development and expression of suppressive traits in kenaf were greatly influenced by cultural practices in addition to the genotypic expression of traits (Agbaje *et al*., 2008). Tilled plots produced kenaf plants with higher agronomic traits than no-till plots and this gave a head-start to kenaf plants over *I. cylindrica* in competition. Hence, better expression of weed-suppressive traits was recorded in the tilled plots in both kenaf genotypes in contrast to kenaf agronomic and weed-suppressive traits recorded in the no-till plots. Although kenaf genotypic differences were not markedly expressed in both agro-ecologies, the interaction of plant spacing and land preparation methods showed in the variations recorded in kenaf traits and *I. cylindrica* growth.

Plant height has been marked as an essential trait for both component yield (bast-fibre, core-fibre, and seed) and weed suppression as *I. cylindrica* biomass had a significant negative correlation with plant height in the Derived savanna and southern Guinea savanna. Cultural practices from crop selection should encourage rapid crop establishment, kenaf plant growth, and weed suppression (Aluko and Olasoji, 2017). Agbaje *et al*., (2008) emphasized the importance of timely intervention of cultural practices for optimum kenaf performance. The advantage of the use of a high kenaf plant population or narrow row spacing suggested by Agbaje *et al*., (2011) is not limited to optimum fibre yield and ease of fibre processing. Narrow row spacing enhances rapid canopy coverage and smothering of weeds in soybeans (Aluko *et al*., 2012). In the same vein, the kenaf plant with a broad canopy and prolonged canopy longevity will intercept solar radiation and suppress weed biomass accumulation. This supports the findings that canopy structure impacts the absorption of radiation, evaporation and transpiration, dry matter accumulation, and yield (Rahman *et al*., 2005; Rezvani *et al*., 2010).

CONCLUSION AND RECOMMENDATION

Speargrass density was higher in Eruwa than in Kishi. Tillage gave superior kenaf performance at both agroecologies. Sowing kenaf at the spacing of 50 cm x 10 cm reduced *I. cylindrica* growth. Ifeken 400 had higher weed control efficiency than Ifeken DI 400 in the Derived savanna, but both genotypes had comparable weed control efficiency in the southern Guinea savanna. Kenaf agronomic traits are retarded by uncontrolled speargrass growth significantly ($P \leq 0.001$) at both locations. Hence, cultural practices should enhance kenaf plant growth for better suppression in *I. cylindrica* endemic agroecologies. Speargrass-infested fields should be ploughed and kenaf sown with close spacing for weed management. Ifeken 400, with superior weed-suppressive traits and optimum yield, is recommended for effective *I. cylindica* suppression. Plant spacing of 50 x 10 cm and 50 x 15 cm plant spacing are ideal in an integrated *I. cylindica* management scheme.

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APPENDICES

Table 1: Effects of tillage methods, plant spacing, and genotypes on agronomic traits at 10 WAP in Eruwa and Kishi.

	Number of leaves/plant (no/plant) at 10WAP		Stem butt-girth (cm) at 10 WAP		Seeds/capsule (no/plant)		Stem mid-girth (cm) at 10 WAP	
Spacing	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**
50 × 10 cm	46.00bc	48.00b	1.21b	1.22b	16.00c	16.00b	0.62bc	0.68b
50 × 15 cm	45.00c	51.00b	1.23b	1.26b	17.00bc	16.00b	0.58bc	0.72ab
50 × 20 cm	52.00ab	49.00b	1.25b	1.23b	16.00c	17.00b	0.54cd	0.71b
50 × 25 cm	52.00ab	58.00ab	1.30b	1.32b	18.00ab	16.00b	0.67ab	0.81ab
Weed-free	58.00a	64.00a	1.51a	1.56a	19.00a	19.00a	0.75a	0.89a
Weedy control	21.00d	24.00c	1.02c	1.11c	10.00d	12.00c	0.48d	0.54c
Tillage method								
Tilled	50.00a	57.00a	1.25a	1.32a	18.00a	18.00a	0.64a	0.90a
No-till	45.00b	43.00b	1.12b	1.18b	16.00b	16.00b	0.49b	0.55b
Genotype								
Ifeken 400	42.00b	53.00b	1.23a	1.26a	18.00a	17.00a	0.57b	0.73a
Ifeken DI 400	52.00a	58.00a	1.22a	1.24a	16.00b	17.00a	0.62a	0.72a
T*G	NS	NS	NS	NS	NS	NS	NS	NS
T *S	NS	NS	NS	NS	NS	NS	NS	NS
G*S	*	*	NS	NS	*	NS	*	NS
T*G*S	NS	NS	NS	NS	NS	NS	***	NS

Legends: T*G- Tillage and genotype interaction, T*S- tillage and spacing interaction, G*S - genotype and spacing interaction, T*G*S - tillage, genotype, and spacing interactions, * = $P \leq 0.05$, *** = $P \leq 0.001$, NS = not significant, Values with the same letter(s) in the column are not significantly different ($P \leq 0.05$).

Table 2: Effects of tillage methods, plant spacing, and genotypes on yield components in Eruwa and Kishi

	Bast-fibre/ha (kg/ha)		Core-fibre/ha (kg/ha)		Seed yield/ha (kg/ha)		Capsule/plant		100-seed weight (g)	
Spacing	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**	**Eruwa**	**Kishi**
50 × 10 cm	3752.72b	4142.87b	5597.00b	6284.08b	402.35b	351.83bc	17.00b	18.00b	2.43a	2.68b
50 × 15 cm	3519.93bc	3886.50b	5237.55b	54192.90c	310.32bc	431.67b	16.00b	19.00a	2.65a	2.77ab
50 × 20 cm	3095.50c	315.23c	5033.66b	5280.55c	299.15bc	298.67c	18.00ab	19.00a	2.41a	2.79ab
50 × 25 cm	2443.94d	2355.27d	3802.60c	4210.46d	275.38cd	425.33b	19.00ab	21.00a	2.66a	3.08a
Weed-free	5216.40a	5176.71a	7427.32a	7024.72a	646.90a	645.88a	21.00a	22.00a	2.53a	2.91ab
Weedy control	782.40e	527.40e	1289.90d	1004.80e	176.77d	130.71d	10.00c	11.00c	2.58a	2.78ab
Tillage method										
Tilled	3791.80a	3834.80a	5824.10a	5902.90a	464.36a	541.53a	21.00a	25.00a	2.67a	2.86a
No-till	2829.80b	2637.95b	4161.20b	4746.20b	339.08b	219.83b	14.00b	12.00b	2.62a	2.80a
Genotype										
Ifeken 400	3162.70b	3217.10a	4818.20a	5103.40a	353.45a	392.57a	18.00a	21.00a	2.68a	2.85a
Ifeken DI 400	3458.90a	3255.65a	5167.10a	5545.70a	350.24a	368.79a	17.00a	16.00b	2.61a	2.82a
T*G	NS	NS	NS	NS	0.3485	0.4239	NS	NS	NS	NS
T*S	NS	NS	NS	NS	0.5481	0.3729	NS	NS	NS	NS
G*S	NS	NS	***	***	0.7227	0.7655	*	*	NS	NS
T*G*S	NS	NS	NS	NS	0.8426	0.6549	NS	NS	NS	NS

Legends: T*G- Tillage and genotype interaction, T*S- tillage and spacing interaction, G*S -genotype and spacing interaction, T*G*S - tillage, genotype and spacing interactions, *** = P≤ 0.001, * = P≤ 0.05. NS = not significant, Values with the same alphabet(s) in the same column are not significantly different (P≤0.05).

Table 3: Effects of tillage methods, plant spacing, and kenaf genotypes on relative yield loss, weed control efficiency, and *I. cylindrica* growth in Eruwa and Kishi.

	Relative yield loss (%)		Weed control efficiency (%)		Speargrass shoot weight (g/m^2)		Speargrass rhizome weight (g/m^2)	
Spacing	Eruwa	Kishi	Eruwa	Kishi	Eruwa	Kishi	Eruwa	Kishi
50 × 10 cm	50.90c	65.41bc	84.83b	79.87b	38.65d	34.91d	10.43d	8.01c
50 × 15 cm	60.32b	57.76c	81.27b	76.73bc	49.75cd	39.72cd	9.09d	9.88b

50 x 20 cm	62.24b	70.47b	76.44c	72.64cd	55.65bc	47.35b	15.05c	9.99b
50 x 25 cm	65.05b	58.08c	72.06d	71.16d	65.85b	51.81b	24.22b	9.17bc
Weed-free	19.14d	16.18d	94.54a	91.55a	14.76e	13.04e	3.42e	3.48d
Weedy control	79.42a	86.88a	13.20e	27.19e	205.53a	123.16a	72.15a	41.24a
Tillage method								
Tilled	50.21b	46.81b	73.49a	73.78a	47.82b	45.08b	14.86b	12.51b
No-till	58.21a	78.11a	67.28b	65.92b	68.15a	57.26a	21.75a	14.75a
Genotype								
Ifeken 400	56.44a	61.48a	75.85a	69.47a	58.41a	51.81a	17.03b	13.96a
Ifeken DI 400	55.91a	63.45a	64.92b	70.23a	57.58a	51.53a	19.58a	13.30a
T*G	NS	NS	NS	NS	NS	NS	NS	NS
T*S	NS	**	***	NS	*	*	NS	NS
G*S	NS	NS	**	NS	NS	NS	NS	NS
T*G*S	*	*	NS	NS	*	*	*	***

Legends: T*G- Tillage and genotype interaction, T*S- tillage and spacing interaction, G*S - genotype and spacing interaction, T*G*S - tillage, genotype and spacing interactions, ** = P ≤ 0.01, *** = P ≤ 0.001, * = P ≤ 0.05, NS = not significant. Values with the same alphabet(s) are not significantly different (P ≤0.05).

Table 4: Relationship between agronomic traits and *I. cylindrica* growth in Eruwa and Kishi

	Eruwa				Kishi			
	Plant height 6WAP	Plant height 10WAP	LA 6WAP	LA 10WAP	Plant height 6WAP	Plant height 10WAP	LA 6WAP	LA 10WAP
SY	0.63***	0.70***	0.56**	0.61***	0.61***	0.63***	0.54**	0.59***
RYL	-0.58***	-0.63***	- 0.43**	- 0.48**	-0.51**	-0.53***	- 0.38**	-0.45**
WCE	0.65***	0.63***	0.42***	0.47***	0.61***	0.67***	0.38***	0.44***
RhDW	- 0.43**	- 0.59**	-0. 48**	- 0.58**	- 0.45**	-0.51**	- 0.43**	- 0.55***
SDW	-0.53**	-0.61*	- 0.51	-0.61**	-0.52**	-0.56*	- 0.44***	-0.56**

Legends: SY – seed yield, LA – leaf area, CW – canopy width, RYL- relative yield loss, WCE – weed control efficiency, RhDW- rhizome dry weight, SDW – shoot dry weight, P≤ 0.001 = ***, P ≤ 0.01= **, P ≤ 0.05 = *

Table 5: Relationship between kenaf traits, weed control efficiency, relative yield loss, and *I. cylindrica* growth in Eruwa and Kishi

	Eruwa				**Kishi**			
	CW 10WAP	SBG	BFY	CFY	CW 10WAP	SBG	BFY	CFY
SY/ha	0.67***	0.25*	0.51***	0.54***	0.63**	0.31*	0.53**	0.52**
RYL	-0.65***	-0.65***	-0.77***	-0.85***	-0.61***	-0.62***	-0.63***	-0.79***
WCE	0.66***	0.44***	0.68***	0.71***	0.65***	0.35**	0.61***	0.67***
RhDW	-0.58***	-0.65***	-0.73***	-0.80***	-0.52***	-0.64***	-0.65***	-0.68***
SDW	-0.62***	-0.62**	-0.74***	-0.79***	-0.60***	-0.56**	-0.67***	-0.72***

Legends: SY – seed yield, SBG – stem butt girth, WCE – weed control efficiency, RYL- relative yield loss, RhDW – rhizome dry weight, SDW – shoot dry weight, CW – canopy width, BFY – bast-fibre yield, CFY – core-fibre yield, P ≤ 0.001 = ***, P ≤ 0.05 = *, P ≤ 0.01= **.

Table 6: Relationship between seed yield, relative yield loss, weed control efficiency, and *I. cylindrica* growth in Eruwa and Kishi

	SY	RYL	WCE	RhDW	SDW
SY		- 0.76***	0.57***	- 0.52***	- 0.56***
RYL	-0.91***		- 0.72***	0.56***	0.61***
WCE	0.60***	-0.62***		- 0.71***	- 0.81**
RhDW	-0.57***	0.52***	-0.93***		0.89***
SDW	-0.62***	0.62***	-0.85***	0.81***	

Legends: SY – seed yield, WCE – weed control efficiency, RYL- relative yield loss, RhDW – rhizome dry weight, SDW – shoot dry weight, P ≤ 0.001 = ***, P ≤ 0.01= **