IMPACT OF SPACING ON DENSITIES OF PHYTOPARASITIC NEMATODES ASSOCIATED WITH SORGHUM-BAMBARA GROUNDNUT INTERCROPPING SYSTEM IN BENUE STATE

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SUMMARY

Sorghum is popularly intercropped with Bambara groundnut in Benue State, Nigeria using different spatial arrangements. This study investigated the possible impact of such practice on the presence and multiplication rates of some phytoparasitic nematodes (PPNs) associated with the intercropping. A field experiment was conducted in 2019 at the Teaching and Research Station of Federal University of Agriculture, Makurdi, Nigeria. The experiment was laid out in Randomized Complete Block Design (RCBD) with three varieties of sorghum and four intercropping spacings (0 cm, 10 cm, 15 cm and 20 cm) with Bambara groundnut in four replicates. The initial and final populations of PPNs in each plot were obtained and reproduction factor (Rf) was calculated for each nematode genus identified. The Rf values were subjected to analysis of variance (ANOVA) and means separated using Duncan's New Multiple Range Test at 5% level of probability. Results showed that six nematode genera; Pratylenchus, Meloidogyne, Helicotylenchus, Criconema, Tylenchus and Trichodorus were recovered from all experimental plots. Even though found, the distribution of Rotylenchus, Xiphinema, Tylenchulus and Longidorus were sporadic and limited only to a few experimental plots. The Rf values of Meloidogyne spp. (6.98, 5.38 and 6.08), Pratylenchus spp. (7.36, 7.27 and 6.67) and Helicotylenchus spp. (5.06, 5.87 and 5.67) calculated from plots where only sorghum var. Deko, CRS.01 and SK.5912 were planted, were generally higher compared to intercropped plots, especially at 10 cm intra-row spacings with Bambara groundnut. Irrespective of the sorghum varieties planted, the nematode multiplication rates of Criconema spp. (6.00, 5.75 and 6.33), Trichodorus spp. (5.00, 5.67 and 4.75) and Tylenchus spp. (8.00, 7.00 and 7.00) were also the highest in plots where only sorghum was planted as sole crops. On the contrary, the least multiplication rates of these nematodes were recorded in plots intercropped with sorghum and Bambara groundnut at a spacing of 10 cm. Populations of PPNs in sorghum-Bambara groundnut intercropping system can be managed by maintaining an intra-row spacing of 10 cm. Such spatial arrangement can also be introduced during the sequence of any crop rotation scheme.

Keywords: Sorghum, Plant-parasitic nematode, Bambara groundnut, Intercropping, Spac

SORGHUM [*Sorghum bicolor* (L.) Moench] is one of the important staple crops grown mainly for its grains. Global production of sorghum was estimated at 57,893,378 tonnes while in Nigeria the crop was cultivated over an average area of 5,397,024 ha and production was 6,665,000 tonnes making Nigeria the second largest producer after the United States of America (FAO, 2020). It is known to have wide adaptability and tolerant to environmental stress such as low fertility, drought, salinity, acidity, as well as aluminum poisoning and even more tolerant to water logging (Marulak *et al*., 2017). Sorghum is intercropped with a number of crops including cowpea (Oseni and Aliyu, 2010), pigeon pea (Egbe, O. M. and Bar-Anyam , 2010), soybean (Egebe, 2010; Yusuf *et al*., 2016), maize (Sani *et al*., 2011), and bambara groundnut

(Gworgwor, 2002; Alhassan and Egbe, 2013) among other possible staples in Nigeria. Although not as pronounced in the upper northern fringes of Nigeria, intercropping sorghum with bambara groundnut is becoming popular among smallholder farmers in Benue State to optimize soil use and preparation. Bambara groundnut [*Vigna subterranea* (L.) Verdc] is a traditional or indigenous crop, which is mainly grown as a subsistence crop by farmers and to some degree for income generation.

Bambara groundnut occupies a peculiar position in the diet of the people of West Africa and some authors (Ocran *et al*., 1998; Mkandawire, 2007) have placed it as the third most important grain legume after groundnut and cowpea in the region. Bambara groundnut is a drought-tolerant and nutritious indigenous African grain legume (pulse) with high protein content, but it is underutilized (Jideani, and Diedericks, 2014). Due to Bambara plant's nitrogen fixation abilities, it is applied in intercropping and crop rotation with other grains such as sorghum (Dakora and Keya, 1997). As the cultivation of sorghum-Bambara groundnut intercropping is becoming popular among farmers, the mitigation of associated plant-parasitic nematodes (PPNs) that result in yield losses in these crops individually, must also be put into consideration with the framework of disease management.

It has been reported that plant-parasitic nematodes (PPNs) cause an estimated crop yield loss of 14.6% in tropical and sub-tropical climates and losses of 8.8% in developing countries (*Nicol et al.,* 2011). Plant-parasitic nematodes are considered the "unseen enemies" of plants because the symptoms observed in the aerial parts of plants are generally associated with forms of abiotic stress (e.g. lack of nitrogen, water stress). In recent years, research has provided increasing evidence that substantial yield advantages can be achieved from intercropping compared to sole cropping. The beneficial interaction that is most widely applicable in intercropping systems is better use of environmental resources. This is often attributed to the fact that different crops can complement each other and achieve improved yield stability (Sinoquet and Cruz, 1995). Intercrops of sorghum and various legumes have typically shown yield advantages between 25-40% (Willey, and Osiru, 1972; Wahua and Miller, 1978).

Since sorghum and Bambara groundnut as individual crops, are not exempted from the destructive activities of soilborne plant-parasitic pathogens such as plant-parasitic nematodes, it has become imperative that sustainable and adoptable strategies are sought that will ensure the mitigation of these PPNs. Previous studies have suggested that plant diversity could reduce pathogens and disease pressure compared to cultivating a single crop (Ampt *et al*., 2019). It is against this backdrop that this study was carried-out to (i) investigate the effects of using different spatial arrangements in a sorghum-bambara groundnut intercrop on plant-parasitic nematode fauna and (ii) determine which of the spatial arrangements in the intercrop will result in the least final population density of the plant-parasitic nematodes recovered from the rhizosphere of the intercrop.

MATERIALS AND METHODS

Description of Experimental Site

The experiment was conducted at the Teaching and Research Station of Federal University of Agriculture, Makurdi, Benue State located on latitude 07º41'N of the Equator, Longitude 05º40'E of the Greenwich Meridian and 98 m above sea level in the Southern Guinea Savannah Agro-ecological zone of Nigeria during the 2018 cropping season, between July and December.

Source of Seeds and Seeding

Seeds of three varieties of sorghum were obtained from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) namely; Deko, CSR.01 and SK.5912. A local cultivar of Bambara groundnut seeds was sourced from the seed bank of a farmer in Makurdi, Benue State. The experimental site was manually cleared of weeds and ridged using cutlass and hoe. Sowing of sorghum and Bambara groundnut were done side by side on the hills of the ridges using the hill method of planting. Sorghum seeds were sown at an intra-row spacing of 30 cm while Bambara groundnut was sown using three different arrangements that resulted in the intercropping patterns.

Experimental Design and Treatments

The experimental setup was laid out in a Randomized Complete Block Design (RCBD) and replicated four (4) times. The site was mapped out into plots using a measuring tape, pegs and twin ropes. The total of 48 experimental units were used and each unit had plot size of 20 m^2 (4 m x 5 m). Each plot consisted of four ridges spaced at 75 cm apart and a distance of 1m space among adjacent plots as alley. The total experimental plot size upon which the experiment was established was 399 m^2 (19 m x 21 m). A total of 12 treatments were evaluated in the study and they consisted of three (3) sorghum varieties intercropped with Bambara groundnut using the spatial arrangements as presented: (i) sole cropping, (ii) 10 cm, (iii) 15 cm and (iv) 20 cm intercropped spacings, respectively.

Nematode Extraction

Soil and root samples were randomly collected from each of the 48 experimental units established on the experimental sites. Each soil samples consisted of six cores 2.5 cm in diameter and 20 cm long using a hand auger at planting, and at harvest. The six- core soil and root samples collected from each experimental unit were bulked into a composite sample from which a subsample of 250 g was finally collected in a polythene bag and properly labeled. The composite samples were kept in good moist condition to prevent excessive heating or drying. Nematode extraction from the soil was done using modified sieving and centrifugation procedure according to Whitehead and Hemming[19] while sampled roots were macerated according to Zuckerman et al.[20]. Identification of plant-parasitic nematodes was done using the pictorial ley of Mai and Lyon[20].

Data Collection and analysis

Data on initial and final nematode populations were determined from 250 ml of composite soil and root samples. The reproduction factor expressed as R, was calculated using the formula; R =P*f* /P*i* (21). Where, *Pf* = Final nematode population *Pi* = Initial Nematode Population. Data collected were subjected to Analysis of Variance (ANOVA) using GENSTAT statistical software. Mean separation was done using Duncan Multiple Range Test at 5% level of probability (7th Edition, 2014).

RESULTS

A total of ten nematode genera were recovered from the rhizosphere of three sorghum varieties intercropped with Bambara groundnut at different spacings as shown in Table 1. The nematode genera included *Pratylenchus, Meloidogyne, Helicotylenchus, Tylenchulus, Criconema, Tylenchus, Rotylenchus, Xiphinema, Trichodorus* and *Longidorus*. Of these phytoparasitic nematode genera, only six were recovered from all the intercropped arrangements including *Pratylenchus, Meloidogyne, Helicotylenchus, Criconema, Tylenchus* and *Trichodorus*. These six phytoparastic nematodes occurred irrespective of the variety and spacing used in the sorghum- Bambara intercropping. The distribution of *Tylenchulus, Rotylenchus, Xiphinema* and *Longidorus* was sporadic and limited to only a few experimental plots. As in Table (1), *Tylenchulus* was only recovered from the rhizospheres of singly planted sorghum var. CRS.01, and intercropped with Bambara groundnut at 20 cm intra-row spacing. *Rotylenchus* was recovered from the rhizosphere of sorghum var. CSR.01 intercropped with Bambara groundnut at 20 cm intra-row spacing. It was also found that when sorghum cv. Deko was intercropped with Bambara groundnut at 20 cm intra-row spacing. *Xiphinema* was found in the rhizospheres of sorghum var. Deko and CSR.01 planted as sole crops. *Rotylenchus* was also found when sorghum var. Deko was intercropped with Bambara groundnut at 20 cm intra-row spacing. *Longidorus* was recovered from the rhizospheres of sorghum var. Deko and SK.5912 intercropped with Bambara groundnut at 15 cm and 20 cm, respectively.

Table (2) showed the effects of intercropping three varieties of sorghum with Bambara groundnut at different spacings on the multiplication rates of *Meloidogyne* spp, *Pratylenchus* spp. and *Helicotylenchus* spp. Results showed that multiplication rates (R-values) of *Meloidogyne* spp. (6.98, 5.38 and 6.08), *Pratylenchus* spp. (7.36, 7.27 and 6.67) and *Helicotylenchus* spp. (5.06, 5.87 and 5.67) were generally higher in plots where the three sorghum varieties were established as sole crops compared to intercropped plots, especially at

10 cm intra-row spacings with Bambara groundnut. Although the highest nematode multiplication rates were observed in plots where sorghum was grown as sole crop, the R-values of nematodes recovered from intercropped plots spaced at 20 cm and 15 cm did not differ ($P > 0.05$) in most cases, with R-values of nematodes in the sole plots. In fact, *Helicotylenchus* spp. multiplied the most on sorghum var. SK.5912 intercropped with Bambara groundnut at a spacing of 20 cm. However, when intercropped at a spacing of 10 cm, multiplication rates of *Meloidogyne* spp. (3.27, 1.83 and 1.64) *Pratylenchus* spp. (4.25, 2.54 and 2.66) and *Helicotylenchus* spp. (2.63, 3.83 and 3.24) were comparatively reduced, irrespective of the sorghum variety planted.

Similar trends were observed when populations of *Criconema* spp., *Trichodorus* spp. and *Tylenchus* spp. recovered from sole and intercropped plots of sorghum and Bambara groundnut were evaluated by computing their R-values (Table 3). Irrespective of the sorghum varieties, the nematode multiplication rates of *Criconema* spp. (6.00, 5.75 and 6.33), *Trichodorus* spp. (5.00, 5.67 and 4.75) and *Tylenchus* spp. (8.00, 7.00 and 7.00) were the highest in plots where only sorghum was planted as a sole crop. On the contrary, the least multiplication rates of these nematodes were recorded in plots intercropped with sorghum-Bambara groundnut at a spacing of 10 cm.

Table 1: Nematode genera recovered from rhizosphere of three sorghum varieties planted solely or intercropped with Bambara Groundnut at different spacings in Makurdi

Genera	Deko				CSR.01				SK.5912			
	Sole	10 cm	15 cm	20 cm	Sole	10 cm	15 cm	20 cm	Sole	10 cm	15 cm	20 cm
Pratylenchus	+	+	+	+	+	+	+	+	+	+	+	+
Meloidogyne	+	+	+	+	+	+	+	+	+	+	+	+
Helicotylenchus	+	+	+	+	+	+	+	+	+	+	+	+
Tylenchulus	-	-	-	-	+	-	-	+	-	-	-	-
Criconema	+	+	+	+	+	+	+	+	+	+	+	+
Tylenchus	+	+	+	+	+	+	+	+	+	+	+	+
Rotylenchus	-	-	-	-	-	-	-	+	-	-	-	-
Xiphinema	+	-	-	+	+	-	-	-	-	-	-	-
Trichodorus	+	+	+	+	+	+	+	+	+	+	+	+
Longidorus	-	-	+	-	-	-	-	-	-	-	-	+

+ = nematode genus is present; **-** = nematode genus is absent

Table 2: Effects of three sorghum varieties planted solely or intercropped with Bambara groundnut at different spacings on the multiplication rates of *Meloidogyne* spp., *Pratylenchus* spp. and *Helicotylenchus* spp.

Variety	Spacing (cm)	Population of associated nematodes per 100g soil								
		Meloidogyne spp.			*Pratylenchus* spp.			*Helicotylenchus* spp.		
		P*i*	P*f*	R	P*i*	P*f*	R	P*i*	P*f*	R
Deko	Sole Cropping	86	600	6.98 a	37	275	7.36 a	16	81	5.06 ab
Deko	10	102	334	3.27 b	44	188	4.25 b	19	50	2.63 c
Deko	15	113	411	3.64 b	49	222	4.52 b	21	82	3.9b c
Deko	20	77	369	4.79 ab	33	203	6.09 a	20	76	3.80bc
CSR.01	Sole Cropping	106	571	5.38 a	46	335	7.27 a	15	88	5.87ab
CSR.01	10	141	258	1.83 c	61	155	2.54 c	18	69	3.83 bc
CSR.01	15	89	391	4.39 ab	38	213	5.52 ab	10	46	4.60 b
CSR.01	20	107	387	3.62 b	46	211	4.55 b	15	4	4.93 b
SK.5912	Sole Cropping	77	468	6.08 a	33	220	6.67 a	18	102	5.67 ab
SK.5912	10	98	161	1.64 c	42	113	2.66 c	21	68	3.24 c
SK.5912	15	88	291	3.31 b	38	213	5.58 ab	16	77	4.81 b
SK.5912	20	111	386	3.48 b	48	211	4.38 b	10	68	6.80 a
F.pr (P≤0.05)				0.008			<0.001			0.03
CV (%)				39.33			31.13			26.19

Means followed by the same letter in column indicate no significant differences based on Duncan's New Multiple Range Test; Each value is an average of three replications; CV = Coefficient of Variation; SED = Standard Error Difference; Pi = Initial nematode population; Pf = Final nematode population; R = Reproduction factor

Table 3: Effects of intercropping three varieties of sorghum with Bambara groundnut at different spacings on the multiplication rates of *Criconema* spp., *Trichodorus* spp. and *Tylenchus* spp.

Variety	Spacing (cm)	Population of associated nematodes per 100g soil								
		Criconema spp.			*Trichodorus* spp.			*Tylenchus* spp.		
		P*i*	P*f*	R	P*i*	P*f*	R	P*i*	P*f*	R
Deko	Sole Cropping	3	18	6.00a	3	15	5.00 a	1	8	8.00 a
Deko	10	8	11	1.38d	3	7	2.33 c	2	3	1.50 d
Deko	15	7	11	1.57d	3	11	3.67 b	2	6	3.00 bc
Deko	20	7	23	3.29b	1	4	4.00 b	2	5	2.50 c
CSR.01	Sole Cropping	8	46	5.75 a	3	17	5.67 a	1	7	7.00 a
CSR.01	10	8	10	1.25 d	3	5	1.67 d	1	3	3.00 bc
CSR.01	15	4	11	2.75 c	3	9	3.00 b	2	9	4.50 b
CSR.01	20	8	19	2.38 c	2	7	3.50 b	2	7	3.50 bc
SK.5912	Sole Cropping	3	19	6.33 a	4	19	4.75 a	1	7	7.00 a
SK.5912	10	6	17	2.83 c	2	3	1.50 d	2	3	1.50 c
SK.5912	15	6	17	2.83 c	2	5	2.50 c	3	8	2.67 c
SK.5912	20	8	27	3.38 b	2	7	3.50 b	3	8	2.67 c
F.pr ($P \leq 0.05$)				0.001			0.05			0.03
CV (%)				53.83			38.08			57.12
SED (±)				0.51			0.38			0.64

Means followed by the same letter in columns indicate no significant differences based on Duncan's New Multiple Range Test; Each value is an average of three replications; CV = Coefficient of Variation; SED = Standard Error Difference; Pi = Initial nematode population; Pf = Final nematode population; R = Reproduction factor

DISCUSSION

This study has shown that planting sorghum as an intercrop with Bambara groundnut at higher spacing of 20 cm resulted in higher nematodes populations as compared to intercrop with Bambara groundnut at 10cm spacing. This may be likely due to competition for nutrients at closer spacing, there by inhibiting the increase in nematode populations compared to sole cropping of cereals. In a similar study (Oostenbrink, 1966) reported that same hill and same row intercrops reduced nematode infestation in the plots where Sunn hemp and African nightshade were intercropped suggesting that the closer the plants were the better the interaction to reduce nematode pest infestation. This finding also corroborates those of Tweneboah (2000), who reported that Bambara groundnut is not easily attacked by disease and pest in any of its production regions because it has a very low insect pest and disease susceptibility.

The hardy nature of the crop and its drought tolerance may endear it for inclusion in climate change adaptation strategies. However, in damp conditions, it may be susceptible to various fungal diseases (Baudoin and Mergeai, 2001). According to Trenbath (1993) many pests and diseases are attracted when species are grown as sole crops compared to when they are intercropped and carry out less damage under intercropping than sole cropping systems. This may be related to micro-environment effects of associated crops in intercropping compared to sole cropping (Letourneau, 1990; Trenbath, 1993). Parasitic nematodes (eelworms) intercepted by roots of hosts and non-hosts by Trudgill (1991). Intercropping cowpea cultivar PAN 311 also reduced stalk borer *Chilo partellus* (Swinhoe) infestation significantly in sorghum compared to sole crop (Ayisi and Mposi, 2001). Additional advantages are that intercropping patterns will reduce labour peaks, suppress weeds, reduce risks of other pests and diseases (Alhassan *et al*., 2012), stabilize crop yields and returns and optimize the use of natural resources (Siddig *et al*., 2013, Vandermeer, 1989).

The study has also provided increasing evidence that substantial yield advantages can be achieved from intercropping compared to sole cropping. The beneficial interaction that is most widely applicable in intercropping systems is the better use of environmental resources (Karikari, 2000). This is often attributed to the fact that different crops can complement each other and achieve an improved yield stability. Intercropping of sorghum and various legumes have typically shown yield increase in the range of 25-40% (16, 17).

CONCLUSION

Sorghum-Bambara groundnut intercropping systems favourably reduced impacted the plant-parasitic nematode communities. Yet, planting sorghum as an intercrop with Bambara groundnut using a spacing of 10 cm also reduced most of the nematodes encountered, especially that of SK.5912 variety. The rates at which nematode multiplied in sole sorghum plots were generally higher than their multiplication rates on plots intercropped with Bambara groundnut at different row spacing. Hence to ensure lower nematode population, sorghum- Bambara groundnut intercropping at 10 cm is recommended.

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