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Research Article

Host Status of Sole Soya Beans, Sorghum and Intercrops, in Rotation to Root-Knot Nematodes (*Meloidogyne javanica* (Treub, 1885) Chitwood, 1949) in Yola, Nigeria

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ABSTRACT

Soyabeans is known to be attacked by Root-knot nematodes (*Meloidogyne spp*) causing serious yield loss of 17-80%. The use of chemicals to control the pest is successful but expensive and environmentally harazardous. Since sorghum is tolerant by supporting less reproduction of root-knot nematodes (*Meloidogyne spp*) it is used as intercrop and in rotation to study its effect on *M. javanica (MJ)*. The research was aimed at determining the effect of these crops in rotation including their intercrop on *M. javanica* population in soil, their growth and yield. Nine possible rotation combinations over a period of three years was laid. They are sb-sg-sb (T_1), sb-sb/sg-sg(T_2), sb-sb-sb (T_3), sg-sb/sg-sb/sg(T_4), sg-sg-sb/sg(T_5), sg-sb-sb/sg(T_6), sb/sg-sb/sg-sb(T_7), sb/sg-sb-sb/sg(T_8) and sb/sg-sg-sg(T_9) in 2001, 2002 and 2003 growing seasons. Data were collected on establishment count, plant height (8 weeks and 12 weeks), yield/ha,100grain weight, number of nodules/plant, number of pods/plant, number of root galls per plant and number of *M. javanica* j2/250cm^3 of soil. The result indicated that there was significant difference (P=0.05) between the treatments for both sorghum and soyabeans yield. The highest sorghum yield of 1667.20kg/ha was obtained in treatment T_6 in the third year. While that of Soyabeans was 1439.90kg/ha in treatment T_4. However, it was at par with soyabeans yield of 1432.40kg/ha and 1242.40kg/ha in T_1 and T_7 respectively. There was significant difference (P=0.05) between the number of *M. javanica* j 2/250cm^3. The lowest *M. javanica* j2/250cm^3 of soil of 125.30 in the third year was obtained in T_6. Therefore, it could be concluded that T_6 is best crop rotation sequence to reduce the number of *M. javanica* population in the soil.

Key words: Soyabeans, Sorghum, Rotation, *Meloidogyne*, Intercrop

INTRODUCTION

Soyabeans (*Glycine max L.*) is a major crop produced worldwide for its oil content and other uses. World production of Soya beans stood at over 200 million metric tonnes, with over 90% of production coming from USA, Brazil, Argentina, China and India (Food and Agriculture Organization, USA, 2014). In the USA 106, 877, 870 tonnes are produced, while only about 679, 000 tonnes is produced in Nigeria (FAO, 2014).

The low soyabeans production in Nigeria could be attributed to diseases particularly the soil borne diseases. Plant parasitic nematodes particularly *Meloidogyne* spp. are among the most important soil pests of Soyabeans (Slown, 1999; Afolami and Atungwu, 1999; Adegbite, 2003). Ajayi *et al.* (1993) reported 10% yield loss on soyabeans caused by *Meloidoigyne* spp. Now that soyabeans is not cultivated in the middle of Nigeria only (Nasarawa, Benue, Kogi, Niger and Kaduna states) but is cultivated even in the extreme northern states (Sudan Savanna), its value has increased.

On the other hand, sorghum is also cultivated in most of these areas as a major crop in Nigeria. Nigeria is producing over 10 million metric tonnes (FAO, 2014). Sorghum is also attacked by *Meloidogyne* spp. causing yield loss (Babatola and Sdown, 1990; Swarup and Sosa-Mosa, 1990). Therefore, because of more farmers adopting Soyabeans production and its continuous cultivation over large areas, *Meloidogyne* spp. population will increase causing more yield loss. Hence, there is the need to control the root-knot nematodes population build-up. Even though use of nematicides is the most effective,

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in Nigeria it is costly for the resource poor farmers and a threat to the environment. The use of mixed cropping and rotation have also been successful in controlling *Meloidogyne* spp. (Idowu *et al., 1992;* Diop *et al*., 2000). Therefore, this work was conducted with the following objectives:

i. to examine the effect of soyabean-sorghum rotation systems on *M. javanica* population in the soil.
ii. to determine the effect of soyabeans-sorghum mixture on the *M. javanica* population in the soil.

to determine the performance of soyabeans and sorghum in the cropping systems in *M. javanica* infested soil.

MATERIALS AND METHODS

Experimental site

This experiment was carried out at the Teaching and Research Farm of Federal University of Technology, Yola, now known as Modibbo Adama University of Technology, Yola, Nigeria. Yola lies within latitude 9^0 19^{11}N and altitude 12^0 30^{11} E at an altitude of 185.9 M above sea level within the Northern Guinea Savannah zone of Nigeria (Adebayo, 1999). The farm was surveyed for abundance of Root-Knot nematodes (*M. javanica*) as described by (Jada, 2007). The Root-Knot nematodes were extracted and identified as *M. javanica* (Jada, 2007). Soil samples were also taken and physio-chemical properties were analysed (Jada, 2007).

Experimental Layout and Planting

After identifying the nematode infested area, its cropping history for the last 2-3years was also recorded. After ploughing and harrowing the experiment was laid with Nine possible rotation combination as described in Table 1. The crops were planted in a 4x5m plots into Nine and replicated 4times. It was in a complete Randomized Block Design (CRBD) with no space between the plots and blocks. The crops were planted in three rainy seasons of 2001, 2002 and 2003 (Table 1).

Table 1: Treatment of a three-year crop rotation of soyabeans, sorghum and soyabeans intercropped with sorghum in the field

	Year		
Treatment	2001	2002	2003
sb-sg-sb (T_1)	Sb	Sg	Sb
sb-sb/sg-sg(T_2)	Sb	Sb/sg	Sg
sb-sb-sb (T_3)	Sb	Sb	Sb
sg-sb/sg-sb/sg(T_4)	Sg	Sb/sg	Sb/sg
sg-sg-sb/sg(T_5)	Sg	Sg	Sb/sg
sg-sb-sb/sg(T_6)	Sg	Sb	Sg
sb/sg-sb/sg-sb(T_7)	Sb/sg	Sb/sg	Sb
sb/sg-sb-sb/sg(T_8)	Sb/sg	Sb	sb/sg
sb/sg-sg-sg(T_9)	Sb/sg	Sg	Sg

Note: Sb = sole soyabeans, Sg = sole sorghum; Sb/sg = soyabeans intercropped with sorghum; T_1-T_9 = Treatment 1 to 9.

Samsoy-2 variety of soyabeans seeds was obtained from Adamawa Agricultural Development Programme as the commonest variety cultivated by farmers, while sorghum cultivar Pele-Pele which is red in colour was obtained from plant breeding unit of Department of crop production and Horticulture of the University. Sole soyabeans were planted at 75cm x 5cm (266,666 plants/ha), sole sorghum was planted at 75cm x 25cm (53,333 plants/ha), and the soaybeans intercropped with sorghum were planted at 75cm x 10cm (133,333plants/ha) and 75cmx50cm (26,666plants/ha) respectively. Compound fertilizer NPK (15:15:15) at 150kg/ha was broadcasted before planting. Weeding was done manually at 3,6 and 10 weeks after planting. This was done for all the 3 cropping seasons 2001, 2002 and 2003

Data collection from the field crops

For each of the cropping season (2001,2002 and 2003) data were collected from the field and some in the laboratory as follows:

Establishment count was done at 2 weeks after sowing (WAS) and converted to percentage of expected plant population. Plant height was taken on 10 plants at random in sole crops and 10 each for soyabeans and sorghum in intra-cropped plots at 8 WAS and 12 WAS. At 8WAS one Plant of sayabeans from each corner was uprooted and number of nodules were counted and average recorded for each plot (IITA, 1993). Five soyabeans plants were selected at random when the pods have started turning brown and counted, then average per plot recorded.

At 12WAS five plants from each plot for sole crops and 5 for each crop in the intra-cropped plots were uprooted for root galls counting. The galls were counted and gall index scored according to Barker (1985). Ten soil samples were taken in a zig-zag pattern from each plot bulked (Webster and Liver, 1990) and taken to the Laboratory for *M. javanica* juveniles extraction. The juveniles, extraction was done according to Townsend (1962). The number of *M. javanica* at planting in 2001 served as initial population (P_i) while that at maturity served as final population (P_f). However, for subsequent years (2002 and 2003) the P_f of the previous year serve as the P for the current year and the population taken at maturity for that year served as P_f. Therefore, reproduction index of *M. javanica* for each year was calculated as P_f/P_i (Griffin, 1994). Grain yield was obtained by weighing grains from each plot and converted to yield per hectare in kilograms. From each plot yield 100 grains were counted and weighed as 100grain weight.

RESULTS

The farm was cultivated for more than 10years to different crops like Soybeans, maize, sorghum, Okra, Sorrel, Cowpea, Groundnuts, Bambara groundnut and many others. It has a sandy loam dark brown soil with bulk density of 1.6g/cm^3 (Jada 2007) its pH-range from 6.9-7.2, Cation Exchange Capacity (CEC) of 8-14.8cmol/kg and total nitrogen of 0.09%.

At planting the number of *M. javanica* juveniles count had no significant difference (P= 0.05) between the treatment plots with count of 1450±150 j2/250cm^3 of soil.

Effect of Soybeans–Sorghum- Soybeans intra-cropped with sorghum on sorghum performance and host status to *M. javanica* in field for the three cropping seasons 2001, 2002 and 2003

In 2001 cropping season all five parameters measured on plant growth and performance viz = plant height at

8WAS and 12WAS, Establishment count, yield/ha and 100 grain weight showed no significant difference between the treatments at P = 0.05 (Table 2). However, the tallest plants of 112.20cm and 170.98cm at 8WAS and 12WAS was obtained in T_4 and T_5 respectively. As for root- gall index and juveniles count per 250cm^3 of soil significant difference were observed at P = 0.05.

The highest root gall index of 2.63 was obtained in T_9 (soyabeans/sorghum) but at par with root gall index of 2.25 and 2.00 for T_4 and T_5 respectively. In j_2 count per 250cm^3 of soil there was significant difference at P=0.05 between the treatments. The highest J_2 count of 3553.80 per 250cm^3 of soil was obtained in T_9. When one degree of freedom orthogonal comparison was done, there was significant difference at P=0.01 between J_2/250cm^3 of soil.

In the second cropping season of 2002 (Table 3) plant height (8WAS and 12WAS), establishment count, 100 grain weight, root gall index and J_2 count per 250cm^3 of soil showed no significant difference at P= 0.05. At 8WASand 12WAS the tallest plants of 71.30cm and 183.90cm were obtained in T_5 and T_9 respectively, all are sole sorghum in this season (2002). As for J_2/250cm^3 of soil, the highest count of 1179.50 was obtained in T_4 thus in soyabeans intra-cropped with sorghum (2002 cropping season). However, there was significant yield difference at P=0.05, with T_9 (sole sorghum) recording the highest yield of 581.20kg/ha. It is at par with yield in T_1 and T_7

Table 2: Effect of Soyabeans – Sorghum - Soyabean/Sorghum Rotation on Sorghum Performance and Host Status to *M. javanica* in the Field for 2001 Cropping Season:

Rotation cycle	Present	Plant Height (cm)		Establishment count (%)	Yield/ha (kg)	100 grain weight (g)	Root gall index (0-5)	J_2 population/ 250cm^3 of soil
		8WAS	12WAS					
Sg-Sb/Sg-Sb/Sg(T_4)	Sg	112.20^a	161.10^a	93.55^a	876.80^a	2.21^a	1.25^c	562.50^b
Sg-Sg-Sb/Sg(T_5)	Sg	101.53^a	170.98^a	93.40^a	792.20^a	2.24^a	1.50^{bc}	464.50^b
Sg-Sb-Sb/Sg(T_6)	Sg	92.58^a	156.80^a	92.87^a	729.70^a	2.18^a	2.00^{ab}	959.50^b
Sb/Sg-Sb/Sg-Sb(T_7)	Sb/Sg	84.98^a	149.88^a	91.21^a	662.00^a	2.24^a	2.25^a	1364.80^b
Sb/Sg-Sb-Sb/Sg**(T_8)**	Sb/Sg	87.93^a	152.20^a	91.20^a	872.20^a	2.22^a	1.50^{bc}	1364.80^b
Sb/Sg-Sg-Sg(T_9)	Sb/Sg	80.25^a	146.85^a	91.12^a	605.50^a	2.17^a	2.63^a	3553.80^a
SE.		8.47^{NS}	6.0^{NS}	2.84^{NS}	118.50^{NS}	0.04^{NS}	0.13	475.6
CV		22.25	9.41	10.17	38.38	4.65	26.76	66.1
Contrast Sg vs S_b/S_g								**

Note = Sb = Sole soyabeans Sg = sole sorghum, Sb/Sg Soyabean accompany with sorghum; Means with the same letter(s) are not significantly different using DMRT at 5% level of probability. ∗;∗∗;∗∗∗; indicates one degree of freedom orthogonal contrast significant at P=0.05, P=0.01 and P = 0.001 respectively, n-s = not significant; WAS = weeks after sowing.

Table 3: Effect of Soyabeans – Sorghum – Soyabeans/Sorghum Rotation on Sorghum Performance and Host Status to *M. javanica* in Field for the Second Cropping Season 2002.

Rotation cycle Present	Previous 2001	Present crop (2002)	Plant height (cm)		Establishment count (%)	Yield/ha (kg)	100grain weight (g)	Root gall index (0-5)	J_2 population/ 250cm^3 of soil
			8WAS	12WAS					
Sb-Sg–Sb (T_1)	Sb	Sg	67.20^a	163.50^a	93.50^a	460.40^{ab}	2.20^a	1.50^a	730.30^a
Sb-Sb/Sg-Sg(T_2)	Sb	Sb/Sg	61.90^a	157.90^a	91.90^a	232.70^b	2.10^a	1.50^a	1085.50^a
Sg-Sb/Sg- Sb/Sg**(T_4)**	Sg	Sb/Sg	61.50^a	163.10^a	93.60^a	236.90^b	2.50^a	1.30^a	1179.50^a
Sg-Sg-Sb/Sg(T_5)	Sg	Sg	71.30^a	164.90^a	92.90^a	213.30^b	2.30^a	1.00^a	681.00^a
Sb/Sg-Sb/Sg-Sb (T_7)	Sb/Sb	Sb/Sg	68.60^a	153.70^a	91.10^a	286.80^{ab}	2.50^a	1.50^a	768.50^a
Sb/Sg-Sg-Sg(T_9)	Sb/Sg	Sg	64.60^a	183.90^a	91.90^a	581.20^a	2.50^a	1.50^a	597.50^a
SE.			5.30^{NS}	9.50^{NS}	2.50^{NS}	76.51	0.10^{NS}	0.2^{NS}	153.6^{NS}
CV			19.6	14.20	8.80	55.90	12.10	41.80	41.4
Contrast Sg vs Sb/Sg									NS

Note:Sb= sole Soyabeans, Sg = sole sorghum; Sb/Sg= soyabean accompanied with sorghum. Means with the same letters are not significantly different Using DMRT at 5% level of Probability. ∗;∗∗;∗∗∗; indicates one degree of freedom orthogonal contrast significant at P=0.05, P=0.01 and P = 0.001 respectively, n-s = not significant P=0.05.
WAS = weeks after sowing.

Table 4: Effects of Soytabeans – Sorghum- Soyabeans/Sorghum Rotation on Sorghum Performance and Host Status to *M. javanica* in Field for the Third Cropping Season 2003.

Rotation cycle	Previous crop (2001)	Previous crop (2002)	Present crop (2003)	Plant Height (cm)		Establishment count (%)	Yield/ ha(kg)	100grain weight (g)	Root gall index (0-5)	J_2 population/ 250cm^3 of soil
				8WAS	12WAS					
Sb-Sb/Sg-Sg (T_2)	Sb	Sb/Sg	Sg	64.64^{ab}	116.79^{bc}	91.75^a	1268.10	2.62	1.25	130.00
Sg-Sb/Sg- Sb/Sg (T_4)	Sg	Sb/Sg	Sb/Sg	60.34^{bc}	109.98^c	93.24^a	732.80	2.21	1.75	697.30
Sg-Sg-Sb/Sg(T_5)	Sg	Sg	Sb/Sg	59.16^{bc}	123.42^{abc}	93.94^a	783.60	2.81	1.63	400.50
Sg-Sb-Sb/Sg(T_6)	Sg	Sb	Sg	70.79^a	134.91^a	92.50^a	1667.70	2.97	1.25	125.30
Sb/Sg-Sb-Sb/Sg(T_8)	Sb/Sg	Sb	Sb/Sg	65.26^{ab}	128.52^{ab}	93.75^a	893.20	2.83	2.00	443.00
Sb/Sg-Sg-Sg (T_9)	Sb/Sg	Sg	Sg	56.34^c	118.06^c	91.00^a	1085.20	2.79	1.00	260.30
SE.				1.93	3.63	0.95	73.36	0.08	0.66	75.24
CV				7.53	7.3	3.27	16.77	7.21	26.9	53.24
Contrast Sb vs Sb/Sg										NS

Note: Sb = sole soyabeans; Sb/Sg = soyabeans accompanied with sorghum; Sg = sole sorghum. Means with the same letter are not significantly different using DMRT at 5% level of probability. ∗;∗∗;∗∗∗; Indicates one degree of freedom orthogonal contrast significant at P=0.05, P=0.01 and P = 0.001 respectively, n-s = not significant P=0.05. WAS = weeks after sowing.

that is 460.40 and 286.80kg/ha respectively. It should be noted that T_1 is soyabeans/sorghum for the 2002 season. However, one degree of freedom orthogonal comparison between the J_2 count/250cm^3 of soil showed no significant difference at P=0.05 for the sole sorghum and soyabeans/ sorghum intracrop in 2002.

In the third cropping season 2003 and the final in the rotation cropping cycle, all the parameter measured with the exception of establishment count showed significant difference at P=0.05 (Table 4). The shortest plants of 56.34 and 118.06cm at both 8WAS and 12WAS respectively were observed in T_9 thus sole sorghum. At 8WAS and 12WAS the tallest plants of 70.79cm and 134.91cm respectively was observed in sole sorghum; The highest yield of 1667.70kg/ha was obtained in T_6 (sole sorghum for 2003) and it is significantly higher (P=0.05) than yield obtained from all other treatments. The highest 100grain weight of 2.97g was obtained in T_6 (sole sorghum, 2003) and it was significantly higher (P=0.05) than what obtains in all other treatments. The highest root gall index 2.00 was obtained in T_8 (soyabeans/sorghum) which was significantly (P=0.05) higher than galling index for other treatments but at par with that observed on sorghum roots in T_4 and T_5 having 1.75 and 1.63 root gall index respectively. The highest J_2 count 697.30per 250cm^3 of soil was obtained in T_4 (soyabeans/sorghum). The count was significantly higher (O=0.05) than what obtains in all other treatments. Similarly, the one degree of freedom orthogonal comparism between the j_2 count/250cm^3 of soil showed no significant difference (P=0.05) for the sole sorghum and soyabeans/sorghgum intracrop in 2003.

Effect of Soybeans-Sorghum-Soybeans Intracropped with Sorghum on Soybeans Performance and Host Status to *M. javanica* in Field for the three Cropping Seasons 2001, 2002 and 2003

In 2001 cropping season establishment count, 100grain weight, number of pods/plant and root gall index showed no significant difference (P = 0.05) between the treatments (Table 5). While plant height (8WAS and 12WAS), yields/ha, number of nodules per plant and number of *M. javanica* J_2/250cm^3 of soil had significant difference (P = 0.05) between the treatments. At 8WAS the tallest soyabeans plant of 43.93cm was recorded in T_1 (sole soyabeans), but at par with what obtains in T_3, T_8 and T_7 having 35.58cm, 35.85cm and 35.68cm respectively. The soyabeans in T_8 and T_7 are those in soyabeans intracropped with sorghum. At 12WAS the tallest soyabeans plant were obtained in T_1 with 54.68cm height. It is significantly at par (P = 0.05) with soyabeans in all other treatment except those of T_2 that recorded 43.98cm in height. As for yield/ha the highest yield of 1268.80kg/ha was obtained in T_1, which was significantly higher than 643.99kg/ha obtained in T_7 being a soyabeans intra cropped with sorghum. The highest number of

Table 5: Effect of soyabeans-sorghum-soyabeans/sorghum rotation on soyabeans performance and host status to *M. javanica* in the Field for 2001 cropping season.

Treatment number	Present crop	Plant Height (cm)		Establishment count (%)	Yield/ ha(kg)	100 grain (g)	Number of pod plant	Number of nodules plant	Root gall	J_2/250cm^3 of soil.
		8WAS	12WAS							
T_1	Sb	43.93^a	54.68^a	93.48^a	1268.80^a	12.37^a	80.50^a	24.50^c	2.00^a	1402.80^b
T_2	Sb	32.63^b	43.98^b	90.47^a	1082.70^a	11.15^a	71.50^a	32.00^{ab}	2.38^a	1967.80^{ab}
T_3	Sb	35.58^{ab}	46.30^{ab}	93.05^a	1152.90^a	11.64^a	71.25^a	30.25^{bc}	2.25^a	930.80^b
T_7	Sg/Sg	35.68^{ab}	48.35^{ab}	91.20^a	643.00^b	11.90^a	63.75^a	35.00^{ab}	1.75^a	1364.80^b
T_8	Sb/Sg	35.85^{ab}	50.73^{ab}	91.49^a	851.40^b	11.64^a	52.50^a	37.50^a	1.75^a	1364.80^b
T_9	Sb/Sg	32.75^b	47.78^{ab}	88.64^a	696.50^b	12.35^a	54.50^a	32.25^{ab}	1.75^a	3553.80^a
SE.		2.46	2.16	12.56	189.8	0.35	7.58	1.58	0.32	476
CV		16.68	10.9	9.38	48.9	7.30	28.27	12.1	39.48	84.5
Contrast Sg vs Sb/Sg										n-s

Note: Sb= sole soyabeans; Sb/Sg=soyabeans accompanied with sorghum; Means with one column with the same letter are not significantly different using DMRT at 5% level. ∗;∗∗;∗∗∗; and n-s indicates one degree of freedom orthogonal contrast significant at P=0.05; P=0.01, P = 0.001 and n-s = not significant at P=0.05; W.A.S = weeks after sowing.

Table 6: Effect of soyabeans- sorghum-soyabeans/sorghum rotation on soyabeans performance and host station to *M. javanica* in field for the second cropping season 2002.

Treatment number	Previous crop (2001)	Present crop (2002)	Plant Height (cm)		Establishment count (%)	Yield/ ha(kg)	100 grain (g)	Number of pod plant	Number of nodules plant	Root gall index (0-5)	J_2/250cm^3 of soil
			8WAS	12WAS							
T_2	Sb	Sb/Sg	38.34^a	49.42^a	92.12^a	361.50^b	9.89^{ab}	25.19^b	38.75^b	1.50^a	1085.50^{abc}
T_3	Sb	Sb	40.79^a	52.51^a	93.21^a	613.10^{ab}	8.59^c	35.56^a	46.50^a	2.25^a	1459.50^a
T_4	Sg	Sb/Sg	44.08^a	51.42^a	89.99^a	572.60^{ab}	10.32^a	37.44^a	29.75^c	1.25^a	1179.50^{ab}
T_6	Sg	Sb	40.21^a	52.04^a	91.26^a	624.00^{ab}	9.18^{bc}	27.25^b	30.00^c	1.25^a	403.50^{dc}
T_7	Sb/Sg	Sb/Sg	42.92^a	54.38^a	92.76^a	608.20^{ab}	9.42^b	28.06^b	35.00^{bc}	1.50^a	766.50^{bcd}
T_8	Sb/Sg	Sb	37.92^a	53.96^a	93.38^a	652.60^a	9.93^{ab}	41.75^a	40.50^{ab}	1.75^a	549.50^{cd}
SE.			1.85^{NS}	1.77^{NS}	5.34^{NS}	68.14	0.21	1.64	1.75	0.26	164.61
CV			11.16	8.31	3.64	29.18	5.43	12.34	11.69	40.49	47.69
Contrast Sg vs Sb/Sg											n-s

Note: Sb= sole soyabeans; Sb/Sg=soyabeans accompanied with sorghums; Means in the same column with the same letter are not significantly different using DMRT at 5% level. ∗;∗∗;∗∗∗; and n-s indicates one degree of freedom orthogonal contrast significant at P=0.05, P=0.01, P = 0.001 and n-s = not significant respectively. W.A.S = weeks after sowing.

Table 7: Effect of Soyabeans-Sorghum-Soyabeans/Sorghum Rotation on Soyabeans Performance and Host Status to *M. javanica* in Field the Third Cropping Season 2003

Treatment number	Previous crop (2001)	Previous crop (2002)	Present crop (2003)	Plant height (cm)		Establishment count (%)	Yield/ ha(kg)	100 grain (g)	Number of pod plant	Number of nodules plant	Root gall index (0-5)	J_2/250cm^3 of soil
				8WAS	12WAS							
T1	Sb	Sg	Sb	54.20^a	62.30^a	92.80^a	1432.40^a	11.60^a	43.30^a	37.00^{ab}	1.50^c	127.30^c
T3	Sb	Sb	Sb	40.90^a	45.40^c	93.00^a	696.00^b	8.90^c	32.40^b	43.80^a	2.50^a	2161.80^a
T4	Sg	Sb/Sg	Sb/Sg	48.20^c	55.20^b	91.30^a	1439.9^a	10.90^{ab}	36.50^{ab}	30.80^b	1.80^{bc}	697.40^b
T5	Sg	Sg	Sb/Sg	52.10^{ab}	62.40^a	92.2^a	821.70^b	10.40^b	32.20^b	36.80^{ab}	1.50^c	400.50^{bc}
T7	Sb/Sg	Sb/Sg	Sb	49.90^{bc}	56.50^b	93.3^a	1242.40^a	10.80^b	44.90^a	28.80^b	2.00^b	237.80^c
T8	Sb/Sg	Sb	Sb/Sg	48.90^c	56.8	92.9^a	829.30^b	10.10^b	29.80^b	37.80^{ab}	1.50^c	443.00^{bc}
SE.				0.8	0.5	6.1^{NS}	81.10	0.3	2.5	2.2	0.2	88.60
CV				3.9	2.2	4.3	18.40	0.3	16.5	15.3	16.4	32.00
Contrast Sg vs Sb/Sg												**

Note: Sb= sole soyabeans; Sb/Sg=soyabeans accompanied with sorghum; Means in one column with the same letter are not significantly different at 5% level using DMRT. ∗;∗∗;∗∗∗; and n-s indicates one degree of freedom orthogonal contrast significant at P=0.05, P=0.01, P = 0.001 and n-s = not significant at P=0.05. W.A.S = weeks after sowing.

nodules per plant observed was 37.50 in T_8, though it is at par (P = 0.05) with what obtains in T_2,T_7T_9 having 32.00, 32.50 and 32.50 nodules per plant respectively, considering the number of *M. javanica* J_2 per 250cm^3 of soil, the highest was recorded in T_9 with 3553.80J_2/ 250cm^3 of soil. It is significantly higher (P = 0.05) than what obtains in all other treatments but at par (P = 0.05) with what obtains in T_2 that recorded 1967.80 J2/250cm^3 of soil. The number of j2/250cm^3 of soil in sole soyabeans when contrasted with that of soyabeans intra cropped with sorghum showed no significant difference (P=0.05).

In 2002 cropping season (Table 6) plant height at both 8 and 12 WAS showed no significant difference (P = 0.05) establishment count also showed no significant difference (P=0.05) yield per hectare of soyabeans showed significant difference (P=0.05) between the treatments (Table 6). The highest yield of 652.60kg/ha of soyabeans was obtained in T_8 being a sole soyabeans. It was however only significantly higher (P=0.05) than yield in T_2 which had 361.50kg/ha of soyabeans. The 100grain weight in this season showed significant difference (P=0.05) among the treatments. The highest 100grain weight of 10.32g was obtained in T_4. It was however at par with100 grain weight in T_8 and T_2 that 9.93g and 9.89 respectively if number of pods/plant is considered significant difference (P=0.05) was observed. The highest number of pods was 41.75pods per plant obtained in T_8. However, it was at par with number of pod of 37.44 and 35.36 pods/plant obtained in T_4 and T_3 respectively. The highest number of nodules of 46.50 nodules per plant was obtained in T_3 being significantly (P=0.05) higher than what obtained in all other treatments but at par 40.50 nodules/plant obtained in T_8.

The root gall index showed no significant difference (P=0.05) among the treatments. The highest gall index of 2.25 was obtained in soyabeans of T_3. The highest juveniles count of 1459.50/250cm^3 of soil was obtained in solyabeans of T_3. It was at par with 1179.50 and 1085.50 J_2/250cm^3 of soil in T_4 and T_2 respectively

In 2003 cropping season soyabeans plant height at 8 and 12WAS showed significant difference (P=0.05) in Table 7. At 8WAS the tallest soyabeans plant of 54.20cm was obtained in T_1 being significantly (P=0.05) taller than all others but at par with soyabeans in T_5 which recorded 52.10cm. At 12WAS the tallest plant was observed in T_5 with 62.40cm being significantly taller than all others but at par with that of T_1 which recorded 62.30cm. Establishment count showed no significant difference (P=0.05) between the treatments. The soyabeans yield of 1439.90kg/ha was recorded in T_4 and was significantly (P=0.05) higher than yields obtained in all other treatments but at par with 1432.40kg/ha and 1242.40kg/ha in T_1 and T_7 respectively. The lowest yield of 696.00kg/ha was obtained in T_3. In 100grain weight significant (P=0.05) difference was observed between the treatments. The highest weight 11.60g 100 grains was observed T_1 which was significantly (P=0.05) higher than 100 grain weight in all other treatment but at per with what obtains in T_4 (10.90g). The lowest significantly (P=0.05) was 8.90g obtained in T_3. Number of pods per plant showed significant difference (P=0.05) between the treatments. The highest number of pods/plant of 44.90 was obtained in T_7, even though it was at apr with 43.30 pods/plant and 36.50pods/plant obtained in T_1 and T_4 respectively. Number of nodules per plant also recorded significant difference (P=0.05) between treatments. The lowest number of nodules 28.80per plant was recorded in T_7. There was significant difference (P=0.05) in root gall index rating between the treatments. The highest root gall index of 2.50 was recorded in T_3 being significantly (P=0.05) higher than root gall index in all other treatments. The highest number of J_2 of 2161.80/250cm^3 of soil was recorded in T_3 and it was significantly higher (P=0.05) than J_2 counts in all other treatments.

When all the nine possible rotation cycle (T_1-T_9) where consider for j_2 population /250cm^3 of soil for the three years (2001, 2002, and 2003) significant difference (P=0.05) was observed between (Table 8) in all the years. The reproductive index for the various years were also shown (Table 8). In 2001 cropping season the highest J_2 count /250cm^3 of soil of 3553.8 was recorded and Being significantly (P=0.05) higher than counts in all other treatments. In this cropping season soyabeans/sorghum intracrop recorded the highest reproductive index of 1.43. All the sole sorghum treatments (T_4,T_5 and T_6) recorded low reproductive index of ≤ 0.4.

In 2002 cropping season there was significant difference (P=0.05) between J_2 count /250cm^3 of soil in

the nine treatments (Table 8). The highest J_2 of 1459.30/ 250cm^3 of soil was recorded sole soyabeans (T_3) it was significantly (P=0.05) higher than J_2 count in all other treatments but at par with J_2 count of 1179.50 and 1085.50 per 250cm^3 of soil in soyabeans/sorghum intracrop treatments of T_4 and T_2 respectively. The lowest J_2 of 403.50/250cm^{3}of soil was obtained in sole soyabeans treatment of T_6 that had sole soyabeans the previous year as well, even though it was par with J_2 count obtained in T_8, T_9, T_5, T_1, T_7 (549.5, 597.5, 681.0, 730.5 and 768.5 respectively). The highest reproductive index of 2.09 was recorded in T_4 for 2002 cropping season where soyabeans and sorghum were intracropped. However, the previous year 2001, it had sole sorghum. The lowest reproductive index of 0.2 was recorded in sole sorghum of T_9 (2002 season) that had soyabeans sorghum intracrop in 2002 season. In 2003 cropping season there was significant difference (P=0.05) between the treatments (Table 8)

The highest J_2 count of 2161.80/250cm^3 of soil was recorded in sole soyabeans of T_3, it was significantly higher (P=0.05) than J_2 count in all other treatments. The second highest J_2 count of 697.3/250cm^3 of soil was observed in soyabeans sorghum intracrop treatment (T_4) which was at par with 443.0 and 400.5j_2/250cm^3 of soil observed in T_5 and T_8 respectively.

The highest reproductive index of 1.5 was observed in T_3 in 2003 cropping season. The lowest reproductive index of 0.12 was recorded in T_2 that had sole sorghum with soyabeans intracropped with sorghum the previous (2002) cropping season.

The J_2 count/250cm^3 of soil for the different crops were contrasted using one degree of freedom orthogonal contrasts in each year for the 3 years (Table 8). In 2001 cropping season there was no significant difference (P=0.05) between j_2 count/250cm^3 of soil in sole soyabeans verses sole sorghum and that of sole soyabeans verse soyabeans/sorghguim intracrop. However, the J_2 count / 250cm^3 of soil in sole sorghum verse that of soyabeans/sorghum intracrop showed highly significance (p=0.001) difference between them.

In 2002 cropping season, the j_2 count/250cm^3 in sole soyabeans versus that of sole sorghum (one degree of freedom orthogonal contrast) showed significance difference (P=0.05) between them. The j_2 count/250cm^3 of soil contrast between sole soyabeans versus that in soyabeans/sorghum intracrop was highly significantly (P=0.001) different. While the contrast between j_2 count/250cm^3 of soil in sole sorghum versus that of soyabeans/sorghum showed no significant (P=0.05) difference. In the third cropping season (2003) one degree of freedom orthogonal contrast for count/250cm^3 of soil in both sole soyabeans versus sole sorghum and that of sole soyabeans versus soyabeans/sorghum intracrop showed very high significant (P=0.001) difference. However, j_2 count /250cm^3 of soil of sole sorghum versus that of soyabeans/sorghum intracrop showed no significant (P=0.05) difference.

DISCUSSION

In the field for the three years (2001, 2002 and 2003) soyabeans nodulation was not affected by the *M. javanica* population negatively or positively similar result was reported by Ononuju and Fawole (2002). This indicates that the ability of the soyabeans to fix nitrogen for its own and subsequent release into the soil is not affected. In the sole soyabeans where the j_2 of *M. javanica* were consistently high, the plants were stunted. Adegbite and Adesiyan (2001) and Adegbite (2003) observed stunted growth in untreated soyabeans varieties. However, the stunted growth was observed on soyabeans even in soyabeans-sorghum intracrop where j_2 counts were still high, though they should have been taller because of competition for light (Patra et al, 1985; Elemo and Jacobs, 1986). The soyabeans yield/ha were better in soyabeans-sorghum intracrop when compared to the sole soyabeans for all the years. This could be as a result of the *M. javanica* having more roots from the two crops to attack there by reducing the pressure on one crop. Similar results were obtained in a maize- cowpea intracrop that gave higher yield in the soles of each crop (Idowu and Fawole,

Table 8: Second Stage Juveniles (J_2) of *M. javanica*/250cm^3 and Reproductive Index Soil in Soyabeans, Sorghum, Soyabean/Sorghum Rotation in the Field for 2001, 2002 and 2003 Cropping Seasons

Treatments	Cropping sequence	J_2 population of *M. javanica* per 250cm^3				Reproductive index (Pf/Pi)		
		At planting 2001		2002	2003	2001	2002	2003
T_1	Sb-Sg-Sb	2691.0	1402.80	730.50	127.30	0.521	0.521	0.174
T_2	Sb-Sb/Sg-Sg	2341.5	1967.80	1085.50	130.00	0.840	0.552	0.120
T_3	Sb-Sb-Sb	2328.5	930.80	1459.30	2161.80	0.400	1.568	1.481
T_4	Sg-Sb/Sg-Sb/Sg	2368.5	562.50	1179.50	697.30	0.236	2.097	0.591
T_5	Sg-Sg-Sb/Sg	2382.0	464.50	681.00	400.50	0.195	1.466	0.588
T_6	Sg-Sb-Sg	2666.3	959.50	403.50	12530	0.360	0.421	0.311
T_7	Sb/Sg-Sb/Sg-Sb	2408.5	1364.80	768.50	237.80	0.500	0.563	0.309
T_8	Sb/Sg-Sb-Sb/Sg	2756.3	1364.80	549.50	443.00	0.500	0.403	0.806
T_9	Sb/Sg-Sg-Sg	2485.0	3553.80	597.50	`260.30	1.43	0.168	0.436
SE		-	58.13	3.47	110.26			
CV		-	7.0	74.5	399.4			
Contrast		-	N.S	*	***			
sb vs Sg Sb vs Sb/Sg Sg vs Sb/Sg		-	N.S	**	***			
		-	**	N.S	N.S			

Note: Sb= sole soyabeans; Sg= sole sorghum, Sb/Sg=soyabeans accompanied with sorghum; Means in the same column having same letters are not significantly different at 5% level using Duncan Multiple Range Test. *;**;***; Indicates one degree of freedom orthogonal contrast significant at P=0.05, P=0.01 and P = 0.001 respectively; n-s = contrasts not significant at P=0.05. P_i=initial juveniles population; P_f=final juveniles population.

1992). However, they also observed that the effects of sole cropping and intercropping on crop yields and root-knot nematodes *M. javanica* reproduction were inconsistent between locations and season.

Looking at the rotation cycle, the sole soyabeans (T_3) for the whole three years recorded lower yield and higher $j_2/250cm^3$ of soil. In the third year the sole soyabeans in T_3 had only 696kg/ha which is just about half of what obtains in T_1 and T_7 (1432.4kg/ha and 1242.4kg/ha respectively). The two had sorghum in their rotation cycle indicating that sorghum plays a role in reducing j_2 population of *M. javanica* in the soil and improving the yield of the partnering crop (soyabeans) by reducing the number of $J_2/250cm^3$ of soil. Considering the j_2 of *M. javanica* reproduction in the cycle in the third and final year of the rotation, the highest j_2 count $/250cm^3$ of soil was recorded in soyabeans throughout ($2161.8j_2/250cm^3$ of soil). This treatment recorded a reproductive index of 1.5. It indicates the high susceptibility level of the soyabeans. Earlier on increase in root-knot nematode population in fields cultivated with soyabeans in Nigeria were reported (Adegbite, 2003 and Ogunfowora *et al.*, 1983).

The lowest reproductive index of 0.2 was recorded in Sb-Sg-Sb rotation cycle, this indicate that the sole sorghum the second year (2002) is not as good a host when compared to soyabeans. Mcsorley, *et al* (1994) reported that in Floride Sx-17 sorghum cultivar sudan grass did not support reproduction of *M. javanica*. Recently Kirkpatrick and Thomas (2016) observed that sorghum support low reproduction of root-knot nematodes when compared to corn and soyabeans. Earlier on Afolami and Atungwu (2000; 2001) reported high reproduction rates of root-knot nematodes (*M. incognita*) on some soyabean varieties in Nigeria.

Conclusions

It has been concluded from present research that Sb-Sg-Sb shall be used as the rotation cycle to control root-knot nematodes (*M. javanica*) in infested fields. The use of soyabeans intercropped with sorghum in the cycle shall be used more wisely.

Farmers should avoid continuous cultivation of sole soyabeans year in year out in root-knot nematodes infested fields to avoid build-up of *M. javanica*. The use of crop rotation is to discourage use of chemicals and also to convince the farmers in the savannah zone to adopt soyabeans production that is relatively less popular.

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