

Host Status of Interspecific Upland Rice Progenies (*Oryza sativa* × *Oryza barthii*) to *Meloidogyne incognita*

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Abstract

Identification of resistance to various crop pests remains one of the cheapest methods for disease management to resource poor growers. Twenty two interspecific progenies from crosses between *Oryza sativa* and *Oryza barthii* were evaluated along with 11 additional cultivars were evaluated. Plants were inoculated with 5000 *Meloidogyne incognita* while uninoculated plants served as control. Resistant and susceptible checks were used for comparing the reaction of the genotypes. The screenhouse experiment was arranged in a completely randomized design with three replicates and two plants per stand. Data were collected on leaf chlorophyll content, number of leaves, tillers and panicles. At harvest, the number of grains per panicle was enumerated and grains were weighed. Roots were observed for damage and nematode population was estimated in roots and soil and used to calculate the reproductive factor. Number of leaves, tillers and panicles were significantly reduced in inoculated plants. Significant yield reduction ranged from 20%-59% with the higher losses occurring in the crosses. Twenty two lines were designated as susceptible while 10 were tolerant. The promising lines among the crosses were ART 16A8 and ART-16-A9. The use of WAB 56-105 can also be encouraged in areas with low *M. incognita* densities.

Keywords: Chlorophyll content; *Meloidogyne* spp; *Oryza* spp; Wild rice; Yield loss

Introduction

The genus *Oryza* includes twenty-three wild species and two cultivated species (cultigens) [1]. The wild species are widely distributed in the humid tropics and sub-tropics of Africa, Asia, central and south America and Australia [2]. The two cultivated species are African rice (*O. glaberrima* Steud) confined to West Africa whereas common or Asian rice (*O. sativa* L.) is now commercially grown worldwide where weather and soils permit [3]. One of the wild species is *Oryza barthii* A. Chev (1914) also known as Africa annual wild rice, is a plant of wetland and a natural weed of lowland rice which is distributed in tropical Africa from Mauritania east to Ethiopia and south to Botswana and Zimbabwe [4]. Brink and Belay [5] suggested that *O. sativa* may have been introduced to West Africa much earlier than is usually assumed and that *O. barthii* could be derived from hybridization between *O. sativa* and *O. glaberrima*.

One of the main interests for developing new rice lines is for the purpose of selecting for desirable traits to be developed in varieties. One of such traits is resistance to diseases. Diseases such as those caused by nematodes reduce the productivity of the crop in different ecologies that the rice grows. Plant-parasitic nematodes associated with rice include *Meloidogyne* spp, *Hirshmaniella* spp, *Aphelenchoides besseyi*, *Heterodera sacchari* and *Pratylenchus brachyurus* [6,7]. Estimated yield reduction caused by the root knot nematode is 20%-98% [8], white tip nematode is 31% [9], 38% by Cyst nematode and 28% by lesion nematode [10].

The use of resistance as a nematode management option remains one of the cheapest methods for resource poor farmers. Progenies of *O.*

galberrima × *O. sativa* showed variable resistance to the cyst and rice root knot nematode [11]. Several high yielding cultivars of *Oryza sativa* have been screened, but not enough genetic variability has been found for resistance to *Meloidogyne* species causing root-knot disease. The objective of this study was to investigate the reaction of the selected rice lines from *Oryza sativa* × *Oryza barthii* for resistance to the root-knot nematode, *Meloidogyne incognita*.

Material and Methods

The experiment was established at the Roof-top Garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. Nematode extraction, counting and estimation of nematodes from both infected roots and soil were carried out at the Nematology Laboratory of the International Institute of Tropical Agriculture (IITA), Ibadan Nigeria.

Soil sterilization

Sandy-loam topsoil collected from the International Institute of Tropical Agriculture (IITA), Ibadan was sterilized for two hours at 90°C using the soil sterilization machine at the Nematology Laboratory, International Institute of Tropical Agriculture (IITA), Ibadan. The soil was allowed to cool for 24 h, filled into sacks and taken to the Roof-top Garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, where it was transferred into 5 l pots.

Source and extraction of inoculum

Galled roots of *Celosia argentea* infected with root-knot nematodes were collected from the inoculum plots for *M. incognita* at the

University. The inoculum plots were established from a single eggmass of previously identified *M. incognita* using morphometric characters and PCR product [12]. Nematode eggs were extracted from the harvested galled roots using 0.5% sodium hypochlorite and collected in a beaker [13]. The number of eggs per ml of the suspension was determined by counting under a dissecting microscope from three aliquots of 2 ml each. The quantity of nematodes in the volume of suspension and the quantity of inoculum carrying the required number of nematodes for inoculation was calculated.

Sources and planting of rice lines

Twenty-two interspecific hybrids of *Oryza sativa* × *Oryza barthii* upland rice lines produced at the Africa Rice Center (ARC) formerly known as West Africa Rice Development Association (WARDA) (Table 1) and 11 additional cultivars were evaluated in this study. Rice cultivar *CG14* was designated as the resistant check for *Meloidogyne* spp. while *TGS3* was the susceptible check. The other cultivars are released varieties and were selected based on their popularity for high yield and resistance to other diseases. The abbreviated names will be used in future presentations. Planting was in perforated pots filled with 5 l of sterilized soil at the Roof-top Garden of the Department of Crop Protection and Environmental Biology, University of Ibadan.

Line number	Line names	Line abbreviation
101	ART-15-16-12-3-1-B-1-B-3-1-B	ART-15-B1
102	ART-15-16-31-2-1-1-1-B-1-1-B	ART-15-B2
103	ART-15-17-7-8-1-1-1-B-1-1-B	ART-15-B3
104	ART-15-19-5-4-1-1-1-B-1-1-B	ART-15-B4
105	ART-15-21-2-4-1-B-1-B-1-1-B	ART-15-B5
106	ART-15-21-56-2-1-1-1-B-1-1	ART-15-B6
107	ART-15-21-56-2-1-1-1-B-1-1-B	ART-15-B7
108	ART-15-21-56-2-1-1-1-B-2-2-B	ART-15-B8
109	ART-15-22-10-8-1-B-1-B-2-2-B	ART-15-B9
110	ART-15-7-16-38-1-B-2	ART-15-B10
111	ART-16-12-1-28-1-1-1-B-1-1	ART-16-A1
112	ART-16-13-13-2-2-B-1-B-1-1	ART-16-A2
113	ART-16-13-13-2-2-B-1-B-1-2-B	ART-16-A3
114	ART-16-14-1-33-2-B-1-B-1-1-B	ART-16-A4
115	ART-16-16-11-25-1-B-1-B-1-2	ART-16-A5
116	ART-16-17-14-28-3-2-1-B-1-1	ART-16-A6
117	ART-16-21-5-12-3-1-2-B-1-1	ART-16-A7
118	ART-16-4-2-2-2-B-1-B-1-2	ART-16-A8
119	ART-16-5-10-27-1-B-1-B-1-1	ART-16-A9
120	ART-16-5-9-22-3-B-2-1	ART-16-A10
121	ART-16-9-10-15-4-1-1-B-2-1	ART-16-A11
122	ART3-7L9P8-3-B-B-2-1	ART3-7

CV1	BRS PRIMAVERA (<i>O. sativa</i>)	BRS PRIMAVERA
CV2	CG 14R (<i>O. glabarrima</i>)	CG 14
CV 3	MOROBEREKAN (<i>O. sativa</i>)	MOROBEREKAN
CV 4	NERICA 1	NERICA 1
CV 5	NERICA 7	NERICA 7
CV 6	NERICA 8	NERICA 8
CV 7	TGS25 (<i>O. glabarrima</i>)	TGS25
CV 8	TGS3 (<i>O. glabarrima</i>)	TGS3
CV 9	WAB 638-1 (<i>O. sativa</i>)	WAB 638-1
CV 10	WAB 56-104 S (<i>O. sativa</i>)	WAB 56-104
CV 11	ARICA 4	ARICA 4
CV 1-11=checks; line number 101-122 are the intraspecific crosses; ^R =resistant, ^S =susceptible		

Table 1: List of *Oryza sativa* × *O. barthii* interspecific lines and checks used for the experiment.

Screening of rice lines for their reaction to root-knot nematode, *Meloidogyne incognita*

Three seeds per pot were sown in sterile soil contained in 5 l, watered daily and thinned to two seedlings per pot two weeks after planting. Pots to receive inoculum were inoculated with 5000 eggs of *M. incognita* in 10 ml water three weeks after planting while the control pots were un-inoculated. The experiment was laid out in a completely randomized design and replicated three times. Data collection commenced immediately after inoculation and the data were taken at weekly intervals for three months. The parameters observed and recorded were; the number of leaves and number of tillers taken by physical count, height of the rice plants by meter rule, chlorophyll content using SPAD-chlorophyll meter.

The experiment was terminated 12 weeks after inoculation by which time the nematode would have reproduced sufficiently. Harvesting of rice was conducted when the soil was moist by cutting off the top growth (aerial plant part), upturning the pot and shaking the root free of soil. Shoots, roots and soil were collected separately and collected in labeled polythene bags and taken to the laboratory for further work. At harvest, number of panicles and number of seeds per plant were taken by physical count.

The roots collected in individual polythene bags were washed free of soil and weighed. The roots were then assessed for damage (galling index) using a 1-5 scale modified from [14] where 1=no galls (healthy roots), 2=≤ 10 % roots galled, 3 11-35%, 4=36%-65%, 5=66%-100% of total roots with galls. The roots were then chopped into 1-2 cm pieces from which nematodes were extracted with 0.5% sodium hypochlorite as previously described. Soil from each pot was thoroughly mixed and 200 cm³ was taken out from which nematodes were extracted using the extraction tray method [15]. The total number of eggs/nematodes recovered from roots and number of nematodes recovered from soil were summed to get the final nematode population (PF). Nematode reproduction factor (RF) was calculated using Pf/Pi where Pf is the final nematode population and Pi is the initial inoculum. Host status was designated based on Resistant = R ≤ 1, GI ≤ 2, no significant yield

loss; Tolerant: $R > 1$, $GI \leq 2$, no significant yield loss; Hyper-Susceptible: $R \leq 1$, $GI > 2$, significant yield loss; Susceptible: $R > 1$, $GI > 2$, significant yield loss [16].

Data analysis

Data was processed using Microsoft Excel. Data on nematodes count were transformed using square root transformation $\sqrt{X+0.5}$. Data were analyzed with Analysis of variance (ANOVA) using SAS 9.1 statistical analysis system package and the mean were separated using Least Significant Difference (LSD) at $\alpha=5\%$.

Results and Discussion

The number of leaves and number of tillers in inoculated plants were significantly ($p \leq 0.05$) lower in eight and seven out of the ten ART-15 series lines respectively in comparison to uninoculated plants (Table 2). The number of leaves was reduced significantly in three of the rice lines while the number of tillers was reduced in seven lines of the 11 tested ART-16 series lines. Their reaction was similar to the susceptible check indicating that they may be sensitive to the root-knot nematode. Nematode infection at both low and high initial inoculum densities results in poor plant height, number of tillers, number of panicles and grain yield in rice cultivars [17]. Plant-parasitic nematodes damage roots and the reduced function of the roots influences water and nutrient uptake. The three NERICA cultivars tested also produced fewer numbers of leaves and tillers in inoculated compared to control plants. This was similar to the finding of Akpheokhai and Claudius-Cole [18] where nematode inoculated NERICA varieties showed reduced number of leaves and tillers and in addition were shorter than uninoculated plants. Most of the plants

evaluated produced similar number of panicles when comparing inoculated and control plants however, ART-15-B5, ART-16-A4, BRS-Primavera and WAB56-104 had significantly ($p \leq 0.05$) fewer panicles compared to plants that were not inoculated. Chlorophyll content of inoculated plants taken at the vegetative stage of the plants were lower (not significant) compared to the healthy plants but at maturity there was a marked ($p \leq 0.05$) reduction in leaf chlorophyll content of inoculated plants. All the ART-15 series lines showed a significant reduction in chlorophyll content in inoculated plants (Figure 1).

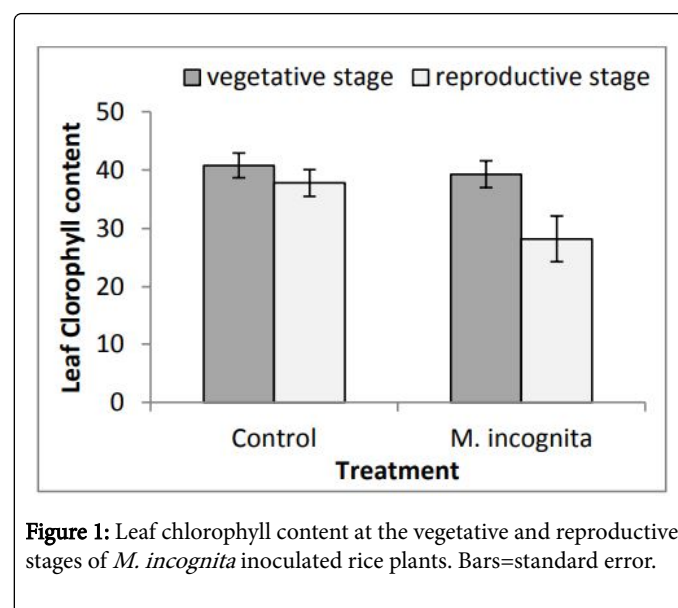


Figure 1: Leaf chlorophyll content at the vegetative and reproductive stages of *M. incognita* inoculated rice plants. Bars=standard error.

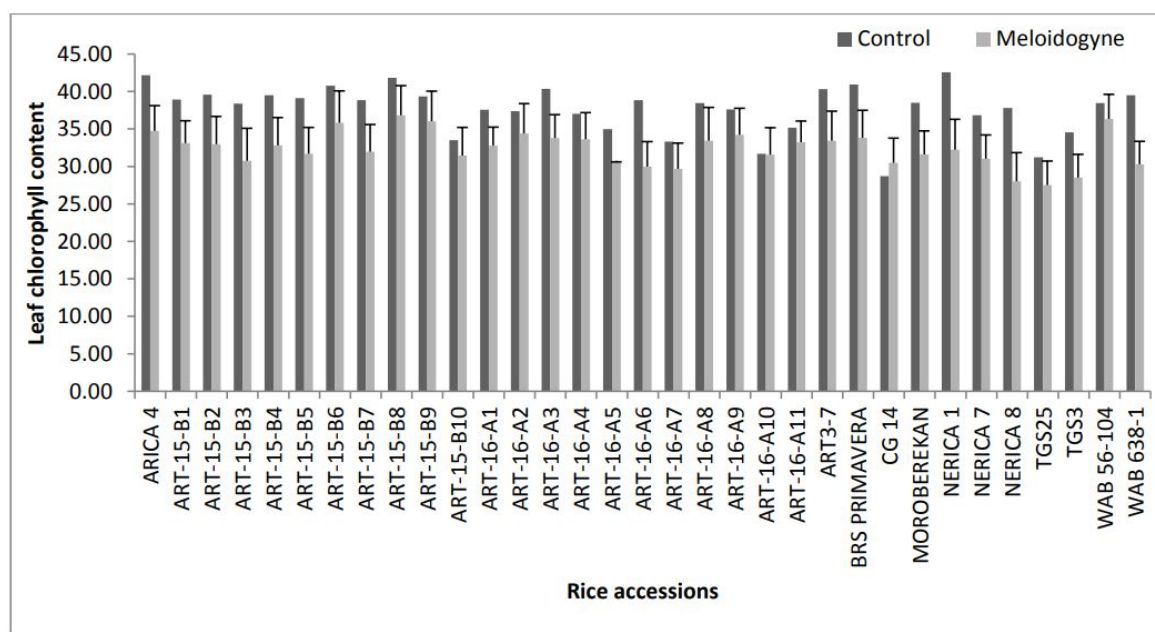


Figure 2: Chlorophyll content in leaves of rice plants infected with root-knot nematode compared to uninoculated plants at maturity. Bar LSD at $p \leq 0.05$

Among the ART-16 series lines, only ART-16-A9 had a non-significant amount of reduction in chlorophyll content of leaves and

was similar in reaction to the resistant check and WAB 56-104 (Figure 2).

Accessions	No. of leaves		No. of tillers		No. of panicles	
	Control	<i>M. incognita</i>	Control	<i>M. incognita</i>	Control	<i>M. incognita</i>
ARICA 4	35.3	24.6*	9	7.9*	6.5	7.7
ART-15-B1	39.7	27.8*	9.6	8.3*	8.3	6.7
ART-15-B2	38.3	21.9*	10	6.9*	5.3	4.7
ART-15-B3	36.8	27.2*	9.6	7.9*	7	4.8
ART-15-B4	22.6	28.6*	8.1	6.3*	6.5	6
ART-15-B5	25.6	22.3*	7.9	6.4*	8.7	4.3*
ART-15-B6	28.8	21.1*	8.3	6.2*	5.2	7.8
ART-15-B7	34.6	23.2*	8.6	6.3*	5.5	6.5
ART-15-B8	40	30.9*	10.3	10.1	9.7	6.7
ART-15-B9	28.4	26.5	8.3	6.9*	9.2	6.7
ART-15-B10	31.8	29.4	10	8.4	5.8	4.8
ART-16-A1	30.4	32.4	10.4	10.3	6.8	7
ART-16-A2	33.9	29.9	8.7	8.8	7.8	5.7
ART-16-A3	31.8	33.7	10.3	8.3*	6.3	5.8
ART-16-A4	34.3	24.5*	10.1	7.4*	6.5	4.2*
ART-16-A5	19.8	22.4	5.7	6.8	5.8	4.3
ART-16-A6	40	28.5*	11.9	8.0*	6.8	5.2
ART-16-A7	27.9	29.4	9	8.1	5.8	5.3
ART-16-A8	28	22.4*	8.2	6.6*	4.8	5.3
ART-16-A9	27.5	26.3	9.1	7.1*	4.3	4.5
ART-16-A10	35.4	29.4	8.4	6.8*	5.3	4.7
ART-16-A11	26.4	21.8	8.3	6.8*	5.3	4.5
ART3-7	25.7	21.2	6.9	6.7	6.2	4.1
BRS PRIMAVERA	25.4	24.1	8.1	8.4	9	5.8*
CG 14	44.9	48.2	19.1	17.9	18	14.2
MOROBEREKAN	19.9	17.9	6.1	5.2	6	5.2
NERICA 1	30.4	26.3*	7.1	6.6	6.3	4.8
NERICA 7	32.7	25.7*	7.9	6.5*	8.3	5.3
NERICA 8	40.7	25.9*	10.9	8.0*	10.7	6.5
TGS25	67.7	55.4	19.9	17.3	16.9	14
TGS3	75.4	54.3*	19.8	14.7*	18	13.7*
WAB 56-104	29.9	27.6	9.1	8.4*	6.7	6.2
WAB 638-1	39.2	36.3	12.7	8.3*	9.8	8.3*
LSD	8.8	5.2	1.6	1.3	4.3	3.7

Values are means of six plants; * = significant difference between inoculated and control plants at $p \leq 0.05$ using LSD

Table 2: Effect of *Meloidogyne incognita* on number of leaves, tillers and panicles of *O. sativa* × *O. barthii* accessions.

Accessions	Number of grains per panicle		100 grain weight (g)	
	Control	<i>M. incognita</i>	Control	<i>M. incognita</i>
ARICA 4	110.7	83.0*	2.6	2.5
ART-15-B1	108.7	96.0*	2.9	2.7
ART-15-B2	102.3	88.3*	2.8	2.2*
ART-15-B3	82.3	56.3*	3.5	2.8*
ART-15-B4	76	64.7*	2.6	2.2*
ART-15-B5	96.7	56.0*	2.9	2.6
ART-15-B6	100	84.7*	2.9	1.7*
ART-15-B7	117.7	74.3*	2.9	2.5
ART-15-B8	121	87.3*	2.8	2.5
ART-15-B9	102	75.7	2.8	2.4
ART-15-B10	70	42.3*	3.7	3.1
ART-16-A1	88	77.3	2.8	2.6
ART-16-A2	114.3	71.7*	2.9	2.8
ART-16-A3	107	77.3	3.4	2.9
ART-16-A4	109.3	79.3*	2.7	2.4*
ART-16-A5	108	94.7	3.1	2.4*
ART-16-A6	110	74.7*	2.8	2.5
ART-16-A7	115	82.7*	2.9	2.8
ART-16-A8	110.7	93.3*	3.3	2.6*
ART-16-A9	113	90.7	2.7	2.1
ART-16-A10	135	103.7*	3.2	2.8
ART-16-A11	87	68.3*	3.1	2.5*
ART3-7	103.3	74.3*	2.9	2.6*
BRS PRIMAVERA	144.7	79.3*	2.4	2.0*
CG 14	85.7	78	3	2.5
MOROBEREKAN	88	65.7	2.8	2.5
NERICA 1	101	84.0*	3	2.7
NERICA 7	83.3	62.7*	3.5	3.2
NERICA 8	111	92.0*	2.7	2.2

TGS25	72	65.3	2.2	1.8
TGS3	82	51.3*	2.3	1.6*
WAB 56-104	87.7	72.7	2.5	2.4
WAB 638-1	96.3	79.7*	2.9	2.1*
LSD	28.1	24	0.6	0.5

Values are means of six plants; * = significant difference between inoculated and control plants at $p \leq 0.05$ using LSD

Table 3: Effect of *Meloidogyne incognita* on number of grains per panicle and 100 grain weight of 33 rice genotypes.

The reduction of chlorophyll in leaves is evidence that the nematode hampered root function and that the gall formation by the nematode is a nutrient sink that draws assimilates from the plant [19]. The consequence of reduced chlorophyll content is that the plant is further unable to sequester assimilates for storage, thus leading to yield reduction.

Generally, the majority (17) of the *O. sativa* × *O. barthii* lines produced significantly more grains per panicle and were comparable to the high yielding *NERICA* and *ARICA 4* cultivars (Table 3). This implies that they have good agronomic and yield traits. However, when inoculated with *Meloidogyne incognita*, number of grains per panicle was reduced significantly ($p \leq 0.05$) in all except one (*ART-15-B9*) of the *ART-15* series lines. In the *ART-16* series lines the reduction in number of grains per panicle was not significant for *ART-16-A1*, *ART-16-A3*, *ART-16-A5*, *ART-16-A10*, *ART-16-A11*, and *ART3-7*. The 100 grain weight was significantly lower in four out of the ten *ART-15* series lines and five out of the ten *ART-16* series lines. The 100 grain weight in the susceptible *TGS3* check was the lowest among all inoculated lines while *ART-16-A3* had the highest 100 seed weight among the inoculated progenies followed by *ART-16-A2*, *ART-16-A7*, and *ART-16-A10*. Line *ART-15-B3* when inoculated had among the highest values for 100 grain weight but it was significantly lower than the value from the control plants. Among the cultivars *NERICA 7* was among the highest yielding in terms of 100 grain weight irrespective of nematode inoculation.

The highest yielding lines (5) were *ART-15-B1*, *ART-15-B8*, *ART-15-B9*, *ART-16-A2*, and *ART-16-A7*, which were in a similar yield range with the high yielding *ARIKA*, *BRS Primavera* and the resistant *CG14* cultivar (Table 4). The percentage yield reduction was significant in majority (23) of the lines and cultivars evaluated. Significant yield reduction ranged 20%-59% with the highest yield reduction of 59% occurring in *ART-15-B6* and *ART-15-B10*. Yield was significantly reduced in 22 lines out of the 30 rice lines evaluated [20]. Galls on the rice plants were generally small, with majority occurring at root tips which resulted in reduced root volume. Similar observation was made by Adebayo and Salawu [21].

Genotype	Yield (grain weight) (g)		Yield Reduction (g) (%) Reduction	Gall index	Total nematode population	Reproductive Factor (RF)	Host Rating
	Control	<i>M. incognita</i>					
ARICA 4	18.3	12.9	5.4 (29.5)*	2	181.3	6.6	Susceptible
ART-15-B1	20.8	16.8	4.0 (19.5)*	2	203.9	8.3	Susceptible
ART-15-B2	16.6	7.6	9.0 (54.2)*	2	238.1	11.3	Susceptible
ART-15-B3	11.9	7.3	4.6 (38.7)*	2	150.5	4.5	Susceptible
ART-15-B4	16.9	9.8	7.1 (42.0)*	2	256.2	13.1	Susceptible
ART-15-B5	13.8	13.2	0.6 (4.3)	2	168.3	3.7	Tolerant
ART-15-B6	13.7	5.6	8.1 (59.1)*	3	234.5	11	Susceptible
ART-15-B7	14.5	11.8	2.7 (18.6)	2	200.5	8	Tolerant
ART-15-B8	22.3	12.2	10.1(45.3)*	3	220.6	9.7	Susceptible
ART-15-B9	18.2	9.3	8.9 (48.9)*	2	274.4	15.1	Susceptible
ART-15-B10	16.1	6.6	9.5 (59.0)*	3	260.7	13.6	Susceptible
ART-16-A1	10.9	9.5	1.4 (12.8)	2	228.5	10.4	Tolerant
ART-16-A2	19.7	10.9	8.8 (44.7)*	2	291.6	17	Susceptible
ART-16-A3	12.6	8.9	3.7 (29.4)	2	277.1	15.4	Tolerant
ART-16-A4	13.1	9.1	4.0 (30.5)*	2	203.9	8.3	Susceptible
ART-16-A5	14.6	8.2	6.4 (43.8)*	2	150.4	4.5	Susceptible
ART-16-A6	16.9	9.6	7.3 (43.2)*	2	205.4	8.4	Susceptible
ART-16-A7	20.4	11.3	9.1 (44.6)*	3	121.5	3	Susceptible
ART-16-A8	9.9	9.9	0.0 (0.0)	2	107	2.8	Tolerant
ART-16-A9	9.6	8.4	1.2 (12.5)	2	159.8	5.1	Tolerant
ART-16-A10	15.3	10.3	5.0 (32.7)*	2	234.5	11	Susceptible
ART-16-A11	16.2	9.3	6.9 (2.6)*	2	199	7.9	Susceptible
ART3-7	11.9	10.3	1.6 (13.4)	2	125.3	5.2	Tolerant
BRS PRIMAVERA	18.1	9.8	8.3 (45.9)*	3	141.6	4	Susceptible
CG 14	20.7	17.5	3.2 (15.5)	2	14.1	0.4	Resistant
MOROBEREKAN	13.1	9.5	3.6 (27.5)*	2	162.8	5.3	Susceptible
NERICA 1	11.9	10.5	1.4 (11.8)	2	204.3	8.3	Tolerant
NERICA 7	15.8	7.9	7.9 (50.0)*	2	176.9	6.3	Susceptible
NERICA 8	16.5	7.8	8.7 (52.7)*	3	164.1	5.4	Susceptible
TGS25	12.5	11.4	1.1 (8.8)	2	119.8	2.9	Tolerant
TGS3	12.4	6.9	5.5 (44.5)*	2	190.7	7.3	Susceptible
WAB 56-104	18.5	15.8	2.7 (14.6)	2	121	3	Tolerant
WAB 638-1	13.1	9.1	4.0 (30.5)*	2	198.6	7.8	Susceptible

	8.9	6.5		16.3	2.8	
Values are means of 6 plants; same letters in a row indicate no significant difference using LSD at $P \leq 0.05$; Galling index on a scale of 1-5 with 1=no galls and 5=65-100% galling; Host status based on Resistant= $R \leq 1$, $GI \leq 2$, no significant yield loss; Tolerant: $R > 1$, $GI \leq 2$, no significant yield loss; Hyper-Susceptible: $R \leq 1$, $GI > 2$, significant yield loss; Susceptible: $R > 1$, $GI > 2$, significant yield loss; \dagger = significant yield difference						

Table 4: Yield, nematode damage and host resistance of the *O. sativa* × *O. barthii* progenies inoculated with *Meloidogyne incognita*.

The number of nematodes were in multiples of the initial inoculum, which is reflected in the reproductive factor (RF) that was more >2 in all genotypes except for the resistant check. The lowest range of RF was 2.8, 3.0, and 30 in *WAB 56-104*, *ART-16-A8*, and *ART-16-A7* respectively. The ability of the lines to permit multiplication of the nematodes indicates that they are good hosts of *M. incognita*. In a similar study by Adebayo and Salawu [21] and Afolami and Orisajo [22] galling index and reproductive factor were high showing sensitivity of the tested lines to *M. incognita*. Effective inoculation is reported to result in moderate to high galling severity and high multiplication of *Meloidogyne graminicola* in susceptible rice and wheat plants [14]. Except for the resistant check, none of the lines and cultivars tested were designated as resistant. Of the 32 cultivars that were compared to the resistant check, 22 were susceptible while 10 were tolerant. This is similar to the findings of Afolami and Orisajo [22] who identified five tolerant lines and 15 susceptible of the twenty lines evaluated. The status of *WAB 56-104* in this study is similar to the findings by De Waele et al. [20] where it was categorized as one of the less susceptible cultivars among those evaluated in their study. Tolerance is a good trait for the grower on the short term because the crop is able to produce yield that is not significantly lower compared to those not challenged with the nematode. In the long term however, such crops build up root-knot nematode populations in the soil to a point where the tolerance trait is unable to sustain and the plant becomes susceptible. In addition, such field will have a high nematode load in the soil such that production of any other crop that is susceptible becomes challenging. A preferable trait would be one in which the nematode populations are reduced rather than increased. The promising lines among the crosses are *ART 16A8* and *ART-16-A9*. The use of *WAB 56-105* can also be encouraged in areas with low nematode densities. These lines can also be used as parents for further breeding research for developing resistant lines.

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