Response of upland rice cultivars to *Meloidogyne* species

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Summary

Two screening tests and a field experiment were conducted with upland rice cultivars to identify sources of resistance to *Meloidogyne* species and to evaluate their susceptibility with or without fertilization. In the first test, 41 upland rice cultivars (21 *Oryza sativa* and 20 *O. glaberrima*) were screened. *O. sativa* cultivars were generally susceptible and *O. glaberrima* cultivars resistant. Such widely used *O. sativa* cultivars as IRAT 13 and Iguape Cateto were susceptible whereas IS 335 and IS 358 were fairly resistant. In the second test, seventeen cultivars (eight improved and nine traditionnal non improved) were screened. Most improved cultivars (IRAT 109, IRAT 112, IRAT 106 and IRAT 133) were highly tolerant whereas most traditionnal cultivars were susceptible. A penetration and development study showed that cultivars rated susceptible were more favorable for larval penetration, development into adult females and reproduction than resistant or tolerant ones. In the field experiment Iguape Cateto gave up to 435% yield increase over the control with DBCP treatment and fertilizer application. In the presence of high *M. javanica* populations however no fertilizer response was observed. Symptoms of *Meloidogyne* attack include root galls (mostly terminal) consecutive with stopped longitudinal growth (characteristic roots), reduced stand, reduced tillering and panicle numbers as well as reduced general top growth with or without chlorosis and yield decrease. The use of characteristic roots as damage index is discussed.

Résumé

Réponse de certains cultivars de riz pluvial à Meloidogyne *spp.*

Deux tests de criblage et un essai au champ ont été réalisés sur des cultivars de riz pluvial afin d'identifier d'éventuelles sources de résistance aux espèces de *Meloidogyne* et d'évaluer leurs dégâts au champ avec ou sans engrais. Dans le premier test, 41 cultivars de riz pluvial (21 d'*Oryza sativa* et 20 d'*O. glaberrima*) ont été examinés. Les cultivars d'*O. sativa* sont généralement sensibles et ceux d'*O. glaberrima* résistants. Des cultivars d'*O. sativa* communément utilisés comme IRAT 13 et Iguape Cateto sont sensibles tandis que IS 335 et IS 358 sont assez résistants. Dans le second test, 17 cultivars (8 améliorés et 9 traditionnels non améliorés) ont été examinés. La plupart des cultivars améliorés (IRAT 106, IRAT 109, IRAT 112 et IRAT 133) sont très tolérants alors que la plupart des cultivars traditionnels sont sensibles. Une étude de la pénétration et du développement montre que les cultivars sensibles sont plus favorables à la pénétration larvaire, au développement en femelles adultes et à la reproduction que les cultivars résistants. L'essai au champ donne une augmentation de rendement par rapport au témoin de 435% à la suite d'un traitement au DBCP et de l'apport d'engrais. Par contre, en présence de fortes populations de *M. javanica,* l'apport d'engrais n'améliore pas les rendements. Les attaques de *Meloidogyne* se caractérisent par des galles racinaires (généralement terminales) accompagnées d'un arrêt de la croissance longitudinale (racines caractéristiques), d'une réduction de la levée et du tallage ainsi que d'une réduction du rendement. L'utilisation des « racines caractéristiques » comme indice des dégâts est discutée.

The association of *Meloidogyne* with rice roots was observed in the Ivory Coast for the first time in 1960 (Luc & de Guiran, 1960). Fortuner (1981) has shown that this nematode, along with *Helicotylenchus*, is present in all the major upland rice producing areas of the country. Babatola (1980) also observed *Meloidogyne incognita* in all the upland rice producing regions of Southern Nigeria. The presence of *Meloidogyne* has been associated with tillering reduction, delayed maturation and yield reduction in many other countries (Chantanao, 1962; Ibrahim *et al.*, 1972; Sharma, 1981). Fortuner and Merny (1979) estimated that nematodes cause 20 to 30% yield reduction annually to rice production. Screening tests of upland rice cultivars for resistance to *Meloidogyne* spp. have recently been conducted in Nigeria (Babatola, 1980) and in Brazil (Sharma, 1981). In both cases, quite a few cultivars were found susceptible. Fortuner (1977) demonstrated in Senegal that *Hirschmanniella oryzae* causes less damage to irrigated rice in the presence of adequate fertilization. Diomandé (1981) obtained about the same result in the Ivory Coast, using *M. incognita* on IRAT 13 in microplots. The present work was undertaken to evaluate the resistance or tolerance of few rice cultivars and to assess *Meloidogyne* damage under field conditions with or without fertilization.

Materials and methods

Screening upland rice cultivars for resistance to *Meloidogyne incognita*

In order to compare the reactions of different types of rice cultivars, two screening tests and one penetration test were conducted.

— *Oryza sativa vs O. glaberrima :* 41 upland rice cultivars (21 of *O. sativa* and 20 of *O. glaberrima*) were tested. Equal numbers of *M. incognita* larvae from three different populations (one from Northern Ivory Coast, one from the Center and one from Southern Ivory Coast) were mixed and used as inoculum. PVC tubes (3 cm diameter by 28 cm high) were filled with oven-sterilized field soil up to 25 cm leaving 3 cm for watering the tubes. These tubes were pushed down into wet sand in the greenhouse at about 25°. Five day germinated seeds were transplanted singly into the tubes with twenty replications per cultivar. 1 050 larvae of the above described inoculum were inoculated to each tube five days after transplanting. Thirty and sixty days after inoculation, ten tubes for each cultivar were pulled out of the sand and the plants extracted. Characteristic roots (short roots with variously shaped swollen tips) were counted for each tube. Roots from the ten replicates of a given cultivar were combined and put in the mist chamber for root nematode extraction. Likewise, the soil from the ten replicates of a given cultivar was collected in a bucket containing four liters of water. An aliquot of one liter was used to extract soil nematodes in the elutriator.

— *Improved vs traditional O. sativa cultivars :* Seventeen cultivars (eight improved and nine traditional non improved) were tested using the same experimental procedure as above. Seeds were obtained from the Laboratory of Genetics at ORSTOM Adiopodoumé for the traditional cultivars and from IDESSA/DCV at Bouaké for the others.

— *Penetration and subsequent development of juveniles in rice roots :* Three resistant cultivars (OG 008, CG 11 and CG 18), two tolerant cultivars (IRAT 109 and IRAT 112) and three susceptible cultivars (IS 173, Z9-9B and Z15-6A) were used in this test. Seeds were germinated in moist chamber and transplanted five days later singly in small vials half-filled (5 ml) with sterile soil ; 40 vials were used per cultivar, twenty for the penetration study and twenty for the development study ; 50 larvae were inoculated to each vial in 0.5 ml water 24 hours after transplanting. Four days later, plants were removed from the vials and their roots washed up. For the penetration study, the roots of 20 plants were stained with lactophenol-cotton blue as described by Cadet and Merny (1976). Such stained roots were spread between two pieces of glass and stained penetrated nematodes in the roots could easily be counted on the dissecting microscope. For the development study, the remaining twenty plants were transplanted to hydroponic solution. Males and eventual larvae exited from roots were counted weekly when the nutrient solution is being renewed. After four weeks, roots were stained with acid fuchsin, blended for five, ten and twenty seconds successively, releasing the colored young and adult females, which were counted. (Cadet & Merny, 1976).

Damage to susceptible and resistant cultivars under field conditions with and without fertilization

The test was set up on the ORSTOM farm in an area previously covered with *Pueraria phaseoloides*, a good host for *Meloidogyne* species ; the area was quite uniformly infested with *M. javanica.* Each of six blocs (24 × 9 m) separated by 1 m band was divided into eight plots (9 × 3 m). A 2^3 factorial experiment with six randomized complete blocks was set up to study simultaneously the main effects of rice cultivars, DBCP application, fertilization as well as their eventual interactions. Rice cultivars used were Iguape Cateto and CG 11 and the resulting 8 treatments were as follow :

S : Iguape Cateto (*O. sativa* cultivar) ; no DBCP ; no fertilizer.

SF : Iguape Cateto ; no DBCP ; with fertilizer (200 kg/ha NPK 10-18-18 at seeding followed by 50 kg/ha urea at tillering and panicle initiation).

ST : Iguape Cateto treated (DBCP at 60 l/ha applied with hand applicator, two weeks before seeding) ; no fertilizer.

STF : Iguape Cateto ; treated ; with fertilizer.

G : CG 11 (*O. glaberrima* cultivar) ; no DBCP, no fertilizer.

GF : CG 11 ; not treated ; with fertilizer.

GT : CG 11 ; treated ; no fertilizer.

GTF : CG 11 ; treated ; with fertilizer.

Ten rows per plot were directly sown with a 30 cm spacing between rows and between plants within rows. Weeding, fungicide (2 kg/ha kasumin — 2% Kasugamycin a.i. —) and insecticide (5 l/ha curacron — a.i. 500 g of profenophos) were applied every fifteen days before panicle initiation. Only three blocks were covered with a net against birds. Plots were sampled right before nematicide application, on sowing day and once every fifteen days thereafter. Samples consist of soil (randomly taken in fifteen points within each plot) and roots (from four plants at random) from which nematodes were extracted with Seinhorst's elutriator and mistifier respectively. The following observations were made : Weekly tiller count during the tillering period, panicle count every three or four days during the panicle emergence period. Yield was obtained only from the two middle rows of the three covered blocks on Iguape Cateto. CG 11 had produced no satisfactory yield by the end of the test. At the end of the experiment, four plants were randomly pulled per plot using a hoe and their characteristic roots counted.

Results

Screening

The *O. glaberrima* cultivars tested are all highly resistant to *M. incognita* (low numbers of characteristic roots and low nematode final populations). The *O. sativa* cultivars are susceptible to a varying degree (Tab. 1). IS 358 and IS 335 seem fairly resistant whereas such commonly used cultivars as IRAT 13 and Iguape Cateto are susceptible. IRAT 106, IRAT 109, IRAT 112 and IRAT 133 are tolerant and all the traditional cultivars tested are susceptible (Tab. 2). Correlation between nematode

Table 1

Final populations of *Meloidogyne incognita* and numbers of characteristic roots on *Oryza glaberrima* and *O. sativa* cultivars of upland rice in 60 days

O. glaberrima *cultivars*	*Nematode population (J2/g of root)*	*Characteristic roots (per plant)*	O. sativa *cultivars*	*Nematode population (J2/g of root)*	*Characteristic roots (per plant)*
OG 008	0	0	IS 358	703	1.3
CG 74	62	0.3	IS 335	783	1.4
CG 67	114	0.3	IS 337	1 053	1.6
MG 007	134	0.3	IS 300	1 858	1.6
CA V6	156	0.3	IS 328	1 757	1.6
LG 009	489	0.3	IS 276	1 800	1.8
MG 021	511	0.3	IS 340	2 386	1.8
OG 15	568	0.3	IS 302	2 619	2.0
LG 061	293	0.4	IS 289	3 712	2.4
CG 11	60	0.5	Moroberekan	1 614	2.5
DG 15	1 109	0.5	IS 168	4 812	3.2
CG 84	1 930	0.5	IS 338	2 102	3.3
TO 580	77	0.6	IS 126	4 700	3.3
CG 18	305	0.6	IS 220	5 357	4.2
CG 24	464	0.6	IS 254	3 954	5.0
LG 052	138	0.7	IRAT 13	6 607	5.4
CG 45	247	0.7	IS 251	4 309	5.9
OG 1	347	0.8	Iguape Cateto	6 840	6.3
MG 029	844	0.9	ACC 10-18-55	12 647	6.9
CG 13	981	1.0	IS 283	9 055	7.4
			IS 173	14 372	11.8
Means	441.45	0.5		4 421	3.8

Table 2

Results of the screening experiment of traditional and improved upland rice cultivars for *Meloidogyne* resistance

Rice cultivars	*Nematode populations (per dm³ of soil)*	*(per g of root)*	*Number of characteristic roots per plant*	*Characteristic root index*
Improved cultivars				
IRAT 109	6 700	1 650	0.7	0.3
IRAT 112	6 300	3 857	1.2	0.7
IRAT 133	8 600	3 313	1.7	0.8
IRAT 106	3 000	1 407	1.8	0.8
IRAT 132	4 100	6 668	3.2	3.5
IRAT 105	2 100	1 076	4.2	3.8
IRAT 144	16 000	7 576	4.9	4.1
IRAT 13	8 800	5 901	5.3	4.5
Traditional cultivars				
CG-18	1 500	756	1.0	0.3
Z1-6A	7 100	12 320	3.5	3.5
Z5-9A	3 000	1 826	4.3	3.7
Z16-4A	3 500	9 251	5.3	4.6
Dourado Precoce	8 100	12 780	5.4	4.5
Z6-5A	2 800	3 226	5.6	4.8
Z2-5A	3 200	7 322	7.4	5.7
Z9-9B	24 800	12 230	7.8	6.2
Z15-6A	11 700	13 809	11.4	6.8

Table 3

Penetration, development and reproduction of *Meloidogyne incognita* in the roots of selected upland rice cultivars

Rice cultivars	% (1) *penetration* (1)	% (2) *males*	% (2) *females*	*Mean number of 2nd generation juveniles per plant*
Resistant				
OG 008	10.1	2.1	0	—
CG 11	16.3	3.0	4.3	—
CG 18	16.1	15.5	22.4	1.5
Tolerant				
IRAT 109	22.7	13.4	47.1	5.9
IRAT 112	15.9	15.1	47.8	3.9
Susceptible				
IS 173	23.3	3.0	70.4	—
Z9-9B	34.8	10.1	60.3	18.5
Z15-6A	29.2	3.7	96.5	92.6

— = not recorded. (1) average percentage of the 50 juveniles initially inoculated. (2) average percentage of the penetrated juveniles.

final populations and numbers of characteristic roots is highly significant for the *O. sativa* cultivars ($r = 0.92^{**}$) and not significant for the *O. glaberrima* cultivars ($r = 0.34$). Macroscopic symptoms observed include root galls (mostly terminal with various shapes : subspherical, hook, spiral) frequently bearing fibrous roots. In most cases, root longitudinal growth is stopped, making characteristic roots generally shorter than normal ones (Fig. 1 VS). Occasionally, galls are not terminal and infected roots are large and distorted. Penetration, development into adult females and reproduction are favored on susceptible and tolerant cultivars and inhibited on resistant ones (Tab. 3). However, tolerant cultivars exhibit fairly low damage (characteristic roots).

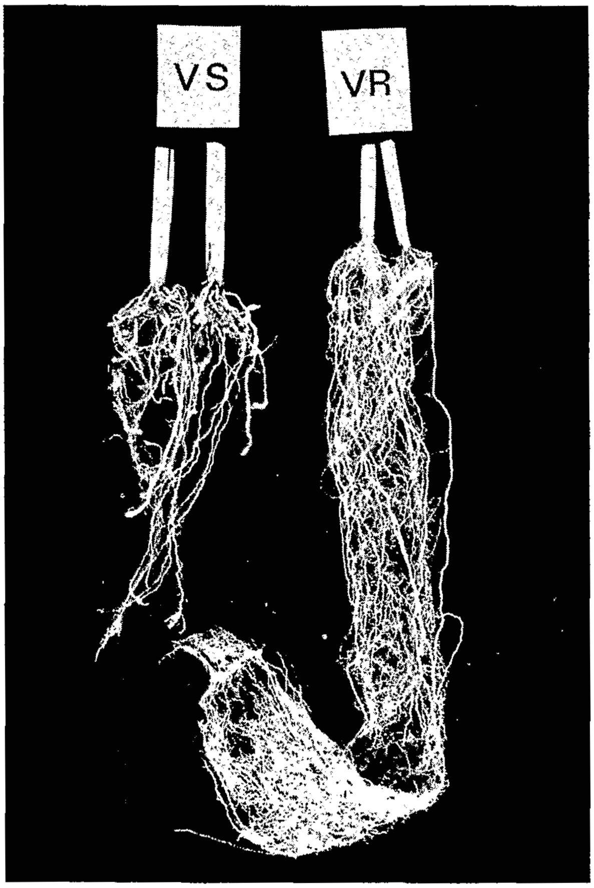

Fig. 1. Symptoms of *Meloidogyne incognita* attack on susceptible (VS) and tolerant (VR) rice cultivars. (Note the absence of characteristic roots and the size of the root system of VR).

Damage under field conditions

The two rice cultivars used give good response to DBCP treatment (Fig. 2 and Tab. 4). CG 11 produces a significantly higher number of tillers than Iguape Cateto. With CG 11, the tillering response to fertilization is apparent in the presence of DBCP treatment (GTF *vs* GT) as well as in its absence (GF VS G). The fertilizer response of Iguape Cateto is apparent only in the presence of DBCP treatment (ST *vs* STF compared to S *vs* SF). Fertilization seems to favor characteristic root formation (Tab. 4).

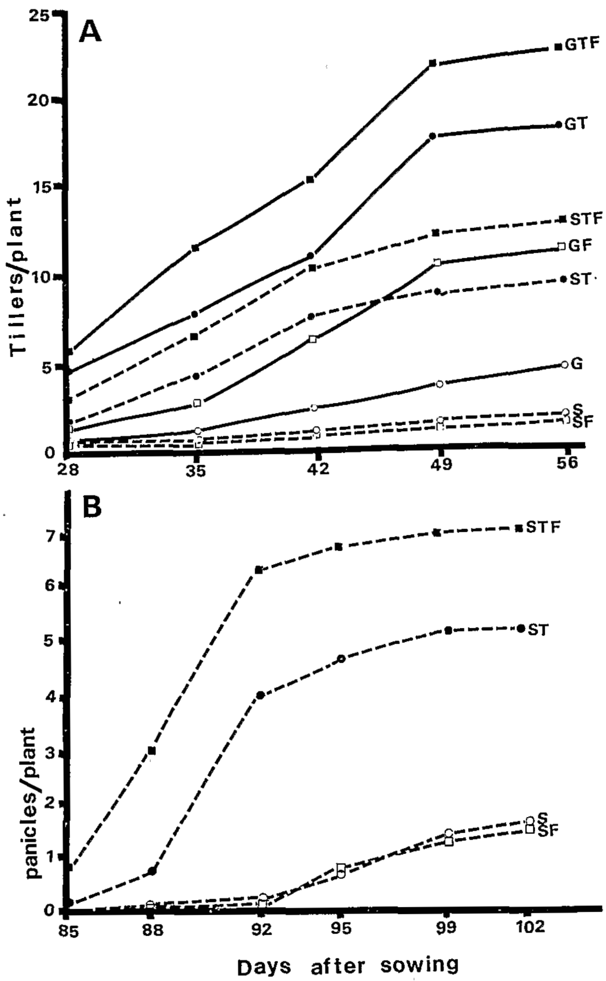

Fig. 2. Effects of fertilization and *Meloidogyne javanica* on the tillering (A) and panicle emergence (B) of two upland rice cultivars (CG 11 and Iguape Cateto). (See text for treatment legends).

Table 4

Comparative effects of fertilization and DBCP treatment on som characteristics of Iguape Cateto (Susceptible cv.) and CG 11 (resistant cv.). (See text for treatment legends)

Treatments	*Tillers/plant*	*Characteristic root (per plant)*	*Nematode population*		*Panicles/plant*	*Yield* (1) *(kg/ha)*	*Yield* (2) *percentage*
			(J2/l of soil)	*(J2/g of root)*			
Iguape Cateto							
S	1.8 g	7.7	11 064	10 063	1.54 jk	620 np	100
SF	1.9 fg	19.5	15 180	7 466	1.53 k	610 p	98
ST	9.3 d	1.0	49	209	5.17 i	2 100 m	338
STF	12.5 c	2.1	68	1 180	7.18 h	2 700 l	435
CG 11							
G	4.5 e	0.5	498	1 418	—	—	—
GEF	11.2 cd	0.3	1 456	1 132	—	—	—
GT	17.7 b	0	6	187	—	—	—
GTF	22.2 a	0	68	388	—	—	—

(1) Mean yield obtained from three replications covered with antibird net. (2) The yield obtained without fertilization and DBCP treatment is taken as 100. — Data not obtained with CG 11.

(Numbers followed by different letters are significantly different at the 5 % level (Ducan's multiple range test).

The beneficial effect of DBCP treatment alone is higher than that of fertilization alone (P = 0.01). With all measured characters, the best results are obtained with the combination of DBCP treatment and fertilization on both cultivars. If one considers the situation without nematicide or fertilizer (S) as control (100%) one gets 98% of the control with SF, 338% with ST and 435% with STF. *M. javanica* final populations are higher with SF or S than with any other treatment (Tab. 4).

Discussion

Meloidogyne spp. represent a potential danger for upland rice production in the Ivory Coast since this nematode is wide-spread (Fortuner, 1980). Whenever the nematode populations are high enough and rice cultivars susceptible, yield loss may be substantial as indicated by our results. Cultivars of Asian origin *(O. sativa)* are more widely used in upland rice production than cultivars from West African origin *(O. glaberrima)* mostly because yield potential of the former is higher. However, *O. glaberrima* cultivars do have some interesting characters. In the present study, they happen to be all resistant to *Meloidogyne incognita*. It seems that root morphology plays a significant rôle in this resistance. Indeed, the fine root system of *O. glaberrima* cultivars do not seem to favor larval penetration or development. IRAT 109 is one of the higher yielding most promising new cultivars released by the rice breeding team at Bouaké. The tolerance of this rice variety to *Meloidogyne* spp. is one more interesting trait.

During the larval count for the penetration study, it was apparent that infection mostly takes place at the tips of larger roots. In most cases, more than one larva were observed in the same tip. By desorganizing the apical meristem with giant cell formation, the nematode may stop root elongation, leading to characteristic root formation. Babatola (1980) and Ibrahim *et al.* (1973) also observed tip infection in their studies. Most symptoms described here are similar to those observed by these authors. It seems therefore that root tip infection is the most frequent ; since such infection swells the root tip and stops downward growth in most cases, the term characteristic root seems appropriate to designate roots so affected. Usual root knot index is difficult to use with this type of symptoms. To comply with the 0-9 general scale adopted in the standard Evaluation System of the International Rice Testing Program (1975) we suggest to take into account only the percentage of visibly affected large roots (characteristic roots index) in order to rate knotted rice roots as follow :

0 — no characteristic root
1 — less than 5% characteristic roots
3 — 6 to 25%
5 — 26 to 50%
7 — 51 to 75%
9 — 76 to 100%.

Fertilization normally improves plant root system making it capable to sustain both the nematode and the plant without much damage to the latter (Wallace, 1973). In the present study however no response to fertilization was obtained in the presence of *M. javanica* on the susceptible cultivar ; in the presence of high populations of *Meloidogyne* species, susceptible rice cultivars are unable to take advantage of fertilizers since their roots have no chance to grow deep enough. It seems that fertilization does not always compensate nematode damage on rice as previously reported (Fortuner, 1977 ; Diomandé, 1981 *a*, *b*, *c*). Nematode population level and the degree of susceptibility of the rice cultivar to the nematode are apparently important factors in determining the type of response obtained. The *Pueraria phaseoloides* cover preceding this experiment gave a high soil nematode density for this study. DBCP treatment as used in this study (60 l/ha), does not seem economically profitable in upland rice production. Economically feasible and profitable control measures must be investigated.

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