AGRONOMIC PERFORMANCE OF SELECTED SWEET POTATO CULTIVARS UNDER GREENHOUSE AND FIELD INFESTED WITH *MELOIDOGYNE INCOGNITA* AND SOILBORNE INSECT PESTS

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ABSTRACT

Lima, F. S. O., G. R. Santos, V. R. Correa, P. R. R. Santos, M. A. R. Correia, and S. R. Nogueira. 2016. Agronomic performance of selected sweet potato cultivars under greenhouse and field infested with *Meloidogyne incognita* and soilborne insect pests. Nematropica 46:97-105.

The root knot nematode (RKN), *Meloidogyne incognita*, is widespread worldwide and a major pathogen of several cultivated crops. The use of resistant genotypes is the most effective and environmentally sound way to manage RKN. In this study, we screened 16 selected sweet potato cultivars including Amanda, Bárbara, Beatriz, Beauregard, Brazlândia Branca, Brazlândia Rosada, Brazlândia Roxa, BRS Amélia, BRS Cuia, BRS Rubissol, Carolina Vitória, Duda, Júlia, Marcela, PA-26/2009, and Princesa obtained from Embrapa and Universidade Federal do Tocantins' germplasm bank. Studies were conducted under greenhouse and field conditions and the agronomic performance of the cultivars was evaluated in a nematode and soilborne insect-infested field. All 16 sweet potato cultivars tested were rated as resistant to this nematode both under greenhouse and field conditions with reproduction factors < 1. In the field infested with *M. incognita*, sweet potato cultivars Duda, BRS Amélia, Beauregard, Brazlândia Rosada, and Brazlândia Roxa stood out as superior cultivars, with average yield ranging from 26 to 47 tons per ha. Overall, most cultivars exhibited a fusiform to near fusiform root shape, a good characteristic for the market, and were moderately affected by insects (attack incidence 1 to 30%). As global demand for energy continues to rise, selecting new cultivars of sweet potatoes with increased resistance to nematode diseases and with high yield will be important for food security and biofuel production.

Key words: biofuel, *Ipomoea batatas*, resistance, root knot nematodes, yield.

RESUMO

Lima, F. S. O., G. R. Santos, V. R. Correa, P. R. R. Santos, M. A. R. Correia, e S. R. Nogueira. 2016. Desempenho agronômico de cultivares de batata-doce em casa de vegetação e em área infestada com *Meloidogyne incognita* e insetos de solo. Nematropica 46:97-105.

O nematoide das galhas, *Meloidogyne incognita*, se encontra amplamente distribuído e é um importante patógeno de várias culturas. O uso de cultivares resistentes é a forma mais eficaz e ambientalmente segura para o manejo de nematoides. Neste estudo foram avaliadas dezesseis cultivares de batata-doce, incluindo Amanda, Bárbara, Beatriz, Beauregard, Brazlândia Branca, Brazlândia Rosada, Brazlândia Roxa, BRS Amélia, BRS Cuia, BRS Rubissol, Carolina Vitória, Duda, Júlia, Marcela, PA-26/2009, e Princesa, provenientes do banco de germoplasma da Embrapa Hortaliça e da Universidade Federal do Tocantins. Os experimentos foram conduzidos em casa de vegetação e a campo com o objetivo de avaliar o desempenho agronômico das cultivares em área infestada com insetos de solo e o nematoide *M. incognita*. No geral, todas as dezesseis cultivares testadas foram classificadas como resistentes a *M. incognita* em casa de vegetação e a campo com fator de reprodução <1. Em área de campo naturalmente infestada por *M. incognita*, as cultivares Duda, BRS Amélia, Beauregard, Brazlândia Rosada e Brazlândia Roxa se destacaram como cultivares superiores, com rendimento médio variando de 26 a 47 toneladas por hectare. No geral, a maioria das cultivares apresentou moderada incidência de ataque por insetos (1 to 30%), além da maioria ter apresentado o formato fusiforme, uma característica ideal de mercado. Como a demanda global por energia continua a aumentar, a seleção de novas cultivares de batata-doce resistentes a nematoides e com alto rendimento são importantes para a segurança alimentar e para a produção de biocombustíveis.

Palavras chaves: biocombustível, *Ipomoea batatas*, nematoides das galhas, produtividade, resistência.

INTRODUCTION

As global demand for energy continues to rise, the popularity of biofuel production has increased in recent years as an alternative fuel supply. Cultivated crops such as corn, sugarcane, beets, and sweet potatoes that contain fermentable carbohydrates offer a potential source of ethanol that can be used as a biofuel. Sweet potato [*Ipomoea batatas* (L.) Lam.] is a cultivated crop with desirable characteristics for both human consumption and for production of ethanol. Lately, sweet potato has been included in several agro-energy programs with the objective to diversify alternative sources of biomass for renewable energy production (Araújo *et al.*, 1978; Carvalho and Sato, 2001; Silveira, 2002; Magalhães, 2007).

Sweet potato is native to Central and South America, and is grown in tropical and subtropical regions worldwide. The starchy, sweet-tasting content makes this tuberous crop popular worldwide. Sweet potato is particularly important as a main food crop for low income communities in many Asian and African regions (Erpen *et al.*, 2013).

Brazil is the nineteenth largest sweet potato producer in the world. In the last decade Brazil has produced around 500 thousand tons per year, within an area of about 40 to 46 thousand ha (Anuário Brasileiro de Hortaliças, 2013). Data from the 2013 cropping year listed sweet potato in the 8th place of exported vegetables by Brazil, rendering a gross income of US $2.2 million (Anuário Brasileiro de Hortaliças, 2013).

Due to its robustness and wide adaptation to soil types and climate conditions, sweet potato can be cultivated in most tropical and subtropical regions worldwide. It is mainly cultivated in the south, southeast, and northeast regions of Brazil. The top average yield per hectare is reported in the southeast and west regions, with 15.8 and 28 tons per hectare, respectively (IBGE, 2012). Despite its robustness and the relatively low production cost, the national average yield is estimated at 12.19 tons per hectare, a level that is considered low, likely due to planting of older, susceptible cultivars and poor crop management practices (Silva *et al.*, 2004; Gomes *et al.*, 2015).

Other agronomic challenges associated with sweet potato cropping include pests and diseases. Nematode diseases can be a factor limiting production due to direct yield losses as well as poor quality of the storage roots, which leads to low market value. Several nematode species are associated with sweet potato diseases, including root-knot nematodes, *Meloidogyne* spp., (RKN) and reniform nematodes (*Rotylenchulus* spp.). Among these, *M. incognita* (Kofoid and White) Chitwood, 1949, *M. javanica* (Treub) Chitwood, 1949, and *M. arenaria* (Neal) Chitwood, 1949 are particularly important pathogens of sweet potato (Sasser, 1980; Clark and Moyer, 1988; Massaroto *et al.*, 2010; Pinheiro *et al.*, 2012). *Meloidogyne incognita* affects water and nutrient uptake, resulting in poor growth and low yield (Massaroto *et al.*, 2010; Pinheiro *et al.*, 2012). In some cultivars, symptoms associated with RKN include the formation of spindle-shaped swellings (galls, generally with egg masses) in secondary roots, which are almost unnoticeable by the unaided eye, or they do not form eggs masses at all (Charchar *et al.*, 1991). However, some cultivars are very susceptible to *Meloidogyne* spp. and may exhibit severe symptoms of galling where root defects, such as roughness and cracks on fleshy roots, result in overall low yield, poor quality, and associated secondary infections with bacterial and fungal pathogens (Lawrence *et al.*, 1986; Clark and Moyer, 1988; Charchar *et al.*, 1991; Massaroto et al, 2010; Pinheiro *et al.*, 2012).

Under tropical weather conditions, RKN, including *M. incognita*, can complete 4-5 generations during a single sweet potato growing season, reaching the population density threshold limit of economic damage in a relatively short time frame (Charchar *et al.*, 1991). Thus, it is important to search for new and effective ways to control nematode infection in the field. The most efficient and environmentally safe way to manage nematode infection includes the use of resistant varieties, which helps control the disease and maintain crop yield, while decreasing nematode population densities in the soil for subsequent crops (Davis and Kemerait, 2009; Silva *et al.*, 2014).

Several studies have reported root-knot nematode resistance in sweet potato clones and cultivars in Brazil and other regions (Huang *et al.*, 1986; Lawrence *et al.*, 1986; Maluf *et al.*, 1996; Peixoto et al, 1998; Freitas *et al.*, 2001; Cervantes-

Flores *et al*., 2002; Wanderley and Santos, 2004; Charchar and Ritschel, 2004; Cervantes-Flores, *et al*., 2008; Massaroto, 2008; Massaroto *et al*., 2010; Chaves *et al*., 2013; Kalkmann *et al*., 2013; Gomes *et al*., 2015). Nonetheless, a vast number of promising genotypes remain to be tested for resistance and agronomic performance, especially under warmer temperatures.

The objectives of this study were to evaluate the resistance of 16 selected sweet potato cultivars against *M. incognita* under greenhouse and field conditions and to assess the agronomic performance of these cultivars in a field naturally infested with *M. incognita* and soil-borne insect pests.

MATERIALS AND METHODS

Plant genotypes

Sixteen sweet potato cultivars were obtained from Embrapa Hortaliças and Universidade Federal do Tocantins (UFT) germoplasm banks for this study. The commercial tomato cv. Santa Clara (*Solanum lycopersicum* L.) was used as a nematode-susceptible control.

Nematode inoculation

A population of *M. incognita* (Est I1 Rm: 1.0) collected in sweet potato fields (Palmas, Tocantins State) was used for the inoculation experiments. Identification of the species was done using esterase (Est) phenotype (Carneiro and Almeida, 2001). Prior to inoculation, this population was multiplied on tomato plants (cv. Santa Clara) for 3 mo under greenhouse conditions. Eggs were extracted from infected roots according to Hussey and Barker (1973), using 0.5% NaOCl, blended for 2 min instead of manual agitation. Eggs were recovered under 400-mesh screen and nematodes counted under a light microscope using Peter´s slides (Boneti and Ferraz, 1981).

Nematode resistance under greenhouse conditions

Plants of each cultivar were grown in 3-L pots filled with a mixture of autoclaved sandy-clay red latosol, pH 6.0 and commercial compost (1:1 v/v). Rooted sprouts of about 20 cm were inoculated with 5 mL nematode suspension containing 1,000 eggs + second-stage juveniles (J2) of *M. incognita* by injecting the nematode suspension with a syringe below ground in four places around the base of the stem. Plants were arranged in a completely randomized design with 17 treatments (16 sweet potato cultivars and a susceptible tomato cv. Santa Clara) and five replicates (Table 1). Plants were maintained in the greenhouse at 25 to 30°C, and were watered and fertilized as needed. Sixty days after inoculation, the root system of each plant was removed from the pot and washed under tap water to remove the soil mixture. Nematode eggs were extracted from the entire root system as described above for inoculum. The total number of eggs per plant was quantified under a light microscope using Peter´s slides. Host suitability of the plants to *M. incognita* was described using a reproduction factor (RF), calculated as RF = final nematode population density level/initial population in inoculum (Pi = 1,000). The average RF was submitted to analysis of variance, and the means were separated using the Tukey´s test ($P < 0.05$). Cultivars for which RF ≥ 1 were considered to be susceptible (S) and RF < 1 were considered to be resistant (R) (Sasser *et al*., 1984). Half of the cultivars were assessed in 2012 and half in 2013.

Nematode resistance under field conditions

Two field experiments were carried out in 2012 and 2013 to evaluate the agronomic traits of the sweet potato cultivars (nematode resistance, yield, root shape, and insect damage) in a field that was naturally infested with *M. incognita* and soil-borne insect pests that was located at the experimental station of Faculdade Católica-Palmas, Tocantins state (48º16'34 "W and 10º32'45" S). The sites were characterized by hot semi-humid climate, annual average rainfall of 1,500 mm and average temperature of 27.5°C (Inmet, 2014). Soil chemical characteristics were: field 1: sandy loam texture (sand: 75%, clay: 20%, silt: 5%), pH = 5.7, phosphorus = 5 mg/dm^3, potassium = 91 mg/dm^3, organic matter = 17 g/dm^3, aluminum = 0.3 cmolc/dm^3, calcium = 4.1 cmolc/dm^3, magnesium= 1.9 cmolc/dm^3, hydrogen+aluminum = 1.5 cmolc/dm^3, cation exchange capacity = 7.73, base saturation = 80.6; field 2 - sandy loam texture (sand: 74.36%, clay: 19%, silt: 6.64%), pH 6.1, phosphorus = 118.8 mg/dm^3, potassium = 62 mg/dm^3, organic matter = 20.8 g/dm^3, aluminum = 0.1 cmolc/dm^3, calcium = 4.4 cmolc/dm^3, magnesium = 1.0 cmolc/dm^3, hydrogen + aluminum = 0.33 cmolc/dm^3, cation exchange capacity = 5.89, base saturation = 94.4.

The 2012 study was conducted in an area naturally infested with *M. incognita* and soilborne insect pests (sweet potato weevil, *Euscepes postfasciatus* (Fairmaire, 1849) and rootworms (*Diabrotica* sp.). Prior to planting sweet potato cultivars, the susceptible tomato cultivar Santa Clara had been grown in each plot for 3 mo. Prior to planting sweet potato, soil and tomato root samples (200 cm^3 soil and 10 g roots) infested with *Meloidogyne* spp. were collected from each plot. Nematodes were extracted from root samples as described above for inoculum. Nematodes were extracted from soil using the flotation, sedimentation, and centrifugation methods (Jenkins, 1964). The *Meloidogyne* species present on infected plants was identified from root samples using esterase (Est) phenotyping as described above (Carneiro and Almeida, 2001). The nematode population density present in each sample was estimated by counting the number of nematodes extracted from the roots and the nematodes in the soil under a light microscopy using Peter's slides. All plots were infested with *M. incognita* (Est I1 Rm: 1.0) and the initial population density level (*Pi*) was estimated at approximately 2,000 eggs + J2. To ensure that *M. incognita* was present throughout all plots, 20 d after planting sweet potato cultivars, each plant was inoculated with 5 mL nematode suspension containing 1,000 eggs + J2 of *M. incognita* by injecting the nematode suspension with a syringe below ground in four places around the base of the stem.

The soil in this site was initially prepared with plowing, harrowing, and building up of planting beds (0.4 m wide x 1.25 m length x 0.3 m height). Soil was amended with fertilizer according to chemical analysis of soil and the local technical recommendation, with the following amounts of nutrients 40 kg/ha nitrogen, 120 kg/ha phosphorous, 70 kg/ha potassium, and 1 kg/ha boron. Plants were irrigated as needed.

Sweet potato cultivars that were studied included Amanda, Bárbara, Beatriz, Carolina Vitória, Duda, Júlia, Marcela, PA-26/2009, Princesa, and the susceptible control tomato cv. Santa Clara (Table 2). Plants were arranged in a completely randomized design with 10 treatments (sweet potato cultivars plus a control) and four replicates. Each plot was comprised of four lanes and each lane was planted with five plants (with row spacing 0.8 m wide x 0.25 m length). The ten plants located in the two central lanes were used for data collection. Six months after inoculation, the root systems of three plants collected in the two central rows of each plot were sampled

Table 1. Reproduction of *Meloidogyne incognita* on sweet potato cultivars under controlled conditions, 2012 and 2013.

Year	Cultivar	Eggs + J2[x]	RF[y]	Reaction[z]
2012	Amanda	314 ± 115.94	0.31 b	R
	Bárbara	74 ± 18.52	0.07 b	R
	Beatriz	200 ± 15.85	0.20 b	R
	Carolina Vitória	237 ± 126.22	0.24 b	R
	Duda	184 ± 93.55	0.18 b	R
	Júlia	127 ± 36.87	0.13 b	R
	Marcela	215 ± 69.34	0.22 b	R
	PA-26/2009	297 ± 18.74	0.30 b	R
	Princesa	231 ± 77.80	0.23 b	R
	Tomato – control	13,500 ± 850.6	13.50 a	S
2013	Beauregard	278 ± 86.34	0.28 b	R
	Brazlândia Branca	376 ± 36.27	0.35 b	R
	Brazlândia Rosada	197 ± 43.35	0.20 b	R
	Brazlândia Roxa	240 ± 24.25	0.24 b	R
	BRS Amélia	356 ± 36.27	0.35 b	R
	BRS Cuia	280 ± 43.35	0.28 b	R
	BRS Rubissol	348 ± 38.36	0.35 b	R
	Tomato – control	16,300 ± 520.6	16.30 a	S

[x]Mean values (n = 5) ± standard error of number of eggs + J2 per root system.
[y]Reproduction factor (RF = final population/1,000 eggs + J2 of *M. incognita*); means followed by different letters are significantly different according to Tukey's test ($P < 0.05$).
[z]Reaction of inoculated plants; RF ≥ 1 = susceptible (S); RF < 1 = Resistant (R) (Sasser *et al.*, 1984).

for nematode infection. Roots were washed under tap water and nematode eggs in egg masses were extracted using 1% NaOCl as described previously. Total number of eggs per plant was quantified under a light microscope using Peter´s slides. The average number of eggs was calculated for each plot. Since the initial population in the field (*Pi*) was only estimated, we did not calculate the RF in the field experiment.

Additional agronomic traits analyzed included yield ─ fresh weight of roots in tons per ha ─ and insect damage (galleries and holes on the roots), caused mainly by the sweet potato weevil and *Diabrotica* sp. Insect pest identification was carried out according to (Zucchi *et al.*, 1993). Insect damage was based on a 1-5 scale where 1 = roots with 0% damage, 2 = roots with 1-10% damage, 3 = roots with 11-30% damage, 4 = roots with > 50% damage, of questionable commercial value, and 5 = roots with 100% damage, without commercial value (França *et al.*, 1983). Root shape was also evaluated based on a 1-5 scale where 1 = regular fusiform shape without any cracks, 2 = marketable with some undesirable characteristics such as the presence of galleries and lack of uniformity in root shape, 3 = irregular root shape with galleries present, 4 = very large roots, with galleries and cracks, low market value, 5 = roots completely irregular, deformed, with cracks, without commercial use (Massaroto, 2008). The average number of *Meloidogyne* eggs, potato yield, insect damage ratings, and root shape were analyzed by analysis of variance and the means separated using the Tukey's test ($P < 0.05$).

The trial conducted in 2013 was located in the same experimental area and included the sweet potato cultivars Beauregard, Brazlândia Branca, Brazlândia Rosada, Brazlândia Roxa, BRS Amélia, BRS Cuia BRS, Rubissol, and the susceptible control tomato cv. Santa Cruz (Table 2). The experimental procedures and parameters analyzed were the same as described for the experiment in 2012.

Table 2. Reproduction of *Meloidogyne incognita* on sweet potato cultivars under field conditions, years 2012 and 2013.

Year	Cultivar	Eggs+J2[z]
2012	Amanda	15 ± 7.95
	Bárbara	13 ± 8.89
	Beatriz	0 ± 0
	Carolina Vitória	132 ± 91.76
	Duda	208 ± 142.03
	Júlia	13.56 ± 9.38
	Marcela	2.93 ± 2.62
	PA-26/2009	215 ± 162.50
	Princesa	18 ± 3.30
	Tomato – control	32,800 ± 720.2
2013	Beauregard	20.8 ± 0.92
	Brazlândia Branca	14.4 ± 0.21
	Brazlândia Rosada	10.5 ± 1.92
	Brazlândia Roxa	10.4 ± 3.19
	BRS Amélia	4.1 ± 1.48
	BRS Cuia	22.6 ± 6.18
	BRS Rubissol	30.1 ± 1.79
	Tomato – control	15,800 ± 420.1

[z]Mean values (n = 5) ± standard error of number of eggs + J2 per root system.

RESULTS AND DISCUSSION

The RF values from all 16 sweet potato cultivars inoculated with *M. incognita* under greenhouse conditions indicated they were resistant to this nematode (RF < 1) (Table 1). Similarly, when these cultivars were cultivated under a field naturally infested with *M. incognita*, they did not support nematode reproduction as compared to the control and were considered resistant under field conditions (Table 2).

All 16 sweet potato cultivars behaved as resistant to *M. incognita* both under greenhouse and field conditions. We did not observe any galls in the sweet potato root systems (including both tuberous and secondary roots). Our results are similar to other studies that reported the sweet potato cultivars Bárbara, Marcela, Brazlândia Roxa, Brazlândia Branca, and Princesa as resistant to *M. incognita* (Freitas *et al.*, 2001; Charchar and Ritschel, 2004; Massaroto, 2008; Chaves *et al.*, 2013; Kalkmann *et al.*, 2013). Our results differ from those of Chaves *et al.* (2013), who tested sweet potato genotypes under a slightly lower average temperature (ca. 26°C) and found that the cultivars Amanda and Duda were moderately resistant to *M. incognita* race 2, and Massaroto (2008), who reported the cv. Brazlândia Rosada as moderately resistant to *M. incognita*. We also found Beauregard to be resistant in our studies whereas Cervantes-Flores *et al.* (2002) reported that Beauregard was highly susceptible to several root-knot nematode species, including *M. incognita*. These discrepancies could be due to differences between laboratories in rating schemes or assay techniques, or they may be due to differences in nematode isolates or races of the pathogen. To our knowledge, cultivars Beatriz, BRS Amélia, BRS Cuia, BRS Rubissol, Carolina Vitória, Júlia, and PA-26/2009 have not been screened against *M. incognita* infection and are reported here for the first time as resistant. These cultivars provide additional material for planting or for selecting for other agronomic traits.

The mechanisms of resistance to *Meloidogyne* spp. in sweet potato cultivars are not well understood. Histological observations from susceptible and resistant cultivars infected with *Meloidogyne* spp., indicated that infective juveniles are able to penetrate and infect resistant plants, but oxidative burst and hypersensitive reactions prevented further nematode development within resistant plants (Komiyama *et al.*, 2006). Both qualitative and quantitative types of inheritance have been suggested for root-knot nematodes in sweet potato (Jones and Dukes, 1980; Ukoskit *et al.*, 1997). Molecular and phenotypic data suggest that resistance of sweet potato against *Meloidogyne* spp. is conferred by several genes, possibly acting with different levels of effect. Several Quantitative Trait Loci have been associated with genomic regions with additive effects on resistance to *Meloidogyne* spp. infection in sweet potato (Sano *et al.*, 2002; Cervantes-Flores *et al.*, 2008). Further studies involving fine mapping may reveal genes involved in nematode resistance (Cervantes-Flores *et al.*, 2008).

Sweet potato cultivars showed variable yield results. In 2012, cv. Duda and Júlia showed the highest yields (47.19 and 21.92 ton per ha, respectively), while in 2013, cv. BRS Amelia and Beauregard (31.35 and 27.08 ton per ha, respectively) were the most promising cultivars (Table 3). Overall, most sweet potato cultivars tested in this study showed mid to high yield, except cv. Princesa, PA-26/2009 and Marcela which showed average to a very poor yield (Table 3). These three cultivars showed a yield below or similar to the national average of 12.19 tons per ha (IBGE, 2012).

The other cultivars showed mid to high yields as compared to the national average, although Amanda and Beatriz would still be considered low-yielding

Table 3. Yield, insect damage and root shape of sweet potato cultivars planted in a field naturally infested with *M. incognita*, 2012 and 2013.

Year	Cultivar	Fresh wt. of tuberous roots (tons. ha^{-1})	Insect damage[y]	Root shape[z]
2012	Amanda	14.97 bc[x]	1.87 ± 0.11	2.25 ± 0.22
	Bárbara	19.70 bc	2.25 ± 0.22	3 ± 0.51
	Beatriz	15.22 bc	1.75 ± 0.22	2 ± 0
	Carolina Vitória	18.22 bc	2 ± 0.51	1.75 ± 0.22
	Duda	47.19 a	2.37 ± 0.33	2.25 ± 0.22
	Júlia	21.92 b	1.62 ± 0.49	1.75 ± 0.22
	Marcela	12.59 bc	2.25 ± 0.42	2 ± 0.36
	PA-26/2009	11.48 bc	1.75 ± 0.42	1.75 ± 0.42
	Princesa	2.55 c	2.75 ± 0.76	1.75 ± 0.42
2013	Beauregard	27.08 ± 1.61	2.25 ± 0.22	2 ± 0
	Brazlândia Branca	24.58 ± 2.22	2.75 ± 0.22	3.25 ± 0
	Brazlândia Rosada	27.76 ± 2.35	3.75 ± 0.22	3 ± 0
	Brazlândia Roxa	26.64 ± 2.21	2.25 ± 0	2.25 ± 0.36
	BRS Amélia	31.35 ± 3.72	4.25 ± 0.36	4.25 ± 0
	BRS Cuia	24.43 ± 3.20	3.25 ± 0.56	3 ± 0
	BRS Rubissol	23.49 ± 1.92	3 ± 0	3.25 ± 0

[x]Means (n = 4) followed by different letters in the column are significantly different according to Tukey's test ($P < 0.05$).

[y]Mean values (n = 4) ± standard error of insect damage (galleries and holes on roots), based on a 1-5 scale. 1 = roots with 0% damage; 2 = roots with 1-10% damage; 3 = roots with 11-30% damage; 4 = roots with > 50% damage, low commercial use; 5 = roots with 100% damage, without commercial use (França *et al.*, 1983).

[z]Mean values (n = 4) ± standard error of root shape, based on a 1-5 scale. 1 = regular fusiform shape, without any cracks; 2 = acceptable shape, with some undesirable characteristics, such as the presence of galleries and uneven shape; 3 = irregular root shape with galleries; 4 = very large roots, with galleries and cracks, barely accepted for the market; 5 = roots completely irregular, deformed, with cracks, without commercial use (Massaroto, 2008).

compared to the most productive commercial cultivars that are currently on the market. Cultivars Duda and BRS Amélia stood out as superior materials with high yield per hectare, and would be excellent choices for growers. Beauregard, which is rich in β-carotene, yielded 27.08 tons per ha, slightly less than the yield of 30 tons per ha reported by Schultheis *et al.* (1999), Cecílio Filho *et al.* (1996) (33.24 tons per ha), and Ozturk *et al.* (2012) (42.84 tons per ha); however, higher than those reported by Câmara *et al.* (2013) (14.38 tons per ha). Differences in yield are likely due to variations in weather, soil type, region, time from planting to harvesting, amount of fertilizer used, insect attack incidence, or other factors that collectively determine the overall yield and quality of commercial roots. The low yield of some cultivars might also be due to climate conditions in the experimental area (annual average temperature above 28°C), and it would be interesting to assess their yield in other regions as well.

Sweet potato cultivars were variable for root shape. Most cultivars showed a fusiform to near fusiform root shape, a characteristic that is most accepted in the market (Table 3). Brazlândia Rosada and Brazlândia Roxa showed an irregular (scale 3) and uneven (2.25) root shape, respectively. These values are slightly different from those reported by Andrade Júnior *et al.* (2012), in which cv. Brazlândia Rosada (1.8) and Brazlândia Roxa (2.2) had root shape near to fusiform. Most sweet potato cultivars showed a moderately low to medium insect attack incidence (1-30%), characterized by galleries and holes on the roots, which lowers marketability (Table 3). Considering the data from insect attack incidence, overall, most cultivars did not show a strong resistance to pest attack, which indicates the needs to implement insect control measures during cultivation of these cultivars.

In summary, we showed in this study that the 16 sweet potato cultivars tested were resistant to *M. incognita* both under greenhouse and field conditions. Most cultivars showed mid to high yield and are an excellent option for growers to be used for food and biofuel production.

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