YIELD AND SOIL INSECT RESISTANCE IN SWEET POTATO CLONES

PRODUTIVIDADE E RESISTÊNCIA DE CLONES DE BATATA-DOCE AOS INSETOS DE SOLO

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ABSTRACT: Sweet potato (*Ipomoea batatas*) is a rustic horticultural crop with high production potential. However, the crop is susceptible to many pests and diseases. The objective of this study was to evaluate 10 genotypes of sweet potato regarding their yield and resistance to soil insects, under Brazilian cerrado soil conditions. Genotypes were selected from the Sweet Potato Germplasm Bank of Embrapa Hortaliças. The experiment was conducted at Água Limpa Farm, belonging to University of Brasilia (UnB), and consisted of a randomized block design, with 10 treatments (genotypes), 10 plants per plot, and four replications. The following traits were analyzed: number of perforations per root, incidence of roots injured by insects, plant resistance degree, root shape, total and marketable root yields, root peel color, root pulp color, pulp total soluble solids, pulp titratable acidity, pulp TSS/TA ratio, pulp moisture, and pulp starch yield. Genotype CNPH 53 (26.78 t ha^{-1}) presented total root yield greater than the commercial variety Brazlândia Rosada (17.54 t ha^{-1}). Genotype Santa Sofia (11.77 t ha^{-1}) and Brazlândia (13.5 t ha^{-1}) had similar marketable root yields. CNPH 53 showed the best agronomic performance, exhibiting moderate susceptibility to soil insects and root shape meeting the market standards. It also had low pulp TA (2.53%); high pulp TSS (12.25 °Brix) and pulp TSS/AT ratio (4.24); pulp moisture content close to 70%; and the highest pulp starch content (11.98%). The traits number of perforations per root, root shape, and pulp TA presented heritability values close to 70%. Marketable root yield, pulp moisture, and pulp starch content demonstrated heritability values greater than 90% and CVG/CVE greater than 1.

KEYWORDS: *Ipomoea batatas*. Agronomic performance. Root quality. Genetic breeding. Insect injury.

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is found in many regions of the world. Its cultivation has increased due to increased consumer interest in food products with functional characteristics. In 2016, Brazil produced 669,454 tons of sweet potato in 49,554 hectares, with a positive variation of 12.3% as compared to 2015 (IBGE, 2015; 2016).

Sweet potato has high production potential since it produces a large volume of roots in a relatively short cycle, at a low cost, throughout the year. It is a rustic crop that grows in poor and degraded soils, presenting great insect resistance, and low response to fertilizer application. However, sweet potato is susceptible to many diseases caused by fungi, viruses, bacteria, and nematodes, and can also be attacked by several insects and mites (RABELLO, 2010).

The West Indian sweet potato weevil *(Euscepes postfasciatus - (Coleoptera, Curculionidae*) and the sweet potato pyralid moths (*Megastes pusialis and M. grandalis, Lepidoptera*, *Pyralidae*) are among the primary key pests reported for this crop. The may cause severe damage if control measures are not effective (SILVA et al., 2008).

In this context, plant breeding improves crop production resulting in increased crop yield due to the development of new varieties, especially those showing insect resistance. Therefore, the use of resistant varieties is an ideal strategy for insect control since it lowers the population of the pest to below the economic injury level and does not

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interfere with the ecosystem. Moreover, its effect is cumulative and persistent; it is not polluting; there is no increase in the production cost; and no specialized knowledge is required for its utilization by farmers (FERREIRA, 2006). Therefore, this study aimed at evaluating yield and soil insect resistance of 10 sweet potato genotypes, under Brazilian cerrado soil conditions.

MATERIAL AND METHODS

The experiment was conducted from January to July 2014, at Água Limpa Farm, belonging to University of Brasilia (UnB) (16°S and 48°W, 1,100 m asl), located in Brasilia, DF, Brazil. It consisted of a randomized block design, with 10 treatments (genotypes), 10 plants per plot, and four replications, totaling 40 plots. Genotypes were selected from the Sweet Potato Germplasm Bank of Embrapa Hortaliças. Three to four-bud cuttings (20 cm long) were taken from these genotypes and pre-rooted during 45 days in polystyrene (72 cells) filled with Bioplant® (Bioplant Agricola Ltda, Nova Ponte, MG, Brazil) artificial substrate.

At 164 days after field planting, roots were harvested. Seven roots per plot were randomly selected and the following traits analyzed: number of perforations per root; incidence of roots injured by insects (%); plant resistance degree; root shape; total root yield (t ha^{-1}); marketable root yield (t ha^{-1}); root peel color; root pulp color; pulp total soluble solids (TSS; °Brix); pulp titratable acidity (TA; % citric acid); pulp TSS/TA ratio; pulp moisture (%); and pulp starch yield (%).

Data of total root yield was obtained by weighing all roots from to the same plot. Marketable root yield was obtained after classification of the roots of each plot according to the market standards and by weighing only the selected roots. The resulting values of total and marketable root yields were extrapolated to t ha^{-1}. After the field evaluations, root samples were ground in a food processor and cooled to 5 °C for laboratory analysis.

The starch quantification was performed in 50 g of pulp ground with 100 mL of distilled water, during 50 seconds. The mixture was passed through a fabric filter, and the starch-containing solution was collected and dried in a forced-air-circulation oven at 40 °C for 24 h (ZAVARESE et al., 2009). The remaining physicochemical analyses were performed according to the Analytical Rules of Adolfo Lutz Institute (IAL, 2008).

Root peel color was evaluated using a 1 to 10 scale (1 – white; 2 – cream; 3 – dark cream; 4 – pale yellow; 5 – pinkish; 6 – orangish brown; 7 – purple; 8 – dark purple; 9 – reddish purple; and 10 – brownish purple. For root pulp color, a 1 to 9 scale was used (1 – white; 2 – cream; 3 – dark cream; 4 – pale yellow; 5 yellow; 6 dark yellow; pale orangish; 8 – purplish; 9 – purple pigmented) (KALKMANN, 2011).

The number of perforations per root was counted. The incidence of roots injured by insects was assessed based on the number of perforations per root and an injury grading scale (PEIXOTO et al., 1999; AZEVEDO et al., 2014). The scale varied from 1 (roots free of insect injury and with desirable market appearance) to 5 (roots not meeting the market standards and often not used for animal consumption). Based on the mean incidence of roots injured by insects per plot, genotypes were classified in resistant (R), moderately resistant (MR), moderately susceptible (MS), and highly susceptible (HS) (FRANÇA et al., 1983).

Root shape was evaluated according to a grading scale suggested by Massaroto (2008). The scale ranged from 1 (the nearly ideal shape for sweet potato, regular and fusiform; veins and root cracking are absent) to 5 (irregularly shaped roots which do not meet the market standards; veins and root cracking are present).

A square-root transformation was applied to the data of total root yield and number of perforations per root. Analysis of variance was performed, and the means were grouped by the Scott-Knott test ($P \leq 0.05$). Estimated values of broad-sense heritability (h_a^2), the genetic coefficient of variation (GCV), and the genetic and environmental coefficient of variation ratio (GCV/ECV) were calculated. All analyses were performed using Genes software (CRUZ, 2013).

RESULTS AND DISCUSSION

Differences were observed among treatments for all traits evaluated, except for total root yield (Tables 1 and 2). High variation in the agronomic performance was verified among genotypes for total root yield (Table 1). Genotypes CNPH 53, Brazlândia Rosada, Santa Sofia, and CNPH 29 showed the greatest total root yield while Brazlândia Rosada and Santa Sofia had the highest marketable root yield.

The total and marketable root yields reported in this study for genotype Brazlândia Rosada are higher than those found by Azevedo et al. (2015), who recorded 10.20 and 13.00 t ha^{-1} for total and marketable root yield, respectively. Total root yield of genotypes CNPH 53 and Brazlândia Rosada (Table 1) and marketable root yield of

Brazlândia Rosada were also higher than the reported 2016 national mean of 14,07 t ha^{-1} (IBGE, 2016).

Table 1. Total root yield (TY; t ha^{-1}), marketable root yield (MY; t ha^{-1}), root shape (RS), root peel color (PEC), root pulp color (PUC), number of perforations per root (PR), incidence of roots injured by insects (II; %), and plant resistance degree (RD) in sweet potato (*Ipomoea batatas*), at 164 days after field planting. Brasilia, DF, Brazil.

Genotypes	TY	MY	RS	PEC[1]	PUC[2]	PR	II	RD
Princesa	6.09 a	3.29 c	2.25 a	C	C	55.91 c	3.37 b	S
Brazlândia Rosada	17.54 a	13.75 a	2.74 a	PI	DC	62.49 c	3.69 b	S
Santa Sofia	11.77 a	11.25 a	1.92 a	PI	DC	27.43 b	3.13 b	S
CNPH 29	11.39 a	3.16 c	3.95 b	PI	C	68.43 c	3.41 b	S
Georgia Improved	4.67 a	4.17 c	1.87 a	C	C	62.06 c	2.61 a	MS
Balão	8.75 a	2.42 c	2.82 a	C	C	63.27 c	2.89 a	MS
CNPH 53	26.78 a	5.16 c	2.31 a	PU	C	35.40 b	2.48 a	MS
Batata Africana 1	8.80 a	2.92 c	2.95 a	PI	C	37.58 b	2.65 a	MS
Batata Correntina n°24	6.41 a	3.75 c	2.58 a	PI	C	53.64 c	2.87 a	MS
CNPH 71	5.18 a	8.33 b	2.25 a	DC	C	9.09 a	2.44 a	MS

Different lowercase letters in the columns indicate significant differences (Scott-Knott's test, $P \leq 0.05$); [1]C (cream), PI (pinkish), PU (purple), DC (dark cream); [2]C (cream), DC (dark cream).

The number of perforations per root varied considerably among the evaluated genotypes (Table 1). CNPH 71 presented the best result, with less than 10 perforations per root, demonstrating a low incidence of roots injured by insects and moderate susceptibility. Genotypes Georgia Improved, Balão, CNPH 53, Batata Africana, and Batata Correntina n°24 were also classified as moderately susceptible, although they presented greater number of perforations and injury level. A higher number of perforations per root (19.1) was reported by Carmona et al. (2015a) for genotype CNPH 71. However, a similar incidence of injured roots and the same resistance degree were recorded by those authors. Injury incidence may be related to other factors besides the number of perforations caused by insects. Injured roots can be infected by other pathogens, which accelerate tissue degradation, compromise root market appearance, and influence the resistance degree of the plant.

Ninety percent of the genotypes showed nearly ideal and relatively fusiform-like shape for sweet potato (scores between 1 and 3). Such scores correspond to root shapes classified as excellent and good and meet the consumer market standards. Genotypes Georgia Improved and Santa Sofia presented the best results for root shape. According to Massaroto (2008), sweet potato roots which have good root shape present only several veins or a slightly ununiform shape.

The genotypes evaluated showed variability regarding peel and pulp color. Only one genotype exhibited cream peel and cream pulp, 28 genotypes presented pink peel and cream pulp, and 45 showed purple peel and cream pulp (Table 2). Great variability and distinct peel color and pulp color combinations were verified in a study by Oliveira et al. (2002), which evaluated 55 genotypes from different Brazilian regions. Among the reported colors are those observed in this study and other combinations, such as pinkish peel and white pulp, white peel and cream pulp, brownish purple peel and purple pulp. These findings are relevant to breeding programs aiming to develop new sweet potato varieties for distinct areas of the country. This importance relies on the fact that in many cases, the variety cultivated depends on local market demands and traditions (SILVA et al., 2008).

The genotypes presented a mean value of 10.96 °Brix for TSS content (Table 2). Similar results were observed by Berrones (2012) who studied two sweet potato genotypes in Equador and reported TSS contents of 10.40 °Brix for purple peel and of 10.00 °Brix for pinkish peel sweet potatoes. Carmona (2015b) also observed a variation from 7.61 to 12.31 °Brix in the TSS contents from 23 sweet potato genotypes cultivated in Brasilia (DF). TSS content of 11.25 °Brix was verified for CNPH 71, corroborating our findings. However, the TSS contents of 10.50 °Brix here reported for Brazlândia Rosada and CNPH 29 are greater than those verified by Carmona (2015b). The TSS content, usually expressed as °Brix, indicates the amount of solids (sugars) dissolved in the juice or pulp of fruits and vegetables. TSS contents tend to increase with fruit or vegetable maturation, influencing their flavor, color, and texture. Higher TSS contents are important to the industry since they result in greater yield of the final product (KALKMANN, 2011).

Table 2. Pulp moisture (PM; %), pulp starch yield (SY; %), pulp titratable acidity (TA; % citric acid), pulp total soluble solids (TSS; °Brix), and pulp total soluble solids to titratable acidity ratio (TSS/AT) in sweet potato (*Ipomoea batatas*), at 164 days after field planting. Brasilia, DF, Brazil.

Genotypes	PM	SY	TA	TSS	TSS/TA
Princesa	70.18 a	11.38 a	4.15 b	10.83 a	2.63 b
Brazlândia Rosada	73.35 b	8.84 b	3.52 b	11.25 a	3.29 b
Santa Sofia	74.01 b	6.34 c	2.37 a	10.00 a	4.25 a
CNPH 29	70.91 a	10.39 a	2.53 a	10.50 a	4.24 a
Georgia Improved	71.56 a	9.78 a	4.18 b	11.00 a	2.71 b
Balão	71.73 a	7.99 b	3.80 b	11.62 a	3.16 b
CNPH 53	68.73 a	11.98 a	2.76 a	12.25 a	4.42 a
Batata Africana 1	77.90 c	8.84 b	3.35 b	10.00 a	3.02 b
Batata Correntina n° 24	77.32 c	8.63 b	3.63 b	10.87 a	3.29 b
CNPH 71	68.67 a	5.49 c	3.10 a	11.25 a	4.17 a

Different lowercase letters in the columns indicate significant differences (Scott-Knott's test, $P \leq 0.05$).

Santa Sofia, CNPH 29, CNPH 53, and CNPH 71 presented superior performance concerning TA contents, which were lower than the values recorded for the other genotypes (Table 2). Berrones (2012) found TA contents of 3.4 and 2.5% for purple and pinkish sweet potato peels, respectively. These contents are greater than the values observed for CNPH 71 (3.10%) and Santa Sofia (2.37%). Acidity influences food quality, conservation, and maintenance of its characteristics. Variation in acidity may be due to the food natural compounds, fermentation or food processing. It can also be a result of food deterioration (SANTOS et al., 2012).

Genotypes CNPH 53 (4.42), Santa Sofia (4.25), CNPH 29 (4.24), and CNPH 71 (4.17) also presented the greatest performance for TSS/AT ratio (Table 2). The high TSS/AT values indicate a suitable combination of sugar and acid contents in the roots, resulting in a better flavor and commercial competitiveness. These genotypes are the most precocious among the ones studied since TSS/AT values indicate the sweet potato maturity degree at harvest time (CHITARRA; CHITARRA, 1990).

The pulp moisture content varied between 68.67 and 77.90%. CNPH 71 and Batata Africana 1 presented the lowest and the highest moisture contents, respectively (Table 2). The results here reported are in agreement with the moisture content range found by Kalkmann (2011) and Carmona (2015b) and with the approximate moisture content of 70% at harvest recorded by Silva et al. (2008).

The highest starch contents were observed for CNPH 53, Princesa, CNPH 29, and Georgia Improved while CNPH 71 and Santa Sofia showed the lowest starch contents (Table 2). Root moisture content is usually related to pulp starch content which is directly related to the yield of the sweet potato flour (SILVEIRA, 2008). Low moisture contents are desirable for *in natura* consumption since consumers preffer roots with dry pulps after cooking. Varieties with greater dry matter contents are preffered by the industry as they will potentially have higher starch content and better starch extraction, at the same time that generate less residual water. Under this perspective, sweet potato are advantageous over common tubers since it has higher dry matter content (approximately 68%) (KALKMANN, 2011).

High estimated values of broad-sense heritability were found for marketable root yield (91.87%), pulp moisture content (92.39%), and pulp starch yield (90.07%). These traits presented GCV/ECV values greater than 1. These results are corroborated by Carmona (2015b), whose findings also indicated high heritability estimates and GCV/ECV values for the traits previously mentioned. Heritability expresses the correlation between phenotype and genotype. Therefore, traits with high magnitude of heritability values and GCV/ECV greater than 1 indicate that there is genetic variability among genotypes and they are not highly influenced by the environment. In situations like this, the adoption of less elaborated methods, such as the ones based on mass selection, is suitable for obtaining satisfactory gains during selection (FALCONER, 1981).

Genotypes CNPH53, Brazlândia Rosada, Santa Sofia, and CNPH 29 demonstrated the highest total root yield while Brazlândia Rosada and Santa Sofia presented the highest marketable root yield. Genotypes Georgia Improved, Balão, CNPH 53, Batata Africana 1, Batata Correntina nº 24, and CNPH 71 were moderately susceptible to soil insects. CNPH 53, Princesa, CNPH 29, and Georgia Improved have high dry matter contents and are ideal for the flour industry utilization. High heritability estimates and CVG/CVE greater than 1 were found for marketable root yield, pulp moisture content, and pulp starch content, indicating the existence of sufficient genetic variability for selection and genetic progress.

RESUMO: A batata-doce (*Ipomoea batatas*) é uma hortícola rústica e de elevado potencial produtivo. No entanto, ainda é suscetível a grande número de pragas e doenças. O objetivo deste trabalho foi avaliar dez genótipos de batata-doce quanto à produtividade e resistência a insetos de solo nas condições de solo do cerrado Brasileiro. Os genótipos avaliados foram selecionados do Banco de Germoplasma da Embrapa Hortaliças. O experimento foi conduzido na Fazenda Água Limpa da Universidade de Brasília (UnB) utilizando delineamento experimental de blocos casualizados, com 10 tratamentos, 4 repetições e 10 plantas de batata-doce por parcela. As características avaliadas foram: número de furos por raiz, incidência de danos causados por insetos, grau de resistência da planta, formato de raiz, cor da casca da raiz, cor da polpa da raiz, produtividade total e comercial de raiz, e teor de sólidos solúveis totais (SST), acidez total titulável (AT), STT/AT, rendimento de amido e umidade da polpa. O genótipo CNPH 53 apresentou produtividade total (26,78 t ha^{-1}) superior à variedade comercial Brazlândia Rosada (17,54 t ha^{-1}). O genótipo Santa Sofia obteve produtividade comercial (11,77 t ha^{-1}) próxima à variedade Brazlândia Rosada (13,75 t ha^{-1}). O genótipo CNPH 53 apresentou o melhor desempenho agronômico, exibindo suscetibilidade moderada aos insetos de solo e formato de raiz dentro dos padrões comerciais. Apresentou também baixa acidez (2,53%); alto teor de sólidos solúveis (12,25 °Brix) e de ratio (4,24); teor de umidade da polpa próximo a 70% e maior teor de amido na polpa (11,98%). As características número de furos, formato e acidez apresentaram valores de herdabilidade próximos de 70%. A produtividade comercial, umidade e amido da polpa demonstraram valores de herdabilidade acima de 90% e CVg/CVe maior que 1.

PALAVRAS-CHAVE: *Ipomoea batatas*. Desempenho agronômico. Qualidade de raiz. Melhoramento genético. Danos causados por insetos.

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