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Evaluation of selected cowpea varieties under competition with weeds[1]

Avaliação de variedades de feijão-caupi selecionadas sob competição com plantas daninhas

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ABSTRACT - Cowpea is cultivated in the semi-arid region of Brazil and in various other countries, generally employing traditional varieties, which are grown as intercrops by low-income, illiterate farmers who lack technical assistance. Under such conditions, the use of herbicides is limited, and weed control is usually carried out by hoeing. Combining more varieties that are more competitive against weeds, and planting at higher planting densities using different cropping practices could reduce the work of weeding. In a preliminary study, 48 traditional varieties of the cowpea were grown with only one weeding, and evaluated for dry-grain yield. The aim of the present study was to evaluate the green- and dry-grain yields of six varieties: three that proved to be more productive (Umarizal, Itaú and Upanema), and three that had low yields (Mossoró, Santa Cruz and São Miguel) in the preliminary evaluation. The varieties were submitted to two types of weed-control management (one or two weedings). A randomised block design was used, in split plots with five replications. Weed management was applied to the plots, and the traditional varieties to the subplots. It was found that, in terms of the effect on the yields under evaluation, there was no difference in the number of weedings. The Umarizal, Itaú, Upanema and Mossoró varieties were the best for green-grain production, with the first two also being superior in the production of dry grain.

Key words: *Vigna unguiculata*. Traditional varieties. Weeding. Grain yield. Green-bean yield.

RESUMO – O feijão-caupi é cultivado no semiárido brasileiro e em vários outros países, em geral com variedades tradicionais. Os cultivos são realizados em consorciação por agricultores com baixa renda, analfabetos e que carecem de assistência técnica. Essas condições limitam o uso de herbicidas e o controle das plantas daninhas é feito usualmente com capinas à enxada. A combinação de variedades mais competitivas com plantas daninhas, plantadas em maiores densidades de plantio e outras práticas culturais poderia reduzir o trabalho das capinas. Em um trabalho preliminar, 48 variedades tradicionais de caupi foram cultivadas com uma capina e avaliadas quanto ao rendimento de grãos secos. O objetivo do presente trabalho foi avaliar os rendimentos de grãos verdes e secos de seis variedades: três que se mostraram mais produtivas (Umarizal, Itaú e Upanema), e três que apresentaram baixos rendimentos (Mossoró, Santa Cruz e São Miguel), na avaliação preliminar. As variedades foram submetidas a dois manejos de controle de plantas daninhas (uma e duas capinas). Utilizou-se o delineamento de blocos ao acaso, com cinco repetições e parcelas subdivididas. O manejo das plantas daninhas foi aplicado nas parcelas e as variedades tradicionais nas subparcelas. Verificou-se ser indiferente, em termos de influência sobre os rendimentos avaliados, a realização de uma ou duas capinas. As variedades Umarizal, Itaú, Upanema e Mossoró foram as melhores para produção de grãos verdes e as duas primeiras foram superiores também para a produção de grãos secos.

Palavras-chave: *Vigna unguiculata*. Variedades tradicionais. Capinas. Rendimento de grãos. Rendimento de feijão-verde.

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INTRODUCTION

The cowpea [*Vigna unguiculata* (L.) Walp.] is cultivated in the semi-arid region of Brazil and in various other regions of the world by low-income, illiterate farmers who lack technical assistance (CASTRO, 2012; AQUINO; LACERDA, 2015). Weed control is usually carried out by hoeing.

Hoeing is hard and tiring work, and therefore undesirable, especially for the farmer in the semi-arid region, who is often undernourished. Furthermore, weeding is time-consuming and costly. At least two weedings are needed when cultivating the cowpea (MEKONNEN *et al*., 2017), and it is estimated that, for each weeding, at least ten days work is required per hectare. When carried out under the sun of the semi-arid region, weeding becomes even more difficult; on the other hand, on days with a lot of rain, proper weeding cannot be carried out, which can damage the crop.

The use of herbicides might be an alternative to weeding in the cowpea. However, the prospects for this are not encouraging. Herbicides are expensive for farmers in the northeast of the country, and their use requires technical guidance. In addition, the use of herbicides would help to further degrade the semi-arid region, which is recognised as a fragile biome. Finally, the lack of water in the northeast of Brazil could reduce the efficiency of the herbicides.

Combining varieties that are more competitive against weeds with higher planting densities or other cropping practices could reduce the work of weeding. This has been seen, for example, in rice (ZHAO *et al*., 2007). Under such conditions fewer weeds grow, reducing the work of the farmer. Furthermore, rainfall during the critical period of competition between the cowpea and the weeds would be less problematic should timely weedings not be carried out.

Recent studies (ANDREW; STORKEY; SPARKES, 2015; JHA *et al*., 2016; WORTHINGTON; ROBERG-HORTON, 2013) emphasise the importance of using more competitive varieties as an auxiliary measure in weed management. In general, the search for varieties that are more competitive against weeds starts with genotype screening. Such screening has been carried out with various crops, including the cowpea (ASARE *et al*., 2013; MOUKOUMBI *et al*., 2011), and can then be followed by further, more rigorous assessments. In these evaluations, of special interest are those involving genotypes having greater or lesser competitive ability, a kind of divergent selection of the varieties. Post-screening evaluations of divergent genotypes reinforce the preliminary evaluation, and allow the two groups of genotypes to be compared in response to various types of cropping practice. Various studies have been carried out on genetic divergence in the cowpea (TORRES FILHO *et al*., 2018; NGUYEN *et al*., 2017), but no studies were found on divergent selection, which are very common in maize, soya bean and other crops (SATO *et al*., 2014).

In a preliminary study, 48 traditional varieties were grown with only one weeding, and evaluated for dry-grain yield. The aim of the present study was to evaluate, the green- and dry-grain yields of six varieties: three that proved to be more productive (Umarizal, Itaú and Upanema), and three that had low yields (Mossoró, Santa Cruz and São Miguel) in the preliminary evaluation.

MATERIAL AND METHODS

The experiment was carried out on the Rafael Fernandes Experimental Farm of the Federal Rural University of the Semi-Arid Region (UFERSA), located 20 km from the capital of the district of Mossoró in the state of Rio Grande do Norte (RN) (5º11’ S, 37º20’ W, at an altitude of 18 m). The soil in the experimental area is classified as a Red-Yellow Argisol (PVA), according to the Brazilian System of Soil Classification (SANTOS *et al*., 2018). The results of the analysis of a soil sample taken from the experimental area are shown in Table 1.

According to the Köppen classification (1948), the climate in the region is type BSwh’, i.e., very dry, with a mean annual rainfall of 825 mm and greater rainfall during the summer. The region has a maximum mean air temperature varying between 32.1 ºC and 34.5 ºC, and a mean annual rainfall of approximately 825 mm (Carmo Filho; Oliveira, 1989). During the experimental period, several climate data were recorded (Table 2). The experiment was irrigated by sprinkler, with the experimental plots arranged parallel to the sprinkler lines. The amount of water needed was calculated considering the effective depth of the root system to be 40 cm. Irrigation was carried out every two days, and was based on the amount of water retained in the soil at a pressure of 0.40 Mpa. Irrigation was started after sowing and suspended 15 days after the dry pods were first harvested.

Cross-harrowing was carried out twice to prepare the soil. In both experiments, the cowpea received 10 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}. The fertilisers were applied by hand to the bottom of the sowing furrows, both under and to the side of the seeds. Sowing was carried out on 29/10/2015. Four seeds were sown per hole and, 20 days after sowing, the plants were thinned out to leave the two largest plants in each hole. Thirty days after sowing, 10 kg N ha^{-1} were applied as top dressing. Ammonium sulphate, single superphosphate and potassium chloride were used as the sources of nitrogen, phosphorus and potassium, respectively.

Table 1 – Results of the chemical analysis of a soil sample (at a depth of 0 – 20 cm) from the area where the experiment was set up

Characteristic	Result
pH in water	7.60
Phosphorous (mg dm^{-3})	34.40
Potassium (mg dm^{-3})	71.90
Sodium (mg dm^{-3})	37.70
Calcium ($cmol_c$ dm^{-3})	2.50
Magnesium ($cmol_c$ dm^{-3})	0.70
Exchangeable acidity ($cmol_c$ dm^{-3})	0.00
Potential acidity ($cmol_c$ dm^{-3})	0.00
Sum of bases ($cmol_c$ dm^{-3})	3.55
Effective cation exchange capacity of the soil ($cmol_c$ dm^{-3})	3.55
Effective cation exchange capacity of the soil at pH = 7 ($cmol_c$ dm^{-3})	3.55
Base saturation (%)	100.00
Aluminium saturation (%)	0.00
Exchangeable sodium percentage (%)	5.00

Table 2 – Climate data for Mossoró (RN) from October 2015 to January 2016.[1]

Months 2015/2016	Air temperature (ºC)			Total global radiation (mj m^{-2} dia^{-1})	Rainfall (mm)	Relative humidity (%)	
	Maximum	Medium	Minimum			Mínimum	Maximum
October	32.8	28.0	23.2	25.2	0.01	41.4	78.9
November	32.9	28.3	23.6	25.5	0.00	42.3	82.4
December	33.3	28.8	24.2	23.5	0.43	42.7	81.8
January	31.4	27.8	24.2	19.0	6.27	57.4	93.1

[1] Source: Agritempo (2018)

Three sprayings were given to control aphids (*Aphis craccivora* Kock). For the first, 14 days after sowing (DAS), a product with methomyl as the active ingredient was used at a dose of 1.0 L ha^{-1}. The other sprayings were given 43 and 54 DAS using bifenthrin as active ingredient at a dose of 500 mL ha^{-1}.

Before conducting the experiment, another trial was carried out to screen the varieties that are more or less tolerant to weeds. In this preliminary experiment, seeds were obtained from producers contacted at random (that is, an attempt was made to contact farmers randomly, but without drawing names) in each of the following districts in the state of Rio Grande do Norte (one producer from each district): Alexandria, Angicos, Jaçanã, Apodi, Baraúna, Boa Saúde, Bodó, Campo Grande, Campo Redondo, Carnaúba dos Dantas, Carnaubais, Ceará Mirim, Currais Novos, Felipe Guerra, Itaú, Japi, José da Penha, Lagoa d'Anta, Lagoa de Pedras, Lagoa Salgada, Lajes, Luiz Gomes, Macaíba, Monte Alegre, Mossoró, Nova Cruz, Passa e Fica, Pedra Preta, Pedro Velho, Santa Cruz, Santana do Matos, São Bento do Trairi, São Gonçalo do Amarante, São José do Campestre, São José do Mipibu, São Miguel, Martins, São Paulo do Potengi, São Tomé, Senador Eloi de Souza, Serra do Mel, Serrinha, Tangará, Tenente Ananias, Tenente Laurentino Cruz, Umarizal, Upanema and Vera Cruz. Each variety was identified by the name of the district in which it was collected. A brief interview was held with each producer when collecting the seeds with the aim of guaranteeing seeds of a traditional variety. During screening, a randomised block design was used with five replications and treatments corresponding to the 48 traditional varieties mentioned above. The varieties were grown with a single weeding, carried out 30 days after sowing. This procedure was expected to cause moderate competitive weed stress in each variety, considering that, in the region, the cowpea is generally cultivated with two weedings (carried out approximately 20 and 40 days after sowing). The plots comprised one row, 6.0 m in length, containing ten holes (each with two plants). The spacing between rows was 1.0 m, with 0.6 m between the holes in the same row. The plants in the holes at the ends of each row were considered a border. The plants from each row at the sides of each block with the same variety of cowpea were also considered to be borders.

In the experiment on which this study was based, six traditional varieties of cowpea, selected based on the results obtained in the preliminary selection for competitiveness against weeds, were evaluated: three of which proved to be more productive (Umarizal, Itaú and Upanema), and three that had low yields (Mossoró, Santa Cruz and São Miguel). These varieties were submitted to two types of weed-control management (one weeding and two weedings). A randomised complete block design was used, in split plots with five replications. Weed management was applied to the plots, and the traditional varieties to the subplots. Weeding was carried out 30 days after sowing (DAS) in the management with one weeding, and 20 and 40 DAS in the management with two weedings.

Each subplot consisted of four rows, 6.0 m in length. The area occupied by the two central rows was considered to be the working area, disregarding the plants from one hole at each end, which comprised the borders. One row from the working area was used to evaluate the green grain and the other to evaluate the dry grain. A spacing of 1.0 m x 1.0 m was used, with two plants per hole. As such, eight plants were used to evaluate the green grain and eight to evaluate the dry grain.

Green-bean production was obtained from nine harvests carried out from 53 to 78 days after sowing (DAS). The green-bean yield was evaluated from the weight of the pods and of the green grain. The green-grain yield was corrected for a moisture content of 65%. The following were also determined: the number of pods plant^{-1} (based on all the collected pods), the number of beans pod^{-1} (in 10 pods), the 100-grain weight (in five samples), and the length, width, and thickness of 10 pods and 10 grains.

Dry-grain production was determined in four harvests, carried out from 70 to 82 DAS. The dry-grain yield was measured from the weight of the dry grain, which was corrected for a moisture content of 15.5%. In addition, the number of pods plant^{-1} (considering all the harvested pods), the number of beans pod^{-1} (in 10 pods), the 100-grain weight (in five samples), and the length, width and thickness of 10 grains were evaluated. After the final collection of the dry grain, the plants from one randomly chosen hole, together with any weeds found in an area of 1.0 m^2 in the central part of each plot, were collected to determine the shoot dry weight.

After the final dry-bean harvest, samples of the aerial part of the weed population were collected at 91 DAS from 1.0 m^2 of each plot. Each species of weed contained in the samples was identified. The samples were weighed and homogenised, and approximately 100 g were then removed and placed in a forced air circulation oven at 70 ºC to constant weight, to obtain the dry matter of the aerial part of the weeds.

Dry matter estimates for the aerial parts of the cowpea and the weeds were determined by cutting both types of plant close to the ground. The cut material was weighed (the weeds were also identified) and ground in a forage maker. The ground material was homogenised and a sample of approximately 100 g was removed. This sample was placed in a forced air circulation oven at 70 ºC, to constant weight.

The data were submitted to analysis of variance using the SISVAR v 5.3 software, developed by the Federal University of Lavras (FERREIRA, 2010), and the mean values of the treatments were compared using Tukey's test (BRAUN, 1994) at 5 % probability. The data were tested for homogeneity of variance (Bartlett's test) before the analysis of variance was carried out (NOGUEIRA; PEREIRA, 2013).

RESULTS AND DISCUSSION

Characteristics of the weeds

Fourteen weed species were identified in the experimental area, where the most frequent species (considering a rate of occurrence greater than 50%) were *Cenchrus echinatus*, *Commelina benghalensis* and *Digitaria* sp. (Table 3).

It is important to remember that the data in Table 3 were obtained from a survey carried out 91 days after sowing the cowpea. Surveys taken at different times produce different results for the floristic composition of weeds, as demonstrated by Lima *et al*. (2016) and by Imoloame and Osunlola (2017). This is due to the dynamic nature of weed emergence and disappearance in the field.

Table 4 shows the distribution of weed species in the experimental area. Species distribution was not uniform, which may have been due to several reasons. First, the treatments themselves (varieties and weeding), which must have eliminated different species in different plots. The greatest number of weed species for each control method occurred in areas cultivated with the Umarizal variety (nine species in total). The lowest incidence of weeds occurred in plots cultivated with the Santa Cruz and São Miguel varieties (four species) in the managements with one or two weedings, respectively. Second, competition between weed species, as well as competition between the weed species and the crop, must also have eliminated different weed species from various experimental units. Third, it is worth noting that weeds in the soil seed bank can also affect the distribution of these plants in the experimental area. Martin *et al*. (2018) found that species with smaller seeds tended to occur in larger patches than those with larger seeds. Several species showed aggregation patterns that repeated periodically at right angles to the direction of the crop rows. They concluded that the spatial distribution of weeds is the result of both their biology and the local environment caused by the crop (MARTÍN *et al*., 2018). Finally, Zhou *et al*. (2008) found that spatial heterogeneity of the soil plays an active role in maintaining the richness of the plant species.

There was an effect from the weed control x varieties interaction for the fresh and dry matter of the aerial part of the weeds (Table 5). With only one weeding, the greatest weed growth, measured in terms of fresh and dry matter, occurred in the Itaú variety. With two weedings, the greatest weed growth occurred in plots of the Umarizal

Table 3 – Occurrence index of the weed species

Order number	Species	Occurrence index (%)[1]
1	*Adenocalymma* sp.	5
2	*Alternanthera tenella* Colla	8
3	*Amaranthus viridis* L.	2
4	*Borreria verticillata* L.	3
5	*Cenchrus echinatus* L.	100
6	*Commelina benghalensis* L.	95
7	*Cucumis anguria* L.	5
8	*Dactyloctenium aegyptium* (L.) Willd.	15
9	*Digitaria* sp.	83
10	*Herissantia crispa* L.	2
11	*Ipomoea* sp.	3
12	*Physalis angulata* L.	2
13	*Portulaca oleracea* L.	45
14	*Turnera subulat*a Sm.	5

[1] Occurrence index = ratio between the number of experimental units in which a certain weed species occurred and the total number of experimental units

Table 4 – Distribution of weed species in plots of traditional varieties of cowpea cultivated with one or two weedings. The numbers correspond to the number of the species listed in Table 3

Weed management	Variety	Block					Total number of species per subplot
		1	2	3	4	5	
One weeding	Umarizal	5-6-8-9	5-6-8-9	2-5-6-8-9-13	4-5-6-7-9	2-5-6-9-14	9
	Itaú	5-6-9-13	5-6-9-13	5-6-9	3-5-8-9-11-13	5-6-8-9	7
	Upanema	5-6-9-14	5-6-9	2-5-6-9-13	5-6-9	5-6-9-13-14	6
	Santa Cruz	5-6-9-13	5-6	5-6-9-13	5-6-9	5-6-13	4
	São Miguel	5-6	5-6-7-9-13	5-6-9	5-6-9-13	5-6-9-13	5
	Mossoró	5-6-9	2-5-6-8-9-11-13	5-6-9	1-5-6-9-13	5-6-9	8
Total number of species per plot							12
Two weedings	Umarizal	1-5-6-8-9-13	5-6-9	5-6-9	5-6-9-13	2-5-6-9-13	7
	Itaú	5-6-8-10	5-6-9-13	5-6-9	5-6	5-6-9-13	6
	Upanema	5-6-13	5-6-9-13	5-6-9	5-6-9-13	3-5-6-8-9-12	7
	Santa Cruz	1-5-6	5-6-9-13	5-9	5-6-9	5-6-7-9-13	6
	São Miguel	5-6	5-6	5-6-9	5-6-9-13	5-9	4
	Mossoró	5-6-9	5-6-9	5-6-9-13	5-6	4-5-6-9-13	5
Total number of species per plot							12

variety (Table 6). These data suggest that both varieties have greater weed tolerance than weed suppressive ability. The data also show that weeding even has an effect on weeds that are present later during the cowpea cycle, as weed growth was evaluated 91 days after sowing. This may have been due to the main group of weed species that occurred during the experiment being difficult to control (DIAS *et al*., 2009; PEREIRA *et al*., 2015).

Characteristics of the cowpea

The effects of the treatments on green bean yield, evaluated using the weight of the pods and the green grain, and on the main components of green-grain production were similar (Table 7). That is, there was an effect from the varieties (V), but not from the weed management (M) nor the V x M interaction. In terms of the pod and green-grain yields, four varieties were superior: the three varieties selected for their higher dry-grain yield, in addition to the Mossoró variety, selected for lower dry-grain yields in the preliminary evaluation (Table 8). Therefore, selecting for greater competitiveness against weeds, based on higher dry-grain yields may also result in higher green-grain yields. The higher green-grain yields of the varieties under evaluation were mainly due to the greater numbers of pods

Table 5 – Summary of the analysis of variance for the fresh and dry matter data of the aerial part of the weeds.[1]

Source of variation	Degrees of freedom	Mean Square	
		Matter of the aerial part of the weeds (g m^{-2})	
		Fresh	Dry
Blocks	4	304,304.11^{ns}	6,877.98^{ns}
Weed management (M)	1	1,660,006.67^{ns}	67,335.00*
Residual (a)	4	397,069.63	7,940.54
Varieties (V)	5	1,912,032.03**	49,498.27**
M x V	5	408,509.11**	14,824.24**
Residual (b)	40	115,841.82	2,507.73
Overall mean		729	122

[1] ns; *; **:not significant, significant at 5%, and significant at 1%, respectively, by F-test

Table 6 – Mean values for the fresh and dry matter of the aerial part of the weeds, evaluated at the end of the cycle in different varieties of cowpea[1]

Weed fresh matter (g m^{-2})							
Weed management	Selected varieties						Mean
	High yield			Low yield			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	1,364 Aab	1,870 Aa	831 Abc	535 Ac	238 Ac	531 Ac	895
Two weedings	1,019 Aa	799 Bab	569 Aab	407 Aab	380 Aab	200 Ab	562
Mean	1,192	1,334	700	471	309	366	-
CV (%): plots = 86.5; subplots= 46.7							

Weed dry matter (g m^{-2})							
Weed management	Selected varieties						Mean
	High yield			Low yield			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	232 Aab	326 Aa	139 Abc	97 Acd	41 Ad	100 Acd	156
Two weedings	154 Ba	122 Bab	87 Aab	68 Aab	69 Aab	32 Ab	89
Mean	193	224	113	83	55	66	-
CV (%): plots = 72.9; subplots = 41.0							

[1] Within each characteristic and within each group of treatments, mean values followed by the same lowercase letter in the rows and the same uppercase letter in the columns do not differ at 5% probability by Tukey's test

per plant. Path analysis has indicated the number of green pods per plant as the characteristic having the greatest direct effect on green-grain yield (FREITAS *et al*., 2016). There was no difference between the pod and green-grain yields obtained with one weeding, carried out at 30 days, and those obtained with two weedings (at 20 and 40 days after sowing the cowpea) (Table 8). Despite this, the fact that the six varieties had higher pod and green-grain yields with two weedings than with just one weeding may indicate that two weedings are actually superior to one weeding; however, the experimental precision did not allow for significant differences to be detected.

There was an effect from the varieties (V) on dry-grain yield, but not from the weed management (M) nor the V x M interaction (Table 9). On average, the Umarizal and Itaú varieties were the most productive and the São Miguel variety the least. The remaining varieties formed an intermediate group (Table 10).

There were differences between the behaviour of the varieties when considering the green-grain (Table 8) and dry-grain yields (Table 10). There are three possible causes for these differences. First, there is evidence that harvesting green pods affords a greater number of pods per plant (ALIKO *et al*., 2013; RATHOD *et al*., 2010). Second, plants grown for dry-grain production spend more time in the field than plants grown for green-grain production, meaning that they suffer the effects of abiotic and biotic factors for longer. Finally, it should be remembered that green grain and dry grain are products that are harvested and evaluated differently. For example, the ideal time for harvesting green pods depends on the person carrying out the harvest, while for dry grain, the harvest is less subjective.

Table 7 – Summary of the analysis of variance of the data for green-pod and green-grain yield and their components in traditional varieties of the cowpea.[1]

Source of variation	Degrees of freedom	Mean Square				
		10-grain weight (g)	Number of pods plant^{-1}	Number of grains pod^{-1}	Pod weight (kg ha^{-1})	Grain yield (kg ha^{-1})
Blocks	4	5.96^{ns}	76.34^{ns}	0,42^{ns}	2,862,727.27^{ns}	814,734.29^{ns}
Management (M)	1	21.00^{ns}	265.44^{ns}	0,02^{ns}	4,026,414.15^{ns}	2,015,200.27^{ns}
Residual (a)	4	5.05	48.26	1,07	2,491,195.57	893,390.81
Varieties (V)	5	139.68**	578.99**	3,41**	19,058,906.50**	7,943,618.97**
M x V	5	6.70^{ns}	16.74^{ns}	0,34^{ns}	363,859.11^{ns}	123,238.19^{ns}
Residual (b)	40	8.09	25.83	0,66	822,190.89	338,708.57
Overall mean		39.3	18.2	15.9	3.298	2,045

[1] ns; *; **:not significant, significant at 5%, and significant at 1%, respectively, by F-test

Table 8 – Average green-pod and green-grain yield and their components in traditional varieties of the cowpea.[1]

100-grain weight (g)							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	37.9	41.2	38.9	47.0	35.9	38.7	39.9 A
Two weedings	37.4	39.9	37.0	44.5	33.3	40.5	38.8 A
Mean	37.6 bc	40.5 b	38.0 bc	45.8 a	34.6 c	39.6 b	-
CV (%): plots = 5.7; subplots = 7.2							
Number of pods plant^{-1}							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	22.2	20.8	20.7	16.6	10.0	6.3	16.1 A
Two weedings	28.1	28.9	24.2	21.4	11.7	7.7	20.3 A
Mean	25.2 a	24.8 a	22.5 a	19.0 a	10.9 b	7.0 b	-
CV (%): plots = 38.1; subplots = 27.9							
Number of grains pod^{-1}							

Continuation Table 8

Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	15.5	16.3	15.8	17.1	15.1	15.9	15.9 A
Two weedings	15.3	15.9	16.1	16.5	15.2	16.3	15.9 A
Mean	15.4 b	16.1 ab	16.0 ab	16.8 a	15.2 b	16.1 ab	-
CV (%): plots = 6.5; subplots = 5.1							
Pod weight (kg)							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	3,625	3,488	3,601	4,491	1,726	1,302	3,039 A
Two weedings	4,470	4,495	3,894	5,175	1,772	1,536	3,557 A
Mean	4,048 a	3,992 a	3,748 a	4,833a	1,749 b	1,419 b	-
CV (%): plots = 47.9; subplots = 27.5							
Green-grain yield (kg ha^{-1})							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	2,395	2,515	2,376	2,244	932	710	1,862 A
Two weedings	2,814	3,248	2,566	2,726	1,144	874	2,229 A
Mean	2,604 a	2,882 a	2,471 a	2,485 a	1,038 b	792 b	-
CV (%): plots = 46.2; subplots = 28.5							

[1] Within each characteristic and within each factor, mean values followed by the same lowercase letter in the rows and the same uppercase letter in the columns do not differ at 5% probability by Tukey's test

Table 9 – Summary of the analysis of variance of the data for dry-grain yield and its components in traditional varieties of the cowpea.[1]

Source of variation	Degrees of freedom	Mean square			
		100-grain weight (g)	Number of pods plant^{-1}	Number of grains pod^{-1}	Grain yield (kg ha^{-1})
Blocks	4	5.26^{ns}	39.93^{ns}	0.7960^{ns}	143,723.00^{ns}
Mangement (M)	1	1.63^{ns}	246.04*	0.0002^{ns}	765,236.27^{ns}
Residual (a)	4	1.60	18.73	0.3677	109,491.60
Varieties (V)	5	33.53**	489.20**	1.8126**	1,734,803.68**
M x V	5	1.65^{ns}	25.60^{ns}	0.6646^{ns}	118,382.27^{ns}
Residual (b)	40	3.22	26.96	0.5067	117,117.69
Overall mean		20.9	15.2	16.2	953

[1] ^{ns}; *; **:not significant, significant at 5%, and significant at 1%, respectively, by F-test

The differences between cultivars in terms of competitive ability against weeds (Tables 7 and 9) are due to differences in the ability to access light, nutrients and water, as well as differences in allelopathic activity (WORTHINGTON *et al*., 2015). Generally, competition between root systems results in less biomass than does competition between the aerial parts of the competitors involved. Furthermore, competition between root systems is greater when one of the competitors is a grass (KIAER; WEISBACH; WEINER, 2013). In the present study, the most commonly occurring weeds were grasses (Table 3). Another aspect that can influence crop yield, but which has generally not been considered in studies of weed management, is the occurrence of pathogens and pests. The presence or absence of certain weeds can reduce attacks by certain pests. In addition, weed control without pest control resulted in more than a 90% reduction in cowpea yield, while pest control with no weed management caused a loss of 70% in cowpea yield (TAKIM; UDDIN II, 2010). It is possible that varieties that have a greater ability to compete with weeds affect the incidence of pests and diseases in the crop.

The preliminary selection for higher and lower yields as carried out in the present study, may result in the wrong decisions being made: the Mossoró variety, selected for its lower yields, was included among the varieties with higher yields in the present study. It is quite true that the preliminary selection was extremely simple, based on a single experiment, using small plots with no borders, but even so, it allowed more hits than errors: the

Table 10 – Average dry-grain yield and its components in traditional varieties of the cowpea.[1]

100-grain weight (g)							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	20.2	23.2	20.4	23.2	18.3	19.3	20.8 A
Two weedings	19.9	22.5	20.7	23.6	19.0	20.9	21.1 A
Mean	20.1 c	22.9 ab	20.6 bc	23.4 a	18.7 c	20.1 c	-
CV (%): plots = 6.1; subplots = 8.6							
Number of pods plant^{-1}							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	21.3	16.9	15.9	9.8	9.8	5.3	13.2 B
Two weedings	27.2	25.1	18.7	16.0	10.7	5.6	17.2 A
Mean	24.3 a	21.0 a	17.3 ab	12.9 bc	10.3 cd	5.4 d	-
CV (%): plots = 28.5; subplots = 34.2							
Number of grains pod^{-1}							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	15.7	16.2	15.9	16.5	15.9	17.0	16.2 A
Two weedings	15.9	15.7	16.4	17.1	15.8	16.3	16.2 A
Mean	15.8 b	16.0 ab	16.2 ab	16.8 a	15.8 ab	16.6 ab	-
CV (%): plots = 3.7; subplots = 4.4							
Dry grain yield (kg ha^{-1})							
Weed management	Directional selection						Mean
	High competitive ability			Low competitive ability			
	Umarizal	Itaú	Upanema	Mossoró	Santa Cruz	São Miguel	
One weeding	1,298	1,127	962	741	570	342	840 A
Two weedings	1,509	1,599	1,066	1,253	589	379	1,066 A
Mean	1,404 a	1,363 a	1,014 ab	997 ab	580 bc	361 c	-
CV (%): plots = 34.7; subplots = 35.9							

[1] Within each characteristic and within each group of treatments, mean values followed by the same lowercase letter in the rows and the same uppercase letter in the columns do not differ at 5% probability by Tukey's test

three varieties selected for superior yields, and two of the three selected for lower yields behaved as expected. Therefore, out of six attempts, five were successful.

CONCLUSIONS

1. The Umarizal, Itaú, Upanema and Mossoró varieties were the best for green-grain production, with the first two also being superior in the production of dry grain;
2. Of the six varieties preliminarily selected as having high or low competitive ability in terms of dry-grain yield, four showed consistent behaviour in the second evaluation. In terms of green-grain yield, a similar consistency was seen in five varieties;
3. In terms of the effect on the yields under evaluation, there was no difference in the number of weedings.

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