RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação
DOI: https://doi.org/10.18554/rbcti.v6i2.5842

Research paper

Characteristics of production and bixin content in annatto (*Bixa orellana* L.) genotypes according to propagation methods

Características de produção e teor de bixina em genótipos de urucueiros (Bixa orellana L.) em função da propagação

Everardes Públio Júnior[1]; Tiyoko Nair Hojo Rebouças[2]; Abel Rebouças São José[2]; Ivan Vilas Boas Souza[3]; Nilma Oliveira Dias[4]

[1]Professor at the Federal Institute of Bahia, Campus Brumado, Bahia, Brasil. Orcid: 0000-0003-1626-0555. E-mail: everardespublio@ifba.edu.br
[2]Professor at the State University of Southwest Bahia, Campus Vitória da Conquista, Bahia, Brasil. Orcid: 0000-0002-9341-9577; 0000-0002-3179-243X. E-mail: tiyoko@uesb.edu.br; abeljose3@gmail.com
[3]State University of Southwest Bahia, Campus Vitória da Conquista, Bahia, Brasil. Orcid: 0000-0001-8064-2449 E-mail: ivanvbsouza@gmail.com
[4]Municipal Secretariat for Rural Development of Vitória da Conquista, Vitória da Conquista, Bahia, Brasil. E-mail: nodias@gmail.com

ABSTRACT: The annatto (*Bixa orellana* L.) is a perennial plant, characteristic of the Amazon region, belonging to the Bixaceae family. Its economic interest is due to the seed's specific reddish pigment, bixin. Its market corresponds to approximately 90% of the total consumption of natural dyes in the country. Given its economic and social importance, the objective of this study was to evaluate the production characteristics and bixin content in annatto genotypes, seeking a better propagation method and a more productive genotype. The experiment was conducted on a farm in Porto Seguro-BA; the treatments were formed by two genotypes, which were multiplied via asexual and sexual; the design was randomized blocks in a 2x2 factorial scheme, with 5 replications and 7 useful plants per plot. The harvests were carried out 350, 498 and 669 days after planting, when a qualitative analysis of the dehiscence of the capsules was made and the number of monocasia per plant was counted; monocasians were collected and subsequently determined the number of capsules per monocasium; length (cm) and width (cm) of the capsules; number of seeds per capsule; mass of one hundred grains; bixin content; grain yield and total bixin yield. The data obtained were compared by Tukey test at 5% probability. The genotypes show capsule dehiscence; with the physiological maturity of the plant, the production characteristics do not show differences between the genotypes and between the propagation forms; the genotypes had bixin content higher than the national average.

Keywords: Natural Dye, Annatto, Breeding.

RESUMO: *O urucueiro (Bixa orellana L.) é uma planta perene, característica de região amazônica, pertencente à família Bixaceae. Seu interesse econômico é devido ao pigmento avermelhado específico da semente, a bixina. Seu mercado corresponde a, aproximadamente, 90% do total do consumo de corantes naturais no país. Diante de sua importância econômica e social, o objetivo deste estudo foi avaliar as características de produção e teor de bixina em genótipos de urucueiros, buscando o melhor método de propagação e o genótipo mais produtivo. O experimento foi conduzido em uma fazenda no município de Porto Seguro-BA; os tratamentos foram formados por dois genótipos, os quais foram multiplicados via assexuada e sexuada; o delineamento foi em blocos ao acaso em esquema fatorial 2x2, com 5 repetições e 7 plantas úteis por parcela. As colheitas foram realizadas aos 350, 498 e 669 dias após plantio, quando foi feita análise qualitativa da deiscência das cápsulas e contado o número de monocásios por planta; os monocásios foram colhidos e posteriormente, determinados o número de cápsulas por monocásio; comprimento (cm) e largura (cm) das cápsulas; número de sementes por cápsulas; massa de cem grãos; teor de bixina; produtividade de grãos e produtividade total de bixina. Os dados obtidos foram comparados pelo teste de Tukey a 5% de probabilidade. Os genótipos apresentam deiscência das cápsulas; com a maturidade fisiológica da planta, as características de produção não apresentam diferenças entre os genótipos e entre as formas de propagação; os genótipos apresentaram teor de bixina superior à média nacional.*

Palavras-chave*: Corante Natural, Urucum, Melhoramento Genético.*

Revista Brasileira de Ciência, Tecnologia e Inovação DOI: https://doi.org/10.18554/rbcti.v6i2.5842

INTRODUCTION

Annatto (*Bixa Orellana* L.) is a plant of pre-Columbian culture native to Tropical America. It belongs to the botanical family Bixaceae. It is cultivated in tropical regions, known and used since ancient times by indigenous peoples, who used the seeds to paint their skin as a form of ornamentation and as protection against sunlight and insects (FALESI, 1987).

A perennial shrub, annatto has seeds coated with a red carotenoid called bixin, a pigment of high value in national and international markets, mainly in the food sector, due to the demands of the consumer market to replace artificial dyes with natural ones (CORLETT; BARROS; VILLELA, 2007). According to Fabri and Teramoto (2015), its low production cost and toxicity make this pigment extremely attractive for replacing many synthetic dyes.

Playing a crucial role in the socioeconomic development of the Northeast Region of Brazil, it is of enormous importance since 78.2% of its cultivation comes from family farming under rainfed conditions with reduced implantation costs when compared to other cultures (ANSELMO; CAVALCANTI-MATA; RODRIGUES, 2008).

The cultivation of annatto occurs exclusively for the commercialization of the dye present in the seeds. At the time of commercialization, the industry required a bixin content of at least 4.0%. However, many producers cannot reach this percentage, thus limiting the expansion of exports and compromising Brazilian competitiveness in the international market (SANTANA, 2006).

Due to the great genetic variability and being a perennial species, vegetative propagation is a viable method for the multiplication of genetically superior individuals with high productivity and quality (CARVALHO; CARVALHO; OTONI, 2005). It allows the selection of high-yielding, fast-growing cultivars that flower early and abundantly, entering production at two years of age (KALA et al., 2015). However, plants propagated by seeds establish annatto plantations (KALA et al., 2015).

High-productivity clonal plantations represent a viable alternative to those of seminal origin established from the vegetative propagation of superior genotypes. These must present good results in productivity and pigment content, which evaluates these characteristics as fundamental (MANTOVANI et al., 2013).

The sustainability of annatto agribusiness is linked to research focused on the search for high productivity of monochasium per plant, seeds per pod, and high levels of bixin in the seeds (MANTOVANI et al., 2013).

The annatto presents wide variations of color, shape, and size of the fruits, seed productivity, and bixin content. Cross-pollination predomination between individuals, genotypes, and cultivation conditions are responsible for such variations (REBOUÇAS; SÃO JOSÉ, 1996). Vegetative propagation may reduce the variation in these characteristics allowing productivity increase and pigment content.

Based on the importance of the species Bixa Orellana L. and the grain quality demanded by the industry, this work was performed to evaluate the production characteristics and the bixin content in annatto genotypes seeking the best method of propagation and the most productive genotype.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação DOI: https://doi.org/10.18554/rbcti.v6i2.5842

MATERIAL AND METHODS

The experiment was conducted from March 2017 to February 2019, at Fazenda Sempre Viva, in the municipality of Porto Seguro-BA, Atlantic Forest region, with an altitude of 141m and geographic coordinates of 16° 23' South latitude and 39° 20' longitude West of Greenwich. The area is humid tropical, with no defined dry season, climate area Af by the Köppen classification. The average relative humidity of the air is 84.8%, the annual average temperature of 23.3°C, and the pluviometric index is around 1,260 mm.

Dias (2016) previously selected the plants used in the study in a commercial plantation of the cultivar Embrapa 37, from which two genotypes were selected with production attributes superior to the others. In addition, bixin production greater than 220 g plant-1 (122.2 kg ha-1), called genotypes A and B, were multiplied asexually (cuttings) and sexually (seeds).

The cuttings collected from the matrices were planted on the same day in 280 cm3 tubes (190 mm x 63 mm in diameter) with commercial substrate and taken to a greenhouse for approximately 30 days, after which they were placed in a nursery and were exposed to sunlight until they were ready for planting. The seeds were sown in 1,570 cm3 polyethylene bags with a substrate formed by subsoil soil and 5 kg of the formula 4-14-8 (N-P-K) for each m3 of soil and taken to the nursery, covered with a polyethylene screen with mesh that allows only 50% of the light to pass through until they are taken to planting. At approximately six months of age, the seedlings were planted in holes measuring 0.40 x 0.40 x 0.40 m at a spacing of 6 x 3 m; the soil has a loam-clay-sandy texture class **(Table 1**). The cultural treatments were according to the needs of the culture.

Table 1. Soil chemical analysis of the experimental area, Porto Seguro, BA, 2017

Depth (cm)	**pH**	**P**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H^+**	**Na^+**	**S.B.**	**t**	**T**	**V**	**m**
		$mgdm^{-3}$	**$cmol_cdm^{-3}$ de soil**									**%**	
01-20	5,5	1	0,2	2,1	1,2	0,1	5	-	3,5	4	8	42	3
20-40	5,8	1	0,2	2,7	1,2	0,1	3	-	4	4	7	57	2

For P and K, Mehlich Extractor was used; for Ca, Mg and Al, (1N KCl) was used; and for H + Al it was used (0.01M CaCl2 and SMP).

During the experiment, three harvests were made at 350, 498, and 669 DAP, resembling the first three harvests of the culture and period of pods maturation. At the moment of the harverst, a qualitive analysis of pod dehiscence occurred, and the number of monochasia per plant was counted, which were collected and taken to the Biofactory laboratory at the State University of Southwest Bahia for seed moisture determination (%), counting the number of pods per monochasium and verification of pod length (cm) and width (cm) to obtain their shape (relationship between length and width, oval = width equal to or greater than 70% of the length, and lanceolate = width less than 70% of the length). According to the methodology described by Mantovani et al. (2013), the number of seeds per pod, the mass of one hundred grains, bixin content by the potassium hydroxide (KOH) method described by Yabiku and Takahashi (1991); grain yield (with 13% moisture) and total bixin yield expressed in kg ha-^{1}, according to the methodology described by São José et al. (1992).

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação
DOI: https://doi.org/10.18554/rbcti.v6i2.5842

The experimental design was in randomized blocks in a 2x2 factorial scheme (Two genotypes A and B formed the treatments and two forms of propagation, sexual and asexual), with five replications; each plot consisted of seven useful plants.

For statistical analysis, AgroEstat (BARBOSA; MALDONADO JR, 2010) and Assistat (SILVA; AZEVEDO, 2009) software were used.

The data from the 1st harvest, as they did not present data from the Seed B treatment, were not analyzed in a factorial scheme, considering three different treatments. The data obtained were submitted to tests of homogeneity and normality. The values of the productivity of the variable in the 1st harvest and monochasium per plant, grain yield, and bixin yield in the 3rd harvest were transformed into $\sqrt{x}$, as they did not present normality of the data. Analysis of variance (ANOVA) was performed using the F test to compare the means using the Tukey test at 5%.

RESULTS AND DISCUSSIONS

At harvest time (350, 498, and 669 DAP), completely dry pods showed dehiscence for all treatments. The fruit of the Embrapa 37 cultivar, when ripe, usually opens and shows seeds drop when dry (POLTRONIERI et al., 2001; FRANCO et al., 2008; DIAS et al., 2017). Pod dehiscence may favor seed loss and bixin degradation due to exposure to light and moisture (DIAS, 2016).

In the first harvest, at 350 DAP, the Seed “B” treatment did not produce fruits, demonstrating that this treatment has a late production concerning the other treatments. Still, in the first harvest, according to the classification proposed by Mantovani et al. (2013), the treatment Cutting “A” presented pods in the oval shape (73%), with the ratio between length and width equal to or greater than 70%, while treatments Seed “A” and Cutting “B” presented a lanceolate shape. Dias et al. (2017) also observed his variation concerning fruit morphology in genotypes of Embrapa 37 cultivar. In the other harvests (498 and 669 DAP), all treatments showed oval-shaped pods greater than 70%. Poltronieri et al. (2001) and Franco et al. (2008) describe pods of Embrapa 37 cultivar as conical and flattened. Dias (2016) found lanceolate and oval shapes for parents A and B, respectively. Fruit morphological characteristics are a useful tool for determining the genetic variability of annatto cultivars (NISHA; SIRIL, 2014).

The analysis of variance data for the other treatments at 350 DAP showed a statistical difference only for the variable bixin content. Among the treatments studied, statistically, Cutting B presented the highest bixin content different from the treatment “Seed A” (**Table 2**).

Bixin contents ranged from 3.61% (Seed A) to 4.32% (Cutting B). The means of the genotypes propagated by cuttings did not differ significantly. Dias et al. (2017), working with the same cultivar and in the same region of this study, found levels between 2.99 and 5.02% of bixin.

Cultural management, environmental conditions such as humidity, light, temperature, and genetic variability (DIAS et al., 2017) are responsible for the fluctuations in bixin levels for the same cultivar, especially in plantations with seedlings. spread by seed.

The results of the second and third harvests (498 and 669 DAP) showed a statistical difference only in the second harvest for the genotype factor, observed in the monochasia variables per plant and grain yield.

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação
DOI: https://doi.org/10.18554/rbcti.v6i2.5842

Table 2. Production characteristics, monochasium per plant, pods/monochasium, number of seeds per pod, 100 grains mass, bixin content, grain yield, and bixin yield according to annatto genotypes propagation at 350 DAP. UESB, Vitória da Conquista – BA, 2018

Characteristics	Cutting "A"		Seed "A"		Cutting "B"	
Monochasium per plant	7,60	a	6,27	a	9,16	a
Pods / Monochasium	8,67	a	6,61	a	8,51	a
Number of seeds per pod	34,56	a	40,00	a	36,81	a
Mass of 100 grains (g)	2,10	a	1,89	a	1,96	a
Bixin content (%)	3,93	ab	3,61	b	4,32	a
Grains productivity[1] (kg ha^{-1})	(4,19) 19,28	a	(3,27) 14,06	a	(4,76) 30,79	a
Bixin productivity (kg ha^{-1})	0,78	a	0,50	a	1,30	a

The means followed by the same letter, in the line, do not differ statistically from each other, by the Tukey test, at the 5% probability level. 1For analysis, data were transformed into (√x).

Genotype “A” presented higher production of monochasium per plant as opposed to genotype “B” (**Table 3**). It is an important characteristic in annatto breeding since the greater number of monochasium will directly influence the greater production per hectare.

Table 3. Production characteristics, the weight of 100 grains, monochasium per plant, number of seeds per pod, grain yield, bixin content, and bixin yield, as a function of the propagation of annatto genotypes at 498 and 669 DAP. UESB, Vitória da Conquista – BA, 2018

Harverst	Characteristics	Genotypes				Propagation			
		A		B		Cutting		Seed	
2ª	Mass of 100 grains (g)	2,76	a	2,74	a	2,72	a	2,78	a
3ª	Mass of 100 grains (g)	2,47	a	2,43	a	2,47	a	2,43	a
2ª	Monochasium per plant	46,37	a	36,8	b	40,48	a	42,68	a
3ª	Monochasium per plant [1]	(4,66) 24,04	a	(3,82) 16,87	a	(4,75) 25,51	a	(3,74) 15,40	a
2ª	Number of seeds per pod	40,59	a	37,15	a	40,37	a	37,37	a
3ª	Number of seeds per pod	46,33	a	45,14	a	44,93	a	46,53	a
2ª	Grains productivity (kg ha^{-1})	240,11	a	149,55	b	204,75	a	184,91	a
3ª	Grains productivity[1] (kg ha^{-1})	(9,82) 115,07	a	(8,05) 86,54	a	(10,70) 142,32	a	(7,17) 59,30	a
2ª	Bixin content (%)	4,73	a	4,65	a	4,74	a	4,64	a
3ª	Bixin content (%)	4,03	a	4,06	a	4,14	a	3,95	a
2ª	Bixin productivity (kg ha^{-1})	11,29	a	7,02	a	9,74	a	8,56	a
3ª	Bixin productivity[1] (kg ha^{-1})	(2,68) 8,71	a	(2,20) 6,53	a	(2,97) 11,05	a	(1,91) 4,19	a

The means followed by the same letter for the factor in the line do not differ statistically from each other by Tukey's test at the 5% probability level. 1For analysis, data were transformed into (√x).

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação DOI: https://doi.org/10.18554/rbcti.v6i2.5842

Still, in the second harvest, the grain yield of genotype “A” surpassed that of genotype “B” by 90.56 kg ha-1. Between the levels of the propagation factor, no statistical difference occurred while the treatment propagated via asexual means presented grain yield greater than 10% than the treatment via sex.

An average reduction of 48.2% in grain yield per hectare occurred as opposed to the 2nd harvest, probably due to the 3rd harvest having taken place in January and flowering between September and October of the previous year. Annatto flowers practically throughout the year, with the most significant harvest occurring in June/July and a second harvest, in the off-season, between November/December (FRANCO et al., 2008).

Commercial annatto plantations increase the plant numbers in production each year, in addition to the production per plant (FABRI et al., 2015). Maximum yield occurred between 4 and 10 years of age, followed by a gradual yield decline (MATH et al., 2016). Spacing, growing conditions, management practices, and variety influenced yield variation (KALA et al., 2015).

Annatto plants produce between 300 and 600 kg ha-1 and can reach 750 to 900 kg ha-1. A 3-year-old plant, on average, can produce about 0.5 to 1.0 kg of seeds per year (Math et al., 2016). In a 4-year-old plantation of the Embrapa 37 cultivar, Dias (2016) found plants whose productivity was between 561.10 and 2,649.40 kg ha-1, with an average of 1,173 kg ha-1. In the present work, plants aged one year and four months produced an average of 194.83 kg ha-1. According to Franco et al. (2008) and Poltronieri et al. (2001), plants of the cultivar Embrapa 37 produce an average of 2.5 kg dry seeds/year, equivalent to 2777.5 kg ha-1.

The bixin content showed no statistical difference between treatments for the two harvests, which displayed contents between 3.95 and 4.74%. In the three harvests carried out and in all treatments, bixin levels occurred above the national average, which according to Fabri and Teramoto (2015), remains around 3.5%. Similar results were found by Moreira et al. (2014), working with the cultivar Embrapa 37 in the same region as the present study; for these authors, this cultivar stood out from the other treatments, with higher bixin levels (4.83±0.61%), which were significantly different from all other treatments. Also, according to the authors, EMBRAPA genetically improved and developed this cultivar in 2001, which has the highest level of bixin.

The results of the variance analysis for the third harvest (669 DAP) show that an interaction of the factors of the variables pods/monochasium occurred, the mass of 100 grains, and bixin content.

The analysis of the interaction of the components (**Table 4**) shows that the pods/monochasium variable presented better results for genotype A and genotype B when cuttings propagated the first and seeds the latter. The 100-grain mass showed minor results for genotype B when propagated by seed, with no statistical difference between the others, including the bixin content, which showed less significant results only for the A genotype when propagated by seed. These results prove the genetic variability in the annatto crop, especially in plants propagated by seeds.

Revista Brasileira de Ciência, Tecnologia e Inovação
DOI: https://doi.org/10.18554/rbcti.v6i2.5842

Table 4. Results of the comparison of means for the production characteristics, pods/monochasium, weight of 100 grains, and bixin content, derived from the interaction between genotypes and forms of propagation of annatto trees at 669 DAP. UESB, Vitória da Conquista – BA, 2019

Variables	Genotypes	Propagation	
		Cutting	Seed
Pods/monochasium	A	9,36 aA	5,37 bB
	B	6,62 bA	8,66 aA
Mass of 100 grains (g)	A	2,39 aA	2,54 aA
	B	2,55 aA	2,32 bB
Bixin content (%)	A	4,27 aA	3,79 aB
	B	4,02 aA	4,11 aA

Values followed by the same letter, lowercase in the column and uppercase in the same line, do not differ statistically from each other, by Tukey's test at the 5% probability level.

The results of the three harvests showed that the existing differences in the studied genotypes and the propagation forms occur mainly at the beginning of the plants' development, having no significance with the physiological maturity. For the same characteristic, climatic conditions culminated in differences observed between crops during the study period.

Cuttings propagated plants whose bixin content was higher than that demanded by the consumer market (4.0%) and close to those found in the parents, which shows that vegetative multiplication is an alternative to circumvent the genetic variability of this crop. Thus, clonal plantation formation with high grain and pigment productivity is possible from the parental selection with high productivity. Vegetative propagation by cuttings allows for high-yielding selection and fast-growing cultivars, which flower early and abundantly and produce fruit within two years (KALA et al., 2015).

CONCLUSIONS

The form of propagation of the seedlings does not interfere with the bixin content of the seeds. With the physiological maturity of the plants, the production characteristics do not show differences between genotypes. All genotypes, regardless of the form of propagation, presented bixin content above the national average.

REFERENCES

ANSELMO, G. C. dos S.; CAVALCANTI-MATA, M. E. R. M.; RODRIGUES, E. Comportamento higroscópico do extrato seco de urucum (*Bixa orellana L*.). **Ciência e Agrotecnologia**, v. 32, n. 6, p. 1888-1892, 2008. ISSN 1981-1829. DOI: https://doi.org/10.1590/S1413-70542008000600030.

BARBOSA, J. C.; MALDONADO JR, W. **Agrostat – Sistema para análises estatísticas de ensaios agronômicos. Versão 1.0**. Jaboticabal: Departamento de Ciências Exatas, 2010.

DOI: https://doi.org/10.18554/rbcti.v6i2.5842

CARVALHO, J. F. R. P.; CARVALHO, C. R.; OTONI, W. C. Regeneração *in vitro* de urucum (*Bixa orellana* L.) a partir de diferentes tipos de explantes. **Revista Árvore**, Viçosa, v. 29, n. 6, p. 887-895, 2005. ISSN 1806-9088. DOI: 10.1590/s0100-67622005000600007.

CORLETT, F. M. F.; BARROS, A. C. S. A.; VILLELA, F. A. Qualidade fisiológica de sementes de urucum armazenadas em diferentes ambientes e embalagens. **Revista Brasileira de Sementes**, v. 29, n. 2, p. 148-158, 2007. ISSN 0101-3122. DOI: https://doi.org/10.1590/S0101-31222007000200021 .

DIAS, N. O. **Seleção de genótipos da cultivar Embrapa 37 para produtividade e qualidade de urucueiros.** Tese (Doutorado em Fitotecnia) – Curso de Pós-graduação em Agronomia, Universidade Estadual do Sudoeste da Bahia, Vitória da Conquista, BA, 2016. 90 p.

DIAS, N. O. REBOUÇAS, T. N. H.; SÃO JOSÉ, A. R.; AMARAL, C. L. F. Morpho-agronomic characterization and estimates of genetic parameters in annatto plant. **Horticultura Brasileira,** v. 35, n. 2, 2017. ISSN 0102-0536. DOI: https://doi.org/10.1590/S0102-053620170214.

FABRI, E. G.; ABDO, M. T. V. N.; SALAZAR, F. F.; CORDEIRO JÚNIOR, P. S.; CHAVES, T. H. D.; MARTINS, A. L. M. *et al.* Production and carbon stock of annatto tree in agroforestry system, Pindorama, SP, Brazil. In: **XIV World Forestry Congress**, Durban, South Africa, v. 1, 2015. DOI: 10.13140/RG.2.1.3707.3124.

FABRI, E. G.; TERAMOTO, J. R. S. Urucum: fonte de corantes naturais, **Horticultura Brasileira,** v. 33, n. 1, 2015. ISSN 1806-9991. DOI: https://doi.org/10.1590/S0102-053620150000100023.

FALESI, I. C. **Urucuzeiro: recomendações básicas para seu cultivo**. Belém. EMBRAPA- UEPAE de Belém; Belém, PA: 1987. 27 p. (Documentos, 3).

FRANCO, C. F. O.; FABRI, E. G.; BARREIRO NETO, M.; MANFIOLLI, M. H.; HARDER, M. N. C.; RUCKER, N. C. de A. **Urucum Sistemas de Produção para o Brasil**. João Pessoa: Emepa, Apta, 2008. 112p**.**

KALA, S.; KUMARAN, K.; MEENA, H. R.; SINGH, K. Edible Dye for the Future: Annatto (*Bixa orellana* L.). **Popular Kheti**, v. 3, n. 3, p. 214-218, 2015. ISSN 2321-0001. Avaliable from: https://www.researchgate.net/publication/303735928_Edible_Dye_for_the_Future_Bixa_orellana_L. Accessed: 25 Sept. 2021.

MANTOVANI, N. C. GRANDO, M. F.; XAVIER, A.; OTONI, W. C. Avaliação de genótipos de urucum (*Bixa Orellana* L.) por meio da caracterização morfológica de frutos, produtividade de sementes e teor de bixina. **Ciência Florestal**, v. 23, p. 355-362, 2013. ISSN 0103-9954. DOI: https://doi.org/10.5902/198050989281.

MATH, R. G.; RAMESH, G.; NAGENDER, A.; SATYANARAYANA, A. Design and

RBCTI
Revista Brasileira de Ciência, Tecnologia e Inovação
DOI: https://doi.org/10.18554/rbcti.v6i2.5842

development of annatto *(Bixa orellana*, L.) seed separator machine. **Journal of Food Science and Technology**, v. 53, n. 1, p. 703-711, 2016. ISSN 0975-8402. DOI: https://doi.org/10.1007/s13197-015-2019-5.

MOREIRA, V. S.; REBOUÇAS, T. N. H.; MORAES, M. O. B. de.; SÃO JOSÉ, A. R.; SILVA, M. V. da. Atividade antioxidante de urucum (*Bixa orellana* L.) in natura e encapsulado. **Revista Iberoamericana de Tecnología Postcosecha,** v. 15, p. 201-209, 2014. Avaliable from: https://www.redalyc.org/articulo.oa?id=81333269011. Accessed: 25 Sept. 2021.

NISHA, J.; SIRIL, E. A. Evaluation and selection of elite annatto (*Bixa orellana* L.) and identification of RAPD markers associated with yield traits. **Brazilian Journal of Botany.** v. 37, n. 1, p. 1-8, 2014. DOI: https://doi.org/10.1007/s40415-013-0039-9.

POLTRONIERI, M. C.; MARTINS, C. da S.; RODRIGUES, J. E.; COSTA, M. R.; NAZARÉ, R. F. R. de. **Novas cultivares de urucum**: Embrapa 36 e Embrapa 37*.* Belém: Embrapa Amazônia Oriental, 2001. 21p. (Circular Técnica 22).

REBOUÇAS, T. N. H.; SÃO JOSÉ, A. R. **A cultura do urucum:** práticas de cultivo e comercialização. Vitória da Conquista, BA: DFZ/UESB/SBCN, 1996. 42p.

SANTANA, K. C. da. **Seleção de Genótipos de urucueiros (Bixa orellana L.) da Variedade Bico de Pato no Estado da Bahia.** Dissertação (Mestrado em Fitotecnia) - Curso de Pós-Graduação em Agronomia, Universidade Estadual do Sudoeste da Bahia, Vitória da Conquista, BA, 2006. 63 p.

SÃO JOSÉ, A. R.; ALMEIDA, E. C. de. PINHEIRO, A. L.; KATO, O. R.; OLIVEIRA, V. P. de. Características botânicas e de produção a serem avaliadas na pesquisa científica com urucum (*Bixa orellana* L.). **Revista Brasileira de Corantes Naturais**, v. 1, n. 1, p. 7-10, 1992. ISSN 0104-0723.

SILVA, F. de A. S.; AZEVEDO, C. A. V. de. Principal components analysis in the *software* Assistat-Statistical Attendance. In: World Congress on Computers in Agriculture, 7, 2009, Reno. **Anais …** American Society of Agricultural and Biological Engineers, 2009. 1CD-ROM.

YABIKU, H. Y.; TAKAHASHI, M. Y. Avaliação dos métodos analíticos para determinação da bixina em grãos de urucum e suas correlações. In: Seminário de Corantes Naturais para Alimentos, 2, Simpósio Internacional De Urucum, 1991. **Anais**... Campinas: ITAL, 1991. p. 275-279.

Received on: 2021/09/27
Approved on: 2022/05/17