Description of cultivar

Agrosavia La 22: First variety of arracacha in Colombia

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Abstract

In Colombia, about seven regional materials are grown in monoculture and occasionally in associate, the cycle is annual and without planting seasonality, allowing harvesting throughout the year. Production is low with yields ranging from 7 to 13 t ha^{-1} and phytosanitary problems are presented in addition to the presence of commercial roots with unwanted purple pigmentations in the commercialization. In order to offer new genotypes, increase yields and meet the demand for yellow tuberous roots, the variety Agrosavia La 22 is obtained that preserves the color of the root and is the first genotype of this species to be registered in the national register of crops in Colombia. Agrosavia La 22 is the result of the selection of plants from sexual seed that were generated after the process of cross-pollination of accessions preserved in the germplasm bank in Colombia. Qualitative and quantitative descriptors of complete plant, leaf, seed, stem and tuberous root were used, as well as yield variables. After five evaluation cycles the results show that this variety has completely yellow roots, experimental yields of commercial roots of 33.48 t ha^{-1} and non-commercial of 1.31 t ha^{-1}. On average a plant has nine commercial roots, each with an average weight of 271 g, 15 propagules per plant and tolerance to pests and diseases compared to commonly used genotypes.

Keywords: *Arracacia xanthorrhiza*, germplasm, tuberous roots, yellow root, yield.

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The arracacha '*Arracacia xanthorrhiza* Bancroft' belongs to the family Apiaceae, it is considered the only domesticated umbel in South America (Hermann, 1997) and the Andean region is its center of origin (Rueda, 1992). It is mainly planted in South American countries and is known as arracacha, celery, white carrot or racachu in different countries of Andean region and manioc-sauce in Brazil (Dos Santos, 2004). The greatest genetic diversity has been reported in species of the *Arracacia* genus in Colombia where conservation has been favored by various ethnic groups and indigenous cultures that cultivated it for sale or self-consumption (Vásquez *et al*., 2004; Madeira and Ferreira, 2016).

Some authors describe it as a perennial plant, but others consider it annual due to the use in production of tuberous roots (Garnica-Montaña *et al*., 2021). Generally, the production cycle is between 10 and 14 months depending on the altitude zone in a range of 400 to 3 600 meters above sea level (msnm), the ideal altitude in the tropic is 1 500 to 2 500 meters above sea level (Hermann, 1997).

A. xanthorrhiza consists of four parts: the aerial part comprises compound leaves and asexual propagules or seeds attached to a modified stem called strain or crown and, in the underground, the tuberous roots that have white, yellow, orange and purple colors generally develop.

Although all organs are used, this species is mainly cultivated by the tuberous roots used in human food which, have a high nutritional value due to its protein content, nutrients such as Ca, P and Fe and vitamins A, B and C, are easily digestible, provide energy associated with the high content of starch (25%) and they are considered a functional food (Leidi *et al*., 2018; Pinto-Acero *et al*., 2019). In South America they are traditionally used to cook soups, stews, puree, breads, biscuits and drinks (Albano *et al*., 2014).

Sexual reproduction is scarce and dependent on environmental conditions and genotype (Knudsen, 2003). Bell and Constance (1966) reported that *A. xanthorrhiza* is diploid with conformation 2n= 2x= 44 base number n= 22, this condition also appeared in the wild species *Tauschia* to which it is closely related. Moreover, Morillo *et al*. (2004) proposed the species as tetraploid with conformation 2n= 4x= 44 and with base number n= 11 according to the chromosome count and the karyotype, manifesting that 'it is a tetraploid species possibly diploid, so it recommends analyzing the data as a true diploid'.

Globally, Colombia ranks as the second largest producer after Brazil, reporting for 2018 a total of 9 653 ha planted in 15 departments with an average yield of 9.3 t ha^{-1} and a production of 110 058 t; however, about 60% are concentrated in the department of Tolima (MinTIC, 2018). The production system has agri-food, economic and social importance, in many regions between 0.5 to 20 ha are planted, associated with family labor and various production systems (maize, vetch, beans and others), the crop is considered important for food safety (Alvarado and Ochoa, 2010).

Although there is significant genetic diversity in Colombia, one of the main limits in production is the low availability of commercial genotypes. Muñoz *et al*. (2015) report that the regional crop 'common yellow' represents 80% of the planted area in Boyacá and 95% in Tolima, department with the largest planting areas.

This genotype has yields of 10 t ha^{-1}, purple pigmentation of roots at 10%, foliage diseases caused by fungi *Colletotrichum* sp., *Alternaria* sp. and *Cercospora* sp., and pest insects such as trips and aphids, factors considered limiting for producers and marketers, taking into account market demands based mainly on yellow tuberous roots for fresh consumption.

To respond to these limitations, during the year 2013 AGROSAVIA initiated research to obtain a variety of high-performance, low production costs and completely yellow roots. Thus, during the year 2019, the Colombian Agricultural Institute (ICA) assigned the national register of crop to this new variety.

Origin and selection

Since 2013 the Colombian Agricultural Research Corporation-AGROSAVIA promoted research projects to respond to demands of production systems. Research was initiated in Tolima to obtain improved varieties that respond to market requirements and the biotic and abiotic conditions in the region (MADR, 2019) in the arracacha crop. The research process began with the selection of 21 accessions belonging to the nation's system of germplasm banks for food and agriculture (SBGNAA) by vegetative multiplication. In addition, a material from sexual seed was collected, completing 22 initial materials. All genotypes were selected for the yellow pigmentation of their tuberous roots.

Then, a clonal selection process was developed during different production cycles between 2013 and 2015 looking mainly for materials with yellow roots and high production. The result of this process was to identify the genotype from sexual seed as promising material, which was evaluated in 2016 where it was compared with two regional materials planted in the country, 'common yellow' and 'yolk'. To make comparisons between genotypes, an agronomic assessment test (PEA) was established in five locations as a requirement for the distribution and entry of a genotype into the national register of crops of the Colombian Agricultural Institute (ICA).

During 2017, the semi-commercial test was established in areas of 0.5 ha in three locations to corroborate the results obtained during the selection and evaluation process. With the PEA and the semi-commercial test, the stability of the root characteristic with yellow hue, adaptability of the material and its production were confirmed, some characteristics such as its tolerance to pests and diseases compared to the witnesses evaluated were confirmed. Finally, in 2019 the ICA granted the registration of Agrosavia La 22 by resolution No. 00015201 for the Andean natural region with altitudes between 1 200-1 800 meters above sea level, 1 800-2 200 meters above sea level and greater than 2,200 meters above sea level. It is emphasized that during the evaluation process the producers showed interest in the material and demand of the seed on an ongoing basis. Agrosavia La 22, is a variety product of cross-pollination of accessions flourished during 2011, described below.

The ILS 3915 mother plant, which was also able to act as a father, has yellowish green petiole with regularly distributed reddish purple and light-yellow tuberous root, also participated as possible parents, the accessions ILS3916 and ILS3917. The ILS 3916 accession has olive green petioles without secondary coloration and white main root with violet pigmentations and the ILS3917 has olive green petioles with purple stripes and light-yellow root.

Adaptation and yield

Adaptation and performance assessments were carried out on producer farms in the municipalities of Cajamarca and Ibagué, Tolima, located in the Andean area of Colombia, with an average annual rainfall of 826. 4 mm, average temperature of 18.1 °C, sandy soils and living area bmh-PM and bh-MB Regional Autonomous Corporation of Tolima (CORTOLIMA, 2006).

The promising material was collected as 'segregating', then went on to evaluation and selection cycles in batches of producers with different names. In 2013 the 22 genotypes were established at a height of 1985 meters above sea level and were planted as 'plot 22', during 2014 ten accessions selected by adaptation and production were planted, and it was established as 'plot 10' at 1955 meters above sea level and in 2015 the 10 materials were re-evaluated under contrasting conditions at a height of 2 800 meters above sea level. In 2016 it is selected for its good behavior and is planted with the name 'clone22' in a PEA along with regional materials, yolk and common yellow, in five locations of Cajamarca and Ibagué with altitudes of 1 796, 2 040, 2 063, 2 091 and 2 536 meters above sea level. In 2017, the semi-commercial test was established in an area of 0.5 ha in three locations located at 2 062, 2 127 and 2 159 meters above sea level. By field identification, the knowledge of producers and the acceptance of the name in the area they were called Agrosavia La 22.

Table 1 shows the behavior of Agrosavia La 22 during the five evaluation cycles mentioned above. There is important information about petiole with leaves, propagules weight or asexual seed and crown or strain weight in kg plant^{-1}, number of propagules and number of commercial roots per plant. The variety showed an average of 0.55 kg of aerial part (leaf) per plant, 1.08 kg of strain with 16 propagules weighing a total of 0.32 kg plant^{-1}. Commercial root yields ranged from 20 to 56 t ha^{-1} and plants developed between 6 and 14 tuberous roots. Non-commercial yield is between 0.99 and 2.87 t ha^{-1}. In Colombia the commercial roots are roots with a length and diameter greater than 8 cm and 3 cm respectively (CARC, 2014).

Table 1. Agrosavia La22 evaluation in five evaluation cycles in different locations in the municipalities of Cajamarca and Ibagué, Tolima, Colombia.

Year	Process	Altitude (m)	PAE	PPR	PCE	NPR	NRC	PRC	PRNC	CRT
			(kg plant^{-1})			(Num. plant)		(t ha^{-1})		
2013	22 genotypes	1 985	0.9	0.68	0. 2	20	14	56	0	yellow
2014	10 genotypes	1 955	1.33	0.73	1.67	23	7	31.32	2.19	yellow
2015	10 genotypes	2 800	0.15	0.23	1.78	15	6	20.12	1.19	yellow
2016	PEA (1 promising genotype, 2 witnesses)	1 796	0.98	0.28	1.37	16	7	29.26	1. 8	yellow
		2 040	0.25	0.19	1.14	15	12	47.12	1.28	yellow
		2 063	0.42	0.21	0.91	14	6	20.33	1.18	yellow
		2 091	0.48	0.18	0.89	12	12	40.58	2.87	yellow
		2 536	0.45	0.25	0.96	13	10	30.43	1.07	yellow

Year	Process	Altitude (m)	PAE	PPR	PCE	NPR	NRC	PRC	PRNC	CRT
			(kg plant^{-1})			(Num. plant)		(t ha^{-1})		
2017	Semi-commercial test	2 062	0.31	0.23	0.8	14	9	38.25	0.99	yellow
		2 127	0.31	0.24	0.96	16	11	23.75	1.09	yellow
		2 159	0.47	0.29	0.84	17	9	31.12	1.19	yellow

PAE= air part weight; PPR= weight of asexual seed or propagule; PCE= weight of crown or strain; NPR= number of propagules; NRC= number of commercial roots; PRC= commercial roots weight; PRNC= non-commercial roots weight; CRT= tuberous root color. Own elaboration.

Table 2 shows the results of the evaluation of the variety together with the common yellow and yolk regional crops, the first considered commercial material on the national market, but with the disadvantage of presenting purple tuberous roots and low yield (Alvarado and Ochoa, 2010). The results of the PEA allowed to know the behavior against the witnesses, where Agrosavia La22 was mainly noted for has the highest values in production of commercial tuberous roots (33.54 t ha^{-1}) which are completely yellow, in addition the number of propagules (14 propagules plant^{-1}) and commercial roots (9 roots plant^{-1}). Characteristics of great importance to the producer because they are directly associated with yield, income and also to seed collection for future production cycles.

Table 2. Production variables of the agronomic assessment test in five locations in Cajamarca and Ibagué, Tolima, Colombia.

Year	PAE	PPR	PCE	NPR	NRC	PIRC	LRC	DRC	PRC	PRRC	PP	PA
	(kg plant^{-1})			(Num. plant)		(g)	(cm)	(mm)	(t ha^{-1})		(%)	
Common yellow	0.25	0.11	1.16	9	7	52.43	7.2	32.62	17.43	2.62	8.9	91.1
Yolk	0.07	0.05	0.68	6	5	49.36	7.88	28.99	11.9	1.56	0	100
Agrosavia La 22	0.52	0.22	1.05	14	9	57.35	8.94	31.88	33.54	1.55	0	100

PAE= air part weight; PBRO= weight of asexual seed or propagule; PCE= weight of crown or strain; NPR= number of propagules; NRC= number of commercial roots; PINC= individual weight of tuberous root; LNC= tuberous root length; DNC= tuberous root diameter, PRC= commercial root weight; PRNC= non-commercial roots weight; PP= percentage of tuberous root with purple pigmentation; PA= percentage of yellow tuberous root.

Another of the features to highlight of this new variety of arracacha, is the little damage that presented by pests and diseases. The severity levels of *Alternaria* sp., *Cercospora* sp. and *Colletotrichum* sp. did not exceed on average 4. 06% in relation to regional materials, expressing tolerance to these phytopathogens. In relation to pests, the average number of adult individuals of trips and aphids per plant was determined, these sucking insects are usually found in high populations during the early stages of cultivation, however, Agrosavia La 22 had fewer individuals and less damage compared to the rest of the materials (Table 3).

Table 3. Severity (%) of diseases and abundance of pest insects in three yellow rooted genotypes.

Year	*Alternaria* sp.	*Colletotrichum* sp.	*Cercospora* sp.	Thrips	Aphids
	(%) severity			(Num. plant)	
Common yellow	6. 62	1. 44	0. 09	36. 4	20. 25
Yolk	3. 81	3. 34	0. 62	39. 76	13. 77
Agrosavia La 22	1. 73	0. 65	0. 04	26. 69	9. 25

According to the characteristics of the variety, it is recommended to establish a planting density of 20 000 plants ha^{-1} with a distance of 0.5 m between plants and 1 m between grooves and it is harvested between 9 and 13 months after planting. It develops in agroecological areas that have altitudes between 1 800 and 2 700 m, which have a mountain landscape, humid and very humid cold climate with wavy to broken reliefs and characterized by soils derived from volcanic ash, deep, permeable and sandy texture. Fits in maximum temperature conditions of 27 °C, minimum temperature of 9.3 °C, average temperature of 18.1 °C, average relative humidity of 84%, cumulative precipitation of 826.4 mm $year^{-1}$ with bimodal distribution, does not tolerate waterlogged soils and requires a lot of solar radiation.

Description of the variety

Qualitative characterization was carried out taking into account the list of descriptors developed by the International Potato Centre [CIP] 2004, conference (2006) and some adjustments of Agrosavia researchers in the species.

The Munsell Plant Tissue color chart was used to identify the pigmentation of each organ. Agrosavia La 22 has vigorous foliage with yellow green appearance and erect and intermediate growth habit. The plant has an average height of 52.97 cm, canopy layer of 93.7 cm, leaf length 23.88 cm, leaf width 22.66 cm and 46 petioles. The leaves have three or four pairs of elongated and acuminate leaflets, they have light green coloration on beam (5GY4/4, 5GY4/6, 5GY4/8) and green on the underside (5GY4/6, 5GY4/8, 5GY5/6, 5GY5/8) without secondary colorations and the edge of the leaflet is medium and deeply subsection.

The petiole is cylindrical, tubular, succulent and hollow, it has a yellowish green coloration (2.5GY6/6, 2.5GY6/8, 2.5GY7/6) with reddish coloration at the base (5RP3/8, 5RP4/6, 5RP4/8, 5RP3/10, 5RP4/10). The asexual seed or propagule is dark red-purple (5RP3/6, 5RP3/8, 5RP3/10, 5RP4/8, 5RP4/10), pink (5RP5/10) and grayish purple red (5RP5/8) with an average length, diameter and weight of 5.82 cm, 2.91 cm and 15.25 g respectively, the plant forms 13 viable propagules.

The stem is modified, thickened and rich in reserve substances. Tuberous roots have an average horizontal length of 21.2 cm, vertical of 12.9 cm and in total reach up to 3 kg in weight, it has a conical and irregular shape, has yellow external coloration (2.5Y8/6, 2.5Y8/4, 5Y8/6) without secondary colorations and the pulp is 100% yellow (2.5Y8/8, 5Y8/4, 5Y8/6, 5Y8/8), a cortical ring is cross-sectional. One plant produces on average 11 tuberous roots of which 81% is commercial, each commercial root has on average a diameter of 5.16 cm, 16 cm in length and weighs 266 g.

Arracacha flowering is evidenced by three moments: during establishment (79 DDS), formation of tuberous roots and after harvest (Garnica-Montaña *et al*., 2021). In the semi-commercial test flowering was presented in 3.8% of the total plants in Agrosavia La 22. A feature not evaluated but evident in field is the precocity of the plant because the harvest is between 30 and 60 days before 12 months, which should be corroborated with further investigation.

Previous features show that Agrosavia La 22 is an arracacha with productive potential, its high yields, its completely yellow hue and higher percentage of commercial roots could generate solution to the demands and needs of Colombian producers (Figure 1).

Figure 1. a) Agrosavia La 22-variety plant; b) commercial tuberous roots of Agrosavia La 22.

Conclusions

The first arracacha variety was registered in Colombia, yellow, high production and adapted to agroecological conditions of the Andean area that exceeded 40% the yield of the witness crops, the attributes of the new variety are: pigmentation of pulp of tuberous roots 100% yellow, 81% commercial tuberous roots and percentages not exceeding 2.5% foliar diseases caused by *Colletotrichum* sp., *Alternaria* sp. and *Cercospora* sp.

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