Trends in Horticulture (2022) Volume 5 Issue 2
doi:10.24294/th.v5i2.1816

ORIGINAL RESEARCH ARTICLE

Analysis of alternatives for the production of vegetative seed of *Arracacia xanthorrhiza* Bancroft in Tolima, Colombia

Liliana Margarita Atencio Solano*, Jorge Enrique Villamil Carvajal, Johanna Paola Garnica Montaña, Antonio María Martínez Reina

Corporación Colombiana de Investigación Agropecuaria - Agrosavia, Colombia. E-mail: latencio@agrosavia.co

ABSTRACT

The propagation of plant material in the arracacha crop is commonly done vegetatively through asexual seed, this activity has allowed its multiplication and conservation over time. The plant material available is of low quality, affecting the development and potential yield of the crop and therefore the producer's income. The objective of the research was to comparatively analyze two technologies for the production of arracacha seed: local technology and Agrosavia technology. The information for the local technology was obtained from surveys applied to farmers and the selection was made using the deterministic sampling technique, and for the Agrosavia technology through the recording of data and production costs in research lots at commercial scale. Descriptive statistics and calculation of economic return indicators were applied for the two situations. The results show that the use of quality seed allows obtaining higher seed production (251,559 unit ha^{-1}) and tuberous roots (25,875 kg ha^{-1}), being superior to local technology by 14% and 28% respectively; thus, the arracacha producer acquires greater economic efficiency by obtaining lower unit cost per kilo produced and better net income with a marginal rate of return of 316.45. The results achieved are useful for farmers, companies and entities that wish to produce quality seed and support the arracacha production system in Colombia.

Keywords: Asexual Seed; Quality; Production System; Arracacha; Propagation

ARTICLE INFO

Received: 10 April 2022
Accepted: 6 May 2022
Available online: 18 May 2022

1. Introduction

Arracacha (*Arracacia xanthorrhiza* Bancr.) is an important part of the food diet of the human population, due to its high nutritional value represented in the contribution of proteins, calcium, phosphorus, iron, carotenes, vitamins A, B and E[1,2]. In Colombia, the crop occupies an important position in the primary sector due to its planting area and participation in the gross domestic product (GDP). Durante 2019 was planted in 14 departments in a total area of 9,277 ha, which produced 101,604 t with an average yield of 8.5 t ha^{-1}, with the main producing departments being Tolima, Boyacá, Norte de Santander, Cundinamarca and Huila. The municipality with the largest planting area is Cajamarca (Tolima), which provides 53% of national production[3].

Three main arracacha materials are grown in Tolima: yema de huevo, cartagenera and amarilla común. The latter occupies 80–90% of the planted area and is characterized by high agronomic adaptation, good production of tuberous roots, which are yellow with purple pigmentation in the pulp and peel, a condition punished in the fresh consumption market[4,5].

For commercial purposes, the propagation of the arracacha crop is developed through asexual seed, commonly called: seed, propagule, son, shoot or sprout[5]. This type of propagation has been effective in the conservation and production of crops of different root and tuber species. Asexual reproduction uses a plant tissue or section obtained from the mother plant with great potential for cell differentiation[6], resulting in a rapid and effective multiplication of plants, without genetic variability[7].

Low quality propagation material affects crop development, yield potential[8] and producer income. In arracacha-producing areas in Colombia, vegetative seed comes from the same commercial production lots and the extraction process has an inadequate selection[9,10], favoring the dispersion of ntopathogens[11] and affecting crop development, production and quality of commercial roots[2].

This problem has been evidenced in different production regions of countries such as Brazil; for this reason, in Brazil and Colombia, seed production models have been developed that recommend the application of genetic, physical, health and physiological quality criteria to ensure the homogeneity of the material established in the field, health and increase in the production and quality of tuberous roots[12–14].

The objective of this work was to make a comparative analysis of the production technologies of vegetative seed of arracacha in Cajamarca (Tolima), considering the agronomic and economic component of the local production system and the technology recommended by Agrosavia in the framework of the National Seed Plan (2013–2018).

2. Materials and methods

2.1 Location

The present study was conducted in the municipality of Cajamarca, located in the central mountain range in the western part of the department of Tolima, in the altitudinal strip from 1,800 to 2,700 m, a life zone of very humid premontane forest and humid low montane forest, with an average temperature of 17.5 °C, average relative humidity of 84.7% and annual precipitation of 802.1 mm/year[5].

2.2 Agronomic component

Data collection: Two arracacha vegetative seed production technologies were analyzed for the regional material *Amarilla común* during 2015 and 2018. The implementation of descriptive and analytical methods was contemplated to define and compare the two systems.

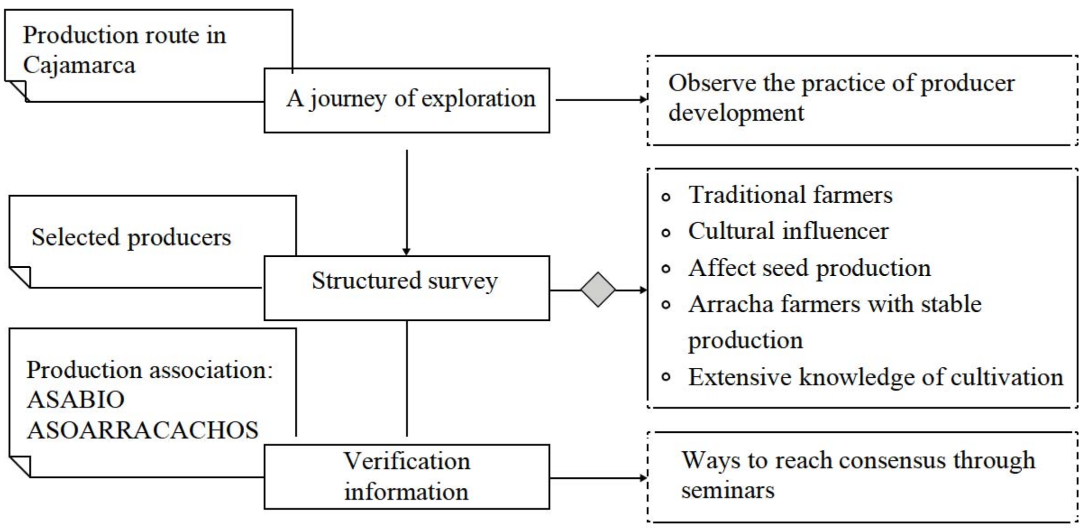

Figure 1. Methodological scheme for the capture of technical information of local arracacha seed production in Cajamarca, Tolima.
* The rhombus ◊ in the figure indicates the producer selection criteria.

Local technology: Corresponds to traditional management in the area; the information collected was obtained from farmers with experience in the production system and who had established commercial plots in the Ródano, Tigrera, Cucuana and Leona villages. The information was collected using the deterministic or non-probabilistic sampling technique[15] (**Figure 1**).

Agrosavia Technology: The information was obtained from the technological recommendations generated by the Colombian Corporation of Agricultural Research - Agrosavia, based on the results of research trials and field validation tests, during three production cycles in the Leona district, each with 12 months for common Amarilla.

Production variables: seed yield (%), seed yield per area (unit ha^{-1}), seed yield per plant (unit/plant), diseased seed (%), tuberous root yield (t ha^{-1}) and tuberous roots with purple pigmentation (%) were taken into account in the data collection for the two technologies.

Table 1. Parameters for the estimation of production costs, economic indicators and marketing margins in two product technologies of arracacha in Cajamarca, Tolima

Equation	**Where:**
$\sum_{Cd=0}^{n} Cd = Cd1 + Cd2 + Cd3 + \cdots + Cdn$	*Cd*: direct costs; Cd_1: seeds; Cd_2: agrochemicals; Cd_3: daily wages, etc.
$\sum_{Ci=0}^{n} Ci = Ci1 + Ci2 + Ci3 + \cdots + Cin$	*Ci*: indirect costs; Ci_1: land rental; Ci_2: financial costs; Ci_3: other, etc.
$CP = Cd + Ci$	*CP*: production costs; *Cd*: direct costs; *Ci*: indirect costs.
$\sum_{Rdo=0}^{n} Rdo = PC1 + PC2 + PC3 + \cdots + PCn$	*Rdo*: yield; *PC*: total production of tuberous roots per hectare.
$CU = \frac{CP}{Rdo}$	*CU*: unit costs; *CP*: production costs; *Rdo*: yield.
$IB = Rdo * PV$	*IB*: gross income; *Rdo*: yield; *PV*: selling price of tuberous roots production.
$IN = IB - CP$	*IN*: net income; *IB*: gross income; *CP*: production costs.
$RT = \frac{IB - Cd}{Cd} * 100$	*RT*: technical profitability; *IB*: gross income; *Cd*: direct costs.
$RN = \frac{IB - CP}{CP} * 100$	*NR*: net profitability; *IB*: gross income; *Cd*: production costs.
$Peq = \frac{CP}{PV}$	*Peq*: break-even point; *Cd*: production costs; *PV*: selling price.
$PPeq = \frac{CP}{IB} * 100$	*PPeq*: break-even percentage; *Cd*: production costs; *IB*: gross income.
$Et = \frac{PV}{CU} * 100$	*Et*: technical efficiency; *PV*: selling price; *CU*: unit costs.
$MBC = \frac{Pc - Pp}{Pc} * 100$	*MBC*: gross marketing margin; *Pc*: consumer price; *Pp*: producer price.
$PDP = 100 - MBC$	*PDP*: producer direct participation; *MBC*: gross marketing margin.
$MNC = \frac{MBC - Cm}{Pc} * 100$	*MNC*: net marketing margin; *MBC*: gross marketing margin; *Cm*: marketing costs; *Pc*: consumer price.

Source: Martínez-Reina *et al*.[20]

2.3 Economic component

For the two technologies, economic indicators were estimated based on the identification of production cost patterns[16], in which the main components are differentiated: unit, quantity, unit value (COP) and total value (COP) of direct, indirect and total costs. Labor was valued according to the agricultural daily wage in the region and the cost of inputs at field price (price paid by the producer for the purchase of the input, plus the cost of transportation to the farm), according to the methodology[17]. For the analysis of crop management activities, we used the methodology employed by Agreda[18]. With the information on yields in the two technologies, unit and return costs were calculated, as well as net income, profitability, break-even point and efficiency[19].

The price of tuberous root was calculated taking into account the average monthly value in the region (1,298 COP kilo^{-1}), this value was multiplied by the yield (Rdo) and the gross income (IB) was obtained. Thus, by subtracting the total production costs (COP) from the IB, the net income (IN) was calculated. Profitability was calculated by the IN/CT ratio. The break-even point (Peq) was also estimated, which is the minimum quantities required to produce to make income equal to costs (**Table 1**).

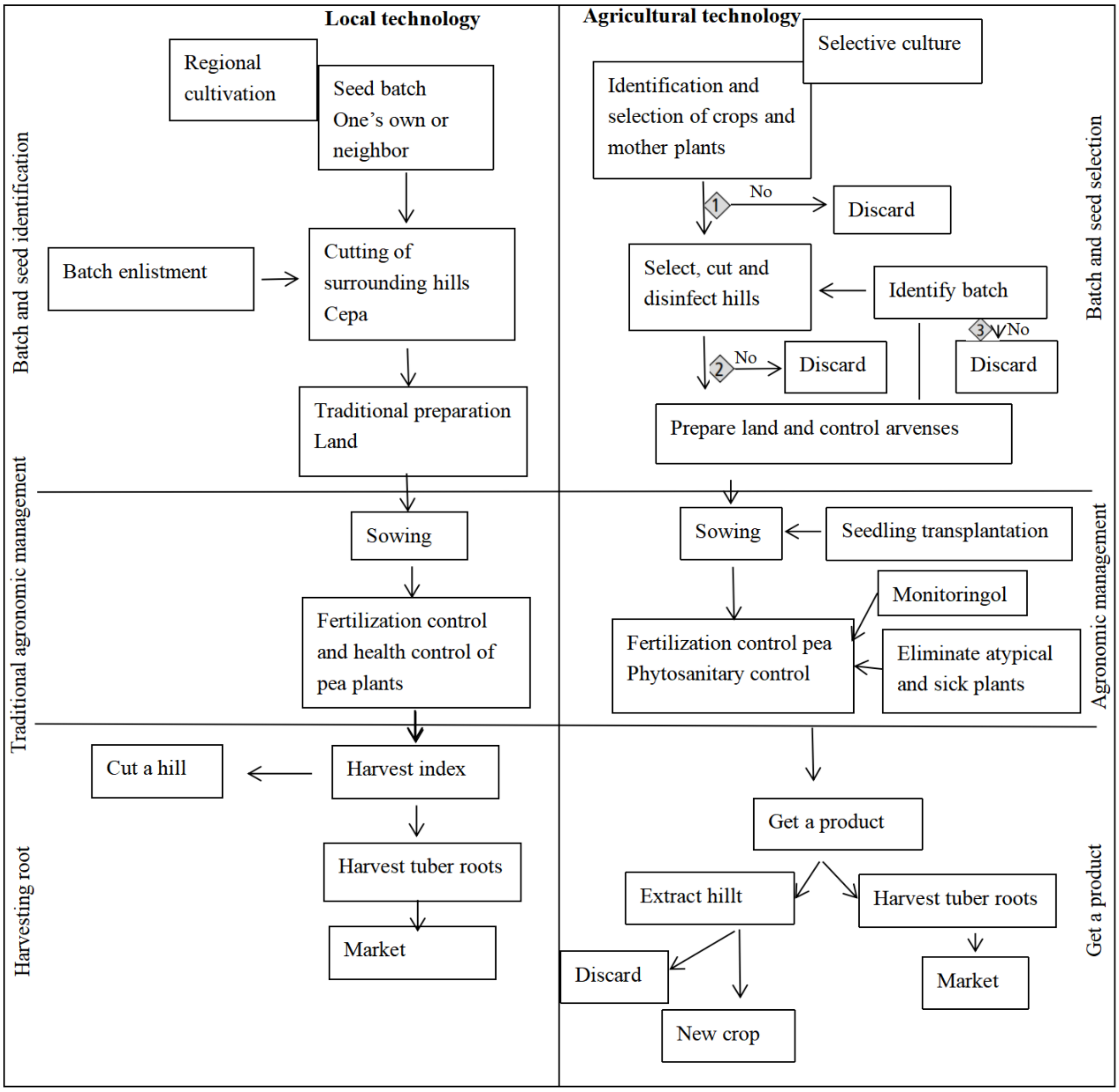

Figure 2. Scheme for two arracacha seed production technologies in Cajamarca, Tolima.

* The diamonds ◊ in the figure indicate that a decision must be made based on the criteria associated with the factor. 1. Does the mother plant meet quality criteria? 2. Does the seed meet quality criteria? 3. Does the lot meet the criteria for the production of arracacha seed?

Once the economic returns for the two production technologies were calculated, a comparative analysis was made, considered as a total pre-budget analysis and then applying the partial budget and marginal analysis[17]. The increase in net income (ΔIN) and the increase in variable cost (ΔCV) were determined from tuber root yields (kg ha^{-1}), field price (COP) and variable costs.

Yields were multiplied by prices, then, variable costs were subtracted and net income was obtained. The increases in net income (ΔIN) and the increases in variable costs (ΔCV) were related to give the Marginal Rate of Return which is the possibility of recovering the additional costs for the technology.

3. Results and discussion

3.1 Agronomic component

The study identified three stages for the two technologies analyzed: lot and seed identification, agronomic management and tuber root harvesting. These are defined with particular activities depending on the production technology (**Figure 2**).

3.1.1 Local technology

Batch and seed identification: According to the information provided by the farmers surveyed, the selection of the lot for planting is based on their empirical experience, without taking into account the incidence of soil pests and diseases, crop rotation and land fallow, which coincides with the findings of Alvarado *et al*.[9]. Meanwhile, seed production is derived from traditional practices, a factor that is common in other arracacha-producing areas.[10,21]

The seed is obtained from plants with a visually healthy aerial part, located in lots with undulating to broken relief, close to the tuberous roots, and its preparation does not include the extraction of the whole plant, so it is not possible to know the health status of the subway organs such as stock and tuberous roots, favoring the spread of pathogens[11]. In the end, the producer obtains seed without homogeneity in age, origin and quality.

Agronomic management. The production system does not have specialized technical assistance and much of the knowledge is passed down from generation to generation. Farming practices include fertilization without soil analysis and continuous drench applications, sanitary management without monitoring of canopy and soil populations, manual weed control and herbicide application close to harvest as a strategy to reduce production costs. These agronomic practices coincide with those documented in the work carried out in the department of Boyacá by Alvarado & Ochoa[22] and Muñoz *et al*.[23].

Harvesting. In the common yellow material, the tuberous roots are harvested at 12 months for the altitudinal range of 1,800 to 2,200 m a.s.l., and at higher altitudes after 13 months of age. In this technology, *the tuberous roots are the main product* and the vegetative seed is considered a by-product with no commercial value, which is why it is acquired by exchange or gift between farmers in a process of local mobilization (spontaneous flow) without applying selection criteria of genetic, physical, physiological and sanitary quality.

3.1.2 Agrosavia technology

Plot and seed selection. It is recommended to select plots with a slope greater than 30%, deep soils with sandy loam texture and good drainage, access to water, absence of production limiting weeds such as *Artemisia* spp, low pressure of pest insects such as chiza and nematodes identified by field diagnosis and microbiological analysis of the soil, lots with rest and crop rotation, avoiding planting in areas established in recent years with tomato and cabbage for sharing soil pathogens.

For obtaining asexual seed, the quality criteria set out in **Table 2** are followed, which are consistent with research on vegetative seed production models in Brazil by Madeira *et al*.[13] and Sousa-Balbino[14].

Agronomic management. The establishment prioritizes pre-rooted seed in seedbeds, after disinfection with 5% sodium hypochlorite and/or 2% agricultural iodine, to reduce losses of material and have homogeneity in the field. Crop nutrition is based on soil analysis, health management according to biweekly and monthly monitoring, which includes the elimination of atypical or diseased plants and weed control using herbicides in the early stages of growth and manual cleaning after root filling. According to Garnica *et al.*[5] and Sousa-Balbino[14], timely crop management following technical recommendations improves yield and ensures quality seed.

Obtaining products. Cultivation is directed with two purposes: semilla and quality tuberous roots. Seed with better yield, greater number per unit area and absence of health problems is achieved, and greater production of tuberous roots with lower percentage of purple pigmentation is obtained (**Table 3**)[12]. To promote the quality of the two products, product readiness activities (seed and tuberous roots) should be programmed in advance of harvest, considering the altitudinal location of the lot.

Table 2. Quality criteria for the selection of plants and seed in the arracacha amarilla común material, Cajamarca, Tolima

Criteria	Plants	Asexual seed
Genetic quality	• Characteristics of common yellow material • Homogeneous characteristics in the crop, without mixing of genotypes	Must correspond to the genotype to be sown
Physiological quality	• Vigorous between 10 and 14 months of age • No nutritional deficiencies • Not affected by water deficit	Round base selected from the periphery of the stock
Physical quality	• Height greater than 50 cm • Weight of tuberous roots between 2 and 2.5 kg • Plants with 30–45 petioles • Plants with 10–15 developed seeds • Internal tissues of seeds and tuberous roots without alterations in coloration. • No mechanical damage • Completely yellow tuberous roots	• Homogeneous characteristics • 2–3 distinct rings of the stock and 5–7 cm in length • Absence of violet pigmentations in internal tissues
Phytosanitary quality	• Leaf spots caused by Alternaria sp., Cercospora sp. and Colletotrichum sp. fungi should not exceed 5% severity. • Plants free of insect pests, virine worms, slugs, thrips, aphids, mites and soil diseases associated with fungi, bacteria and/or nematodes. • Strain without tissue alterations (watery rot or brown pigmentations)	Absence of damage associated with pests and/or diseases.

Source: Authors.

Table 3. Comparative analysis of production variables for two technological methods for obtaining arracacha seed in Cajamarca, Tolima, 2020

Variables	Local technology	Agrosavia technology
Yield (%)	90	95
Seed production (unit ha^{-1})	216,000	251,559
Seed production (unit/plant)	10	22
Diseased seeds (%)	5	0
Tuberous root production (kg ha^{-1})	18,625	25,875
Purple pigmentation of tuberous roots (%)	7	4

3.1.3 Production variables

The methodology applied to the two technologies made it possible to determine production indicators on the basis of which a comparative analysis was made (**Table 3**).

Agrosavia technology showed higher seed production per unit area (251,559 seeds ha^{-1}), 14% more (35,559 seeds) than the *local technology,* which allows the establishment of 12.6 ha on average and guarantees higher yield (95%), uniform plant population, higher yield and less purple pigmentation in tuberous roots (4%).

Similarly, the Agrosavia technology yielded a total tuberous root production of 26,953 kg ha^{-1}, of which 96% (25,875 kg ha^{-1}) corresponded to commercial roots and the remaining 4% (1,078 kg ha^{-1}) to non-commercial roots that were discarded due to the presence of purple pigmentation. In comparison with the *local technology* that achieved a total tuberous root production of 20,027 kg ha^{-1}, where, 93% (18,625 kg ha^{-1}) are commercial and 7%

(1,401.9 kg ha^{-1}) are discarded due to purple pigmentation.

The discussion of technologies focused on the production of arracacha seed; however, commercially the main product is the tuberous root. Under this condition, it is important to highlight that the seed currently has no commercial value, despite this, with the application of recommendations and the emergence of experts for seed production in the future, it could acquire economic value that would in turn represent an added value for the farmer, as happens in Brazil, where planting is generally done from seed selected with quality criteria, which has allowed high yields in production[13].

3.2 Economic component

Based on the production indicators, **Table 4** presents the economic analysis for the two technologies, based on 2020 prices (COP) for fresh tuberous roots and a population density of 16,666 plants ha^{-1}.

Table 4. Comparative analysis of costs and economic returns of two arracacha seed production technologies in Cajamarca, Tolima, 2020

Indicator	Local technology	Agrosavia technology
Labor (COP)	8,135,000	9,472,300
Inputs (COP)	1,435,450	2,210,034
Tools (COP)	898,400	898,400
Subtotal Direct Costs (COP)	10,468,850	12,580,734
Indirect Costs (COP)	2,032,820	2,180,651
Total Costs (COP)	12,501,670	14,761,385
Yield (kg ha^{-1})	18,625	25,875
Unit cost per kg (COP)	671	570
Sales price per kg (COP)	1,298	1,298
Gross Income (COP)	24,175,250	33,585,750
Net Income (COP)	11,673,581	18,824,365
Profitability (%)	93	128
Breakeven point (kg)	9,631	11,372
Percentage of break-even point	52	44
Efficiency	1.9	2.3

Source: Based on Garnica *et al*.[5]

The results show that both technologies are efficient in the commercial production of tuberous roots. The Agrosavia technology allows higher tuber root yields, with a difference of 7,250 kg ha^{-1}, compared to the local technology. In addition, unit costs in Agrosavia technology are lower, with a difference of 101 COP kg^{-1}, which allows a higher income (18,824,365 COP), achieving a favorable difference of 7,150,784 COP ha^{-1}. The break-even point is higher in the local technology, requiring 52% of production to recover production costs, compared to 44% in the Agrosavia technology, which represents economic advantages for the producer.

Marginal analysis is used in some situations when evaluating new technologies in order to proceed with a recommendation[17]. In this case, changes in net income and variable cost were taken, but it should be noted that only the components that changed and were related to changes in net benefit were taken into account. The changes in the net benefit were greater than the variable cost, while the variable cost changed by 2,259,716 COP ha^{-1}, the net benefits changed by 7,150,784 COP and the marginal rate of return was 316.45. This indicates that, for each monetary unit invested, an additional 2.16 COP is recovered and generated, which increases the net income with respect to the investment costs and makes Agrosavia technology viable (**Table 5**).

Table 5. Marginal analysis for two technological alternatives of arracacha production in Cajamarca Tolima, 2020

Indicator	IN	CV	ΔIN	ΔCV	TRM
Local technology	11,673,581	0	7,150,784	2,259,716	316,45
Agrosavia technology	18,824,365	2,259,716			

IN = Net Income, CV = Variable Cost, ΔIN = Increase in Net Income, ΔCV = Increase in Variable Cost.

However, Agrosavia technology incurs higher costs, which are compensated with better yields evidenced by a higher net income, i.e., every time the farmer incorporates this technology to local production, net income increases, which suggests making these changes to the arracacha production system in the region.

4. Conclusions

The arracacha crop in Cajamarca (Tolima) has an informal seed production system developed in three stages: lot and seed identification, traditional agronomic management and harvesting of tuberous roots, where there is a cultural approach based on spontaneous seed mobilization.

The production of quality seed requires the selection of lots with low pest and soil disease pressure and known history, seed selection from mother plants that meet genetic, physical, physiological and phytosanitary quality criteria, agronomic management with an agro-ecological approach and obtaining two products (tuberous roots and quality seed).

The mother plant is the main input for the production of quality seed, the main criteria that define the selection in the common yellow cv. are: vigorous plants free of insect-pests and diseases of the canopy and soil, without nutritional deficiencies and affectation by water deficit, completely yellow roots and without damage by nematodes.

The use of quality seed allows obtaining higher production of seeds ha^{-1} and tuberous roots, with less purple pigmentation, favoring the farmer's income.

Acknowledgments

To the National Seed Program, an inter-institutional agreement between the Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), the Instituto Colombiano Agropecuario (ICA) and the Servicio Nacional de Aprendizaje (SENA), for their support for the development and implementation of the project Consolidation of the core production of selected seeds of improved and regional varieties of arracacha in the Anaime canyon (Tolima) and other producing regions. To the Asociación de Productores de Semillas Andinas (ASABIO), the Asociación de Arracacheros de Cajamarca y Anaime (ASOARRACACHOS) and Juan Felipe Ossa Yepez for the translation of sections of the manuscript.

Conflict of interest

The authors declared no conflict of interest.

References

1. Guerra-Ávila D, González-Melo F, Alvarado-Gaona Á. Evaluation of production and commercial residues ofarracacha (Arracacia xhanthorriza Bance) in Boyacá-Boyacá. Ciencia y Agricultura 2012; 9(2): 77–86.
2. Pinto-Acero YL, Alvarado-Gaona AE, Burgos-Ávila YE, *et al*. Caracterización de tres genotipos de *Arracacia xanthorrhiza* Bancroft mediante parámetros morfológicos y de color (Spanish) [Characterization of three genotypes of *Arracacia xanthorrhiza* Bancroft using morphological and color parameters]. Revista Colombiana de Ciencias Hortícolas 2019; 13(3): 426–434.
3. Ministerio de Tecnologías de la Información y las Comunicaciones (MinTIC). Evaluaciones agropecuarias municipales EVA (Spanish) [Municipal agricultural evaluations EVA]. Datos Abiertos; 2019.
4. Garnica Montaña JP, Villamil Carvajal JE, Atencio Solano LM, *et al*. Caracterización fenotípica de tres cultivares regionales de arracacha (*Arracacia xanthorrhiza* Bancroft) en Tolima, Colombia (Spanish) [Phenotypic characterization of three regional cultivars of arracacha (*Arracacia xanthorrhiza* Bancroft) in Tolima, Colombia]. Ciencia y Agricultura 2021; 18(1): 1–20.
5. Garnica Montaña JP, Villamil Carvajal JE, Vargas Berdugo AM, *et al*. Modelo productivo de arracacha (*Arracacia xanthorrhiza* Bancr.): Agrosavia la 22 para la región andina de Colombia (Spanish) [Production model of arracacha (*Arracacia xanthorrhiza* Bancr.): Agrosavia la 22 for the Andean region of

Colombia]. Corporación Colombiana de Investigación Agropecuaria AGROSAVIA; 2021.
6. Vázquez Yanes C, Orozco A, Rojas M, *et al*. La reproducción de las plantas: semillas y meristemos (Spanish) [Plant reproduction: Seeds and meristems]. México D.F.: Fondo de Cultura Económica; 1997.
7. García Forero D. Protocolo para la propagación vegetativa de las especies Tabebuia rosea (bertol) DC. y Cordia alliodora (Ruíz & Pavón) Oken por medio de propagulos (Spanish) [Protocol for vegetative propagation of Tabebuia rosea (bertol) DC. and Cordia alliodora (Ruíz & Pavón) Oken species by means of propagules]. Colombia Forestal 2002; 7(15): 109–117.
8. Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO). Quality declared planting material. Protocols and standards for vegetatively propagated crops. In: FAO Plant Production and Protection Paper 195. FAO; 2010. p. 126.
9. Alvarado Gaona AE, Muñoz AL, Adame OE. Una aproximación al desarrollo rural, caso el cultivo de arracacha, en el departamento de Boyacá (Spanish) [An approach to rural development, case of the cultivation of arracacha, in the department of Boyacá]. Ingeniería y Región 2016; (16): 53–60.
10. Alvarado Gaona ÁE, Pita Morales LA. Agro-alimentary system of arracacha cultivation (*Arracacia xanthorrhiza* Bancroft), from the multifunctionality, municipality of Boyacá (Boyacá). Conexión Agropecuaria JDC 2016; 6(2): 19–31.
11. Orílio AF, Lucinda N, Dusi AN, *et al*. Complete genome sequence of arracacha mottle virus. Archives of Virology 2013; 158(1): 291–295.
12. Atencio Solano LM, Garnica Montaña JP, Vargas Berdugo AM, *et al*. Manual técnico para la producción de semillas de arracacha bajo condiciones agroecológicas del municipio de Cajamarca, Tolima (Spanish) [Technical manual for the production of arracacha semllas under agroecological conditions in the municipality of Cajamarca, Tolima]. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA); 2019.
13. Madeira N, Ferreira A, Da Silva G, *et al*. Proposição de um sistema de produção de mudas de mandioquinha-salsa (Portuguese) [Proposition of a production system for Peruvian carrot seedlings]. Circular Técnica; 2017.
14. Sousa-Balbino JM. Cultura da batata-baroa (mandioquinha-salsa): Práticas da produção à pós-colheita (Portuguese) [Baroa potato culture (Persian carrot): Production practices to post-harvest]. Vitória ES (editor). Brazil: Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural; 2018.
15. Rodríguez Osuna J. Métodos de muestreos (Spanish) [Methods of sampling]. Madrid: Centro de Investigaciones Sociológicas; 2005.
16. Molina NA, Acuña LE, Marmelicz LA. Costo de Producción y Rentabilidad del Ananá en la Provincia de Misiones (Spanish) [Cost of production and profitability of pineapple in the province of Misiones]. INTA EEA Bella Vista. Serie Técnica 2014; (47): 24.
17. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT). La formulación de recomendaciones a partir de datos agronómicos: Un manual metodológico de evaluación económica (Spanish) [The formulation of recommendations from agronomic data: A methodological manual of economic evaluation]. Mexico; 1988. p. 79.
18. Agreda V. Metodología para el análisis económico (Spanish) [Methodology for economic analysis]. In: Quijandria B, Ruiz ME (editors). Aspectos metodológicos del análisis social en el enfoque de sistemas de producción. Red de Investigación en Sistemas de Producción Animal en Latinoamérica-RISPAL Centro de Estudios y de Desarrollo Agrario del Perú; 1991. p. 93–124.
19. Martínez-Reina AM, Tordecilla-Zumaqué L, Cordero-Cordero C, *et al*. Technological and socioeconomic environment of yard long bean (*Vigna unguiculata* subsp. Sesquipedalis) in the Humid Caribbean of Colombia. Science and Agriculture 2019; 16(2): 7–24.
20. Martínez-Reina AM, Grandett-Martínez L, Tordecilla-Zumaqué L, *et al*. Análisis tecnológico y socioeconómico del sistema de producción local del frijol rosado Zaragoza (*Phaseolus vulgaris* L.) en el Caribe de Colombia (Spanish) [Technological and socioeconomic analysis of the local production system of Zaragoza pink bean (*Phaseolus vulgaris* L.) in the Caribbean of Colombia]. Revista Colombiana de Ciencias Hortícolas 2021; 15(1): 1–21.
21. Alvarado Gaona Á, Ochoa L. Local technologies of arracacha (*Arracacia xanthorrhiza* Bancroft) production at Boyacá, department of Boyacá. Revista Udca Actualidad & Divulgación Científica 2010; 13(1): 125–133.
22. Alvarado ÁE, Ochoa LE. Cultivo de arracacha (*Arracacia xanthorrhiza* Bancroft) en los municipios de Turmequé y Boyacá (Spanish) [Cultivation of arracacha (*Arracacia xanthorrhiza* Bancroft) in the municipalities of Turmequé and Boyacá]. Universidad pedagógica y Tecnológica de Colombia; 2010.
23. Muñoz AL, Alvarado AE, Almanza PJ. Preliminary characterization of arracacha *Arracacia xanthorrhiza* Bancroft crop in the department of Boyaca. Revista de Ciencias Agrícolas 2015; 32(1): 3–11.