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MORPHO-AGRONOMIC EVALUATION OF AIR POTATO (*Dioscorea bulbifera* L.) IN PANAMÁ

Evaluación morfoagronómica de la papa de aire (*Dioscorea bulbifera* L.) en Panamá

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ABSTRACT. The objective for this investigation was to test and validate a proposed technical-productive proposal for handling of *Dioscorea bulbifera* in very humid rainy tropics conditions of the district of Donoso, Panama, and ran for the years 2012 and 2013. The proposal was located in six peasant communities, in each of them three plots with 25 plants were set in each, managing three variants: traditional system, technical system 1 (planting frame 1,5 x 1,5 m) and technical system 2 (planting frame 2,0 x 2,0 m). From the effective monitoring of plots, it was possible to define the phenological stages of the crop, its adaptability to different climate and soil conditions, and the incidence of pests and diseases. Obtained yields fluctuate between 0,79 and 2,0 kg plant^{-1}, with an average of 1,18 kg plant^{-1} in the two years period. Considering yield per area, the average obtained was 3,82 t ha^{-1}. However, the best crop yields were achieved in the technical system 1, with an average of 5 t ha^{-1}. Crop yields of both technical system were always higher than those of traditional system, suggesting that the introduction of a certain level of technology contributes significantly to rising crop yields. Because of its low dependance of external supplies, its high plasticity, resistance to pests and diseases and high durability in stock, It concludes that, *D. bulbifera* has attributes to become a plant resource that can contribute to improve the food security of peasant communities in Panama.

Key words: climate, phenology, pests, crop yield, soil

RESUMEN. El objetivo de esta investigación fue ensayar y validar una propuesta de manejo técnico-productivo de *Dioscorea bulbifera* en las condiciones del trópico húmedo muy lluvioso de Donoso, Panamá; se ejecutó durante los años 2012 y 2013. La propuesta se ubicó en seis comunidades campesinas, estableciéndose tres parcelas de 25 plantas en cada una, manejando tres variantes: sistema tradicional, sistema tecnificado 1 (marco de siembra de 1,5 x 1,5 m) y sistema tecnificado 2 (marco de siembra de 2,0 x 2,0 m). A partir del monitoreo de las parcelas se logró definir las fases fenológicas del cultivo, su adaptabilidad a las condiciones de clima y suelo y la incidencia de plagas y enfermedades. Se obtuvo rendimientos que fluctuaron entre 0,79 y 2,0 kg planta^{-1}, con un promedio de 1,18 kg planta^{-1}, en los dos años. En cuanto a los rendimientos por superficie, el promedio obtenido fue de 3,82 t ha^{-1}. No obstante, los mejores rendimientos por superficie se alcanzaron en el sistema tecnificado 1, con un promedio de 5 t ha^{-1}. Los rendimientos de las parcelas tecnificadas siempre fueron superiores a los de las parcelas tradicionales, lo cual sugiere que la introducción de cierto nivel de tecnificación contribuye, de manera importante, a la elevación de los rendimientos. Por su baja dependencia de insumos externos, su gran plasticidad, su resistencia a plagas y enfermedades y su alta durabilidad en almacén, se concluye que *D. bulbifera* reúne atributos para convertirse en un fitorecurso, que puede contribuir a mejorar la seguridad alimentaria de comunidades campesinas en Panamá.

Palabras clave: clima, fenología, plagas, rendimiento, suelo

INTRODUCTION

The dioscoreaceas are an important food source and are distributed in tropical, subtropical and temperate regions worldwide. The genus *Dioscorea* spp., which belong most cultivated and wild species of the family, includes tropical species originating from Africa, Asia and America (1). Within this genus, edible and commercially valuable species are *Dioscorea alata* (yam), *D. rotundata*, *D. esculenta*, *D. trifida* and *D. bulbifera* (2).

Dioscorea bulbifera is a climbing plant that can reach up to six meters or more in length. It produces basal tubers; however, "bulbils" (or aerial tubers) growing at the base of its leaves are the most important food product.

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By doing a quick review by the Latin American geography, the presence of D. bulbifera was found in peasant plots; where as in other developing countries, species such as yams have a significant importance in family farming, being used primarily as a source of carbohydrate, especially in the region where they reside communities with low purchasing power (3).

The presence and use of *D. bulbifera* as food in the Peruvian Amazon, was observed to be known as "papa acha"[A]. In Mexico it is present as an edible species in home gardens of Chiapas and Tabasco, where it is known as Papa aérea and also in Campeche, where called makal (4). In Nicaragua is known as "papa Caribbean" and it is grown for its tubers for food (5).

D. bulbifera is known as ñame volador in Guanabacoa, Regla, Old Havana, Santiago de las Vegas and Moa in Cuba, where it is used as food, but also has esoteric use in ceremonies of the Yoruba religion (6). Likewise, the use of *D. bulbiferous* as food by indigenous and afro-descendant communities of ten colombian where is called Tabena or yams (7).

Despite recognizing properties in this species acceptable for consumption; outstanding aspect that should be considered before the food crisis that exists in the world today, marketing is almost zero and remains an underutilized crop or semi-wild, as it has never been "domesticated" (8). The exception is observed in Africa, where it devotes special attention to its production and food dimension, as shown by recent research in Ethiopia (9), Nigeria (8, 10) and Ghana (11).

The first documented mention of the genus *Dioscorea,* in Panama was made by the naturalist Seeman (12) in 1852, when he refers to a plant of common name "cabeza de Negro" used as anti-syphilitic by the Indians. From that time until today, gender studies in Panama have privileged aspects of botanical order, orderly manner without addressing aspects of productive order, with the notable exception of *D. alata* (yam) and *D. Trifid* (ñampí) which has high domestic demand. In the case of *D. bulbifera* contradictory results in large measure because such plant genetic resource is present and it is being handled and consumed crudely by peasant and indigenous population of our country from a considerable time.

From these considerations, the present study was conducted with the central objective of evaluating the productive variables of *D. bulbifera*, in very humid tropical conditions of Panama's Caribbean, to validate a proposal for technical-productive management that enhances expanding human consumption.

MATERIALS AND METHODS

A lack of documentation on the agrotechnical management of this crop was used as reference Technical Manual "Cultivation yam" *(Dioscorea alata*) "cash crop belonging to the same genus (13). However, the fundamental practice reference in this assessment constitutes an ethnobotanical study conducted in advance by the authors, in which the traditional knowledge of farming communities on this species (14).

The experiment was conducted during 2012 and 2013 on plots of peasant farmers and their participation in the district of Donoso, west of the province of Colon, on the Caribbean central Panama. In Table I the specific coordinates of the location of the plots are shown.

Table I. Georeferencing of the test plots

Community	North latitude	West longitude
San Luis	8° 55' 52,87"	80° 24' 30,32"
Belorizal	8° 57' 38,74"	80° 21' 38,31"
Concepción	9° 1' 10,29"	80° 22' 1,27"
Guasimo	9° 3' 30,59"	80° 20' 7,76"
El Jobo	9° 3' 29,50"	80° 11' 11,29"
Dominical	9° 2' 52,79"	80° 11' 4,92"

In each of the six communities selected, three plots were established two technical one were located after the other, in a prepared area for that purpose and a "traditional" plot established in backyards and land collaborators for a total of 18 plots, in which 25 plants were established

In the traditional system the plants grow freely, branching between the vegetation of backyard of the houses, with minimal cultural attention. In the technical system spacing it is set planting and use of inert guardians (sticks) is made. In either system further chemical fertilizer was used. In the assessment, two spacings were used:

- Technical system 1 (1,5 m planting distance between rows of 1,5 m between plants).
- Technical system 2 (2,0 m planting distance between rows of 2,0 m between plants).

[A] Mejía, C. K. *Diagnóstico de recursos vegetales de la amazonia peruana*. no. 16, Inst. Instituto de investigaciones de la Amazonía Peruana, Perú, 1995, p. 39.

Common activities for all plots included clearing and veneering, control of ants (*Atta* spp.), the trenching and planting, hand harvesting and storage of tubers. Strict use of local resources for weed and pest control was observed, to ensure maintenance of the plots and study.

During the first year, each plot, soil analysis that included organic matter (%) was performed; pH; texture (%); Potassium content (mg L^{-1}); Phosphorus (mg L^{-1}); Calcium (cmol kg^{-1}); Magnesium (cmol kg^{-1}), Iron (mg L^{-1}) and cation exchange capacity (meq 100 g^{-1}). Black Walkley method modified and the pH was assessed in water was used for determining the content of organic matter. The contents of P, K and Fe were determined with the method of Mehlich 1N, and Ca and Mg with KCl extracting solution. For the ammonium acetate solution at pH 7 was used for the cation exchange capacity. All analyzes were performed in the laboratory of soils at Agricultural Research Institute of Panama (IDIAP).

The planting of the plots was carried out in the two years during the month of April, using tubers (bulbils) collected in the study region. From the moment a record of the variables associated with the growth and development of plants in each plot, as the number of leaves, long stems and internodes (every seven days) is set to determine growth rates and date of onset of bulbils (days after sowing), among others. These measurements were made to eight plants in each plot, chosen randomly.

A control of the pest and disease incidence and resistance showing the crop during its development was carried out. Qualitative aspects were also noted, such as the presence or absence of flowering and the typical signs of the stage of "maturity" of the tubers. Note of inputs used (materials, labor, etc.) in the cultivation of technical plots was taken, in order to obtain a first approximation to the cost of production. For comparative purposes this value is extrapolated to obtain the cost per hectare.

The harvest took place in two years in November, seven months after making the plantation. In the same total collection of tubers from each plot, one by one was made. Each group tuber was counted and weighed, yielding the end the total weight harvested per plot and yield per plant and plot.

The data obtained were captured in a database and processed with STATISTICA (15) statistical package. The data were subjected to an exploratory analysis, obtaining descriptive statistics, histograms and correlations between all indicators and variables. After the establishment of trends and behavior of the variables under study we proceeded to the variance analysis and Tukey test.

RESULTS AND DISCUSSION

Phenological stages of the cultivation

From the systematization in the weekly monitoring plots, six key phenological stages are defined in crop development of *D. bulbifera*, whose production cycle lasts an average of seven months.

Sprouting tubers: it was observed regularly happens between 7 and 10 days after planting, with the emergence of the stem on the floor. This time may be longer sprouting when tubers very small or propagules games tubers used.

Growth and branching: it is typical of a climbing plant and presented with great vigor during the first month, which can reach an average rate of 8 cm per day (Figure 1). During the second and third month the growth rate down slightly to 6,4 cm per day, from the beginning of the tuber to be lower in the coming months.

Branching occurs from the main stem elongation; usually one meter height of the stem base, no impairment has occurred if the growth of the main apex. These growth trends will remain until the appearance of the first signs of "maturation" of the tubers.

Bulking: happen with the appearance of the first bulbils in the axils of leaves. In our experience this occurred from the first half of June; ie, two months after planting. From here the bulking is an ongoing process. This means that they will find tubers at different levels of development and size, even in the final stages of plant growth (Figure 2).

Flowering: the inflorescences were observed from August, four months after planting. Apparently it is unrelated to the bulking, since both processes occur independently unaffected. The reviewed literature suggests that these flowers do not produce viable seeds, which was confirmed two years.

Maturation of tubers: it is considered a "mature" or fit for consumption, who have completed their growth and accumulation of starch and other reserve substances, a fact that is perceived with the disappearance of green parts and greyish in the same time tubercle to be made visible in the onset of senescence of the aerial part of the plant. With this in mind the first edible tubers are observed from October; ie six months after planting. However, most of the tubers reach the complete development at seven months after planting. This feature raises the possibility of harvesting from November, to conclude no later than December because too long implies the fall of an important part of the tubers to the ground, which break off easily reached this time, with consequent losses.

Latency: it is characteristic of underground basal tubercle formed with the development of the plant and of air or bulblet tubers. This latency period coincides with the establishment of the less rainy season of the year, between December and March. Once started the next rainy season basal sprouting tuber occurs, allowing the same strain can be cultivated at least two consecutive cycles.

Climate and soil requirements

The plants in all phenological stages showed an adequate response to very humid tropical conditions of the study region, with more precipitation to 1,500 mm per year, average temperature of 27 °C and relative humidity above 90 %.

As for the soil, generally it can be stated that those used in the experiment did not show significant for crop development restrictions, which means that this species seems to achieve an adequate development without the need for additional fertilization. The soils used are brown with yellow clay loam texture, pH between 4,7 and 5,4, the organic matter content is high with an average of 9,4 % and a cation exchange capacity (CEC) from 19, 4 and 38,9 meq 100 g $^{-1}$. However, serious limitations were observed when the internal and external drainage factor, an element that appears to have affected yields in plots of San Luis and Concepcion in the first year and forcing the transfer of their land to soil with better drainage was evaluated. This preference for loose soil with good drainage had already been noted by pioneering studies of the species (16).

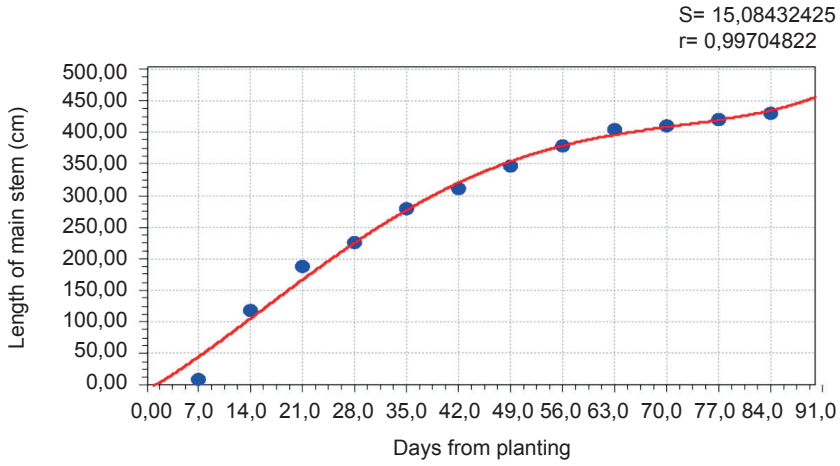

Figure 1. Main stem growth per day

Figure 2. Tubers of D. bulbifera five months after planting

Incidence of pests and diseases

The main pest observed in this culture constitutes leafcutter ants attack (*Atta* spp.), which basically affect the leaves, throughout the plant development. It follows, as a priority task in this regard; eliminate colonies of this insect within a radius of 200 meters around the plot, preferably before planting. The application of insecticide powder pump in the nests was a fairly effective control.

Other insects that appeared sporadically in the plots, but without damage of economic importance were the crickets (*Gryllus* spp.) That can cut the main stem at an early age of the crop. In more developed plants, more than a month of sprouting, and no attacks of this plague are observed.

Affectations caused by lepidoptera larvae that attack occasionally new tubers were also observed; that is to say at the beginning of the bulking stage. With less intensity attacks *Trigona corvina* (Zağanos) was also observed in the tubers of early ages. The attack of aphids (*Aphididae*) can cause lesions on the leaves, without severely affecting production.

Similarly no significant impact on disease *D. bulbifera* was detected. Apparently, it can be attacked by anthracnose (*Colletotrichum gloeosporioides*, Penz) that affects significantly to *D. alata* but this disease reaches only produce severe damage when plants are weakened, which occurs when excessive moisture is present in the ground (ponding) or due to effect leafcutter ant attack. Hence, the importance of ensuring an adequate drainage of the soil, a good selection of it and control leafcutter ant.

No pests was observed, and the incidence of a disease that affects the tubers during storage, which is a desirable feature that allows high viability of the product for consumption, which can last stored three to four months.

Yields

As shown in Figure 3, in the first year the communities of “El Jobo” and “Belorizal” obtained higher yields and significantly different from the rest. This was attributed to the use of very small tubers as “seed” in the first year of study, as it was observed that these plants produce little effect on the growth and branching. Hence, the recommendation to use for propagation, tubers with diameter greater than 5 cm and greater weight to 350 g emerged. The incidence of some limiting factors, such as texture and soil drainage and ant attack (*Atta* spp.) was also noted.

This interpretation derived modifications to counteract these effects. Thus, the yields obtained in all communities in 2013 show a similar behavior, since no significant differences among them are presented. This seems to respond to the fact that in the second year worked with better seed quality (from the 2012 harvest) and plots with soil problems (“San Luis” and “Conception”) were changed of place.

Yields ranged between 0,79 and 2,0 kg plant^{-1}, with an average of 1,18 kg plant^{-1}, in both years, a result which coincides with the recently reported in the region of Orissa in India (17).

In reviewing the behavior of yields per plant per type of plot (Figure 4), the results show no significant differences among the technical plots are presented in the two years of evaluation.

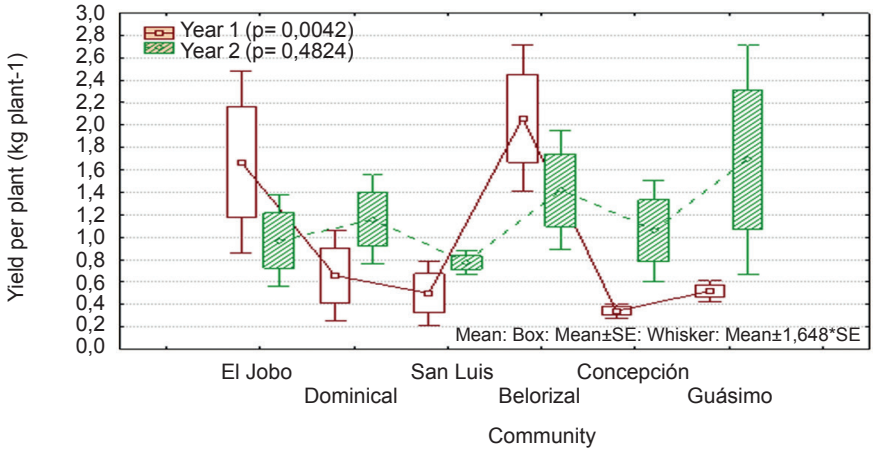

Figure 3. Yields per plant community, 2012 and 2013

In 2013 a higher average yield in plots technologically advanced type 2 significantly different from traditional plots were obtained. This result may be due to greater spacing promotes greater leaf area, whereby increased production of tubers is also enhances.

In both years the technical plots always had higher yields than traditional plots, which is indicative of the level of technology introduced favors increased production in this crop.

In relation to yields per surface (Figure 5) should be noted that in absolute terms, plots technologically advanced type 1 present the best yields (5 t ha^{-1}), similar to that reported by the FAO, which suggests that the planting frame recommended for planting, where what prevails is the intensification of production per area. Furthermore, it can be noted that the above results the plots technologically advanced type 2 showed better yields per plant, so it is not excluded as a framework for planting small plantations, which normally set as peasant farmers.

In none of the two years of study, correlations between yields and variables evaluated in soil analysis were found.

Production cost

By making the balance of expenditure for the establishment of this culture system with levels of technology introduced (Table II) stands primarily a relatively low production cost compared to other species of the same genus as *D. alata,* which reaches high levels of technology and marketing in Panama (13).

However, the main advantage is the low dependence on foreign inputs, as these only represent between 14 and 18 % of the total cost. In contrast high utilization of local resources, especially labor force stands. While the current production of *D. bulbifera* is directed basically to private consumption, this low dependence on external inputs no longer important and decisive for peasant production units where economic resources are limited.

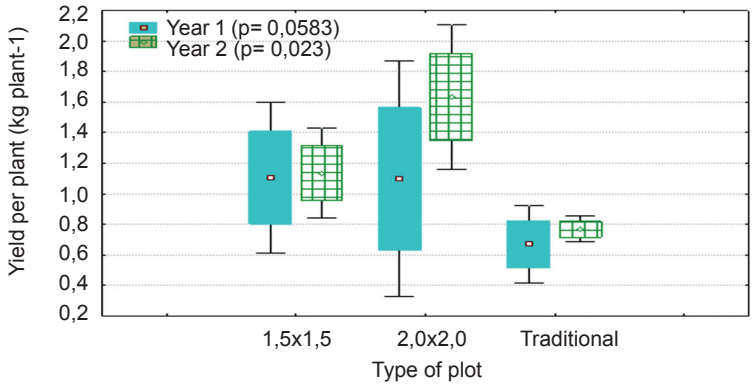

Figure 4. Yield per plant per type of plot, years 2012 and 2013

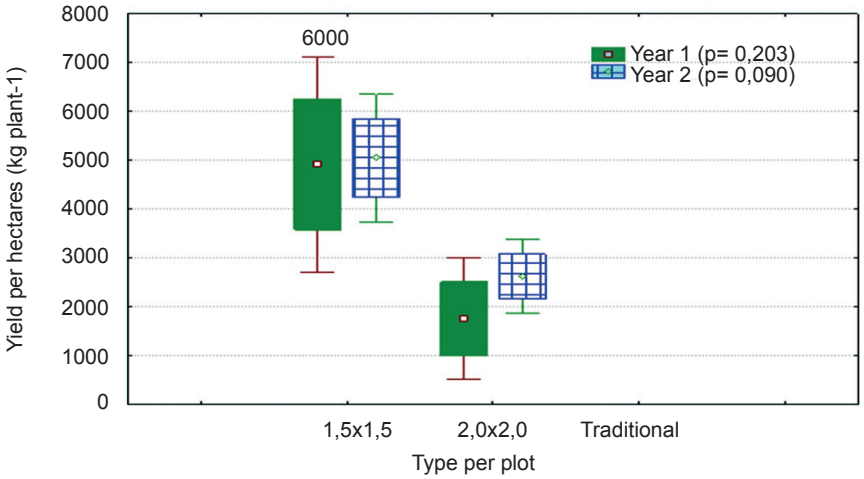

Figure 5. Yields per hectares in technical plots, years 2012 and 2013

Table II. Production cost per hectare estimated in technical plots

Input	Quantity		Unit cost (in USD**)		Sub-total (in USD)	
Type of plot	Technical 1	Technical 2	Technical 1	Technical 2	Technical 1	Technical 2
Miscellaneous tools	global	global			56,00	56,00
Buying of propagules	673 kg	242 kg	0,45	0,45	302,85	108,90
Buying of insecticide	2 Kg	2 Kg	10,00	10,00	20,00	20,00
Strings for mooring	1 rollo	1 rollo	18,00	18,00	18,00	18,00
Sacks for hasvest	100	60	0,20	0,20	20,00	12,00
Wages	48	44	8,00	8,00	384,00	352,00
Total (in USD)					800,85	566,90
Cost labor force/total cost ratio					0,479	0,620

**dollars from Estados Unidos

CONCLUSIONS

- The results of this study strengthen the hypothesis that air potato *(D. bulbifera)* has qualities to become a plant genetic resource that can contribute to food security of the population of these and other poor regions of Panama.
- The yields obtained; although not reach values that can outperform other farinaceous show that it is a species with great potential, since it presents an almost zero consumption of external inputs and low utilization of labor. To this must be added its adaptability to climate and soil conditions very humid tropics, its high disease resistance and pests, as well as its low deterioration in storage.
- Two years of *in situ* evaluation shows that the introduction of minimum levels of technology; in this case, spacing and use of tutors, contribute significantly in raising yields, because with this spatial distribution ensures further development of plants and leaf area, which is crucial in the process of accumulation and bulking.

RECOMMENDATIONS

La intencionalidad de la domesticación de esta especie no se agota con el presente estudio, por lo que se recomienda continuar y ampliar el establecimiento de nuevas parcelas, aplicando la tecnificación alcanzada y haciendo las correcciones pertinentes.

The intent of the domestication of this species is not exhausted by this study, so it is recommended to continue and expand the establishment of new plots, Applying the achieved modernization and making corrections.

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