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Development and productivity in yam (*Dioscorea trifida* and *Dioscorea esculenta*) under different water conditions

Desarrollo y productividad de ñame (*Dioscorea trifida* y *Dioscorea esculenta*) en diferentes condiciones hídricas

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Abstract

The effect of irrigation in the development and production of two species of endangered yam (*Dioscorea trífida* and *Dioscorea esculenta*) (Espitia *et al.*, 2004) was studied. A split-plot experimental design, where the variables were three water conditions: irrigation during the critical stage of the crop with a water application of 888 mm, irrigation during all the crop cycle with 944 mm and, absence of irrigation, using water from precipitation with an offer of 750 mm was used. The planting density was of 10,000 plants per hectare with conventional soil preparation by disks and, the harvesting was eight months after planting. Yield, starch content, length, diameter of tubers and, aerial biomass were measured. *Dioscorea trífida* showed an average yield of 30.6 t/ha and 27 t/ha for *Dioscorea esculenta*, with starch content of 21.3 and 21.6% respectively in wet base; the average length of tubers of *Dioscorea trífida* was 17.4 cm and 11.4 cm for *Dioscorea esculenta*; average diameters and aerial biomass of the plant were 14.4 cm and, 1.1 kg/plant and, 10.5 cm, and 0.67 kg/plant respectively.

Key words: Dioscorea, culture, yield, irrigation.

Resumen

En la región Montes de María (9° 24´ 56,33" N y 75° 23´ 04,19" O), departamento de Sucre, Colombia, en zonas de clima cálido (26 °C y 30 °C) y de clima medio (20 °C y 24 °C), humedad relativa entre 75 y 85% y precipitación de 750 mm durante el ensayo se estudió el efecto del riego en el desarrollo y productividad de dos especies de ñame en peligro de extinción (*Dioscorea trífida* y *Dioscorea esculenta)* en un diseño experimental de parcelas subdivididas, donde las variables fueron tres condiciones hídricas: riego de 888 mm durante la etapa crítica del cultivo, riego de 944 mm durante todo el ciclo del cultivo, y ausencia de riego con una oferta de agua de 750 mm provenientes de precipitación. La densidad de siembra fue de 10,000 plantas/ha, labranza tradicional con arado de discos y cosecha 8 meses después de la siembra. Como variables se midieron rendimiento de ñame, contenido de almidón, longitud y diámetro de tubérculos y biomasa aérea. *Dioscorea trífida* presentó

un rendimiento, promedio, de 30.6 t/ha y *D. esculenta* de 27 t/ha, con contenidos de almidón de 21.3 y 21.6% en base húmeda, respectivamente; la longitud promedio de tubérculos para *D. trífida* fue de 17.4 cm y para *D. esculenta* de 11.4 cm; los diámetros promedio fueron 14.4 cm y 10.5 cm y la biomasa aérea 1.1 kg/planta y 0.67 kg/planta, respectivamente. La aplicación de riego al cultivo produjo un incremento en la producción con respecto al cultivo sin riego, para *Dioscorea trífida* este incremento fue de 78.9% y para *Dioscorea esculenta* de 92.9%.

Palabras clave: Dioscorea, cultivo, rendimiento, riego complementario.

Introduction

The yam is a tropical plant from African and Asiatic origin, it is monocot of the Dioscoreaceae family, which organ of reserve is a tube. It is composed of six genera, among them Dioscorea in the most important with over 600 species identified, although only 12 species are edible (Coursey 1967, cited by Thurst, 1989). The characteristics of the plant change according to the variety grown. The ones from the Dioscorea genera are generally dioecious, it means, they only have feminine or masculine flowers (Santos and Macedo, 2006). In general, it is a climbing plant, with aerial tubers also called small bulbs and, subterranean tubers (Hata *et al.*, 2003). The last ones are the useful part of the plant and are used for human consumption as well as propagation media for new plantations (Cabrera *et al.*, 2008).

Before the introduction of other crops with edible roots, the yam was the main carbohydrate source for people in West and Central Africa (Carmo, 2002). To the Dioscorea genera belong species that, besides serve as food for humans, contain active compounds as saponins and diosgenin, used in the elaboration of pharmaceutical and industrial products, for example, oral contraceptives and cosmetics (Peixoto *et al.*, 2000).

Colombia has the largest yield rate of yam in the world. Characteristics in the productive process such as the seed quality, sowing type, soil type and availability of varieties or clones, are determinants to reach a good yield. In Colombia, in 2011, were produced 395,374 Ton of yam (0.8% of the world production) with a yield of 28.3 t/ha (Reina, 2012).

This tuber has not been considered as a first necessity product to supply the food deficits in the population, as consequence, its establishment is done empirically and there are not technological tools for the crop to increase productive results, therefore, there is a low capacity in agroindustrial development and a lack of knowledge on the advantages of the irrigation technologies in this crop (Sánchez and Mejía, 2011).

A good water management is based on the optimization of the spatial and temporal distribution of the applied water, to increase production and quality of the crops. The adequate irrigation practices are designed to keep a suitable level of water in the soil and reduce contamination, it means, losses by water and nutrient lixiviation under the root zone (Fares and Alva, 2000). The current water availability in the world shows a panorama of shortage, overuse and contamination, in such a way that it is considered a limiting factor for the sustainable development of the crops. The above means that it is compulsory to search ways to increase the use efficiency of this resource, in order to reach the highest impact, both quantity and quality of the product (Phene *et al.*, 1985).

In this research the irrigation effect on the yield of *D. trifida* and *D. esculenta* was studied. It was proposed the use of irrigation having into account that the critical stage of the crop is during the first five months after germination, time during which it is necessary to guarantee a suita-

ble humidity in the soil for a good development of the plant (Montaldo, 1991).

Materials and methods

Localization

The research was performed in experimental units located in the region Montes de María (9° 24' 56.33" N and 75° 23' 04.19" W), in the Department of Sucre, Colombia, with temperatures between 26 °C and 30 °C in the hot weather areas and between 20 °C and 4 °C in the areas with temperate weather, relative humidity between 75 and 85% and rainfall of 750 mm during the experiment (Aguilera, 2013).

In the soil analysis humidity %, pH, organic matter, phosphorus, potassium, cationic exchange capacity (CEC), bulk density and texture were included (ISO 10390: 2002). The crop was established on a soil with 19.23% of humidity, pH 6.22, organic matter 0.74%, phosphorus 101.58 ppm, potassium 0.14 cmol/kg of soil, CEC 7.0 meq/ 100 g of soil, bulk density 1.14 g/cm^3 and sandy loam texture.

Three water conditions in six treatments (Table 1), in a split-plot design with three replicates were evaluated, where the main plot was the water conditions and the subplot was the yam species studied (*D. trifida* and *D. esculenta*) on a random distribution. The experimental area was 2000 m^2 divided in plots of 108 m^2.

The sowing was done in May 2013, on soils with contour ridges to facilitate the drainage and create conditions for crop development, the plantation frame was 1 m x 1 m for a sowing density of 10,000 plants/ha. Conventional disk tillage was used with application of 8 g of NPK 15:15:15 per plant after sowing and the insecticide Lorsban was sprayed to control insects. Harvesting was done eight months after sowing.

To guarantee a good germination, from the crop establishment sprinkling irrigation was used according to the treatments evaluated that are shown in Table 2. To calculate the Evapotranspiration of reference (ETo) and to determine the Evapotranspiration of the crop (ETc) it was used the Penman method modified by FAO (Doorembos and

Table 1. Treatments applied in the experiment.

Treatments	Description	Total water (Prec. + irrigation)
RECDt	*Dioscorea trifida* with irrigation at the critical stage of the crop, described by Montaldo, 1991.	888 mm
RTCDt	*Dioscorea trifida* with abundant irrigation during all the crop cycle.	944 mm
SRDt	*Dioscorea trifida* without irrigation.	750 mm
RECDe	*Dioscorea esculenta* with irrigation at the critical stage of the crop, described by Montaldo, 1991.	888 mm
RTCDe	*Dioscorea esculenta* with abundant irrigation during all the crop cycle.	944 mm
SRDe	*Dioscorea esculenta* without irigation.	750 mm

Table 2. Management of the irrigation treatments.

Treatments	N° of irrigations applied	Irrigation time (min)	Lamina applied (mm)	Sowing date	Harvesting date
REC	6	50	23	05 – 2013	12 – 2013
RTC	9	50	23	05 – 2013	12 – 2013
SR	0	0	0	05 – 2013	12 – 2013

Pruit, 1976); to calculate the field capacity, wilting point, irrigation moment and water lamina, the equations proposed by Ortiz (2000) were considered; the soil water content was estimated with the equations proposed by Doorembos and Pruit (1976).

The evaluated variables were production, starch content (Englyst *et al*,. 1992), growth (length and diameter of tubers) and, biomass, according to the methodology of Damba (2008). The data were collected in 10 plants per experimental unit and the statistical analysis were done with the SAS® 9.1 software. To compare the means the Tukey´s test with 5% significance level was used.

Results and discussion

Yield

There were no differences ($P < 0.05$) in yield between the species, for the interaction irrigation x species but, there were among irrigation treatments as it is observed in Table 3. The average yield for *D. trifida* was 11.7% higher than the yield for *D. esculenta*. In both species the best yields were obtained with the RTC (irrigation at the

Table 3. Analysis of variance for yield and physical characteristics of the yam.

Variable dependiente	Source	DF	Typo III SS	Square mean	F value	Pr > Ft
Yields	Treat.	2	4.60443910	2.30221955	7.97	0.0063
	Species	1	0.24083333	0.24083333	0.83	0.3791
	T x E	2	0.10828526	0.05414263	0.19	0.8314
Starch content	Treat.	2	366.0077778	183.0038889	16.27	0.0004
	Species	1	0.0355556	0.0355556	0.00	0.9561
	T x E	2	1.2744444	0.6372222	0.06	0.9452
Tuber lenght	Trat.	2	10.00743590	5.00371795	6.67	0.0113
	Species	1	64.21813333	64.21813333	85.61	<.0001
	T x E	2	14.39589744	7.19794872	9.60	0.0032
Tuber diameter	Treat.	2	18.34858974	9.17429487	8.19	0.0057
	Species	1	25.75470000	25.75470000	22.98	0.0004
	T x E	2	10.64602564	5.32301282	4.75	0.0302
Aerial biomass	Treat.	2	0.05961819	0.02980910	6.95	0.0099
	Species	1	0.00369603	0.00369603	0.86	0.3716
	T x E	2	0.01697158	0.00848579	1.98	0.1809

Treat. = irrigation treatment. Species: yam species

Table 4. Yield and starch content in yam on water base. Montes de Maria, Departament of Sucre, Colombia.

Irrigation treatments[a]	Yield (t/ha)	Starch content (%)	Starch production (t/ha)
RECDt	24.0 a*	22.0 a	5.28
RTCDt	30.6 a	21.3 a	6.52
SRDt	17.1 b	20.6 b	3.64
RECDe	23.8 a	21.6 a	5.07
RTCDe	27.0 a	18.6 a	5.75
SRDe	14.0 b	20.6 b	2.88

* Values in the same column followed by equal letters are not statistically different ($P > 0.05$).

a. Treatments are described in Table 1.

critical stage of the crop) irrigation (Table 4) and are higher than the ones found by Reina (2002) in the Department of Sucre (10.3 t/ha).

The starch production per hectare (Table 4) for both species was higher in the RTC treatments with differences ($P < 0.05$) among irrigation levels but, not between the species under study neither for the irrigation x species interaction. In this case, the yields were lower than the ones found by Acuña (2012) with values of 24.8% of starch on wet base.

Production of yam/m^3 of water added with the REC treatment were 130 kg, for the RTCDt were 156 kg and for the RTCDe were 16 kg. The results showed that *D. trifida* showed a better response in productivity because of the irrigation.

Growth and biomass production

The average of the tuber length in *D. trifida* was higher than in *D. esculenta* (Table 5) with differences ($P < 0.05$) among irrigation treatments and between species, and in their interaction. For *D. trifida* the best results were obtained with the RTC treatment and for *D. esculenta* with the REC treatment, similar results were found by Montaldo (1991) and González (2003).

The average diameter of tubers in *D. trífida* was also higher than in *D. esculenta*. In this case, as in the tuber length case, there were differences ($P < 0.05$) among irrigations and among species, and also for their interaction. The most favorable results in both species were obtained with the REC treatment, indicating that this is the most suitable treatment to achieve good yield in each species. These results are similar to the ones found by León (1987).

Although there were no differences ($P > 0.05$) between species, the average aerial biomass of *D. trifida* was higher than the one of *D. esculenta*, being the difference between them 0.44 kg/ha. In the Table 5 is observed that there were no differences between irrigation treatments. However, the best results for both species were obtained when the irrigation was applied at the critical stage of the crop, with 888 mm of water, indicating that this amount of water was the most suitable for the species of this study.

Table 5. Growth and aerial biomass parameter of *Dioscorea trífida* and *Dioscorea esculenta* eunder irrigation treatments. Montes de Maria, Departament of Sucre, Colombia.

Irrigation treatments[a]	Tuber diameter (cm)	Tuber lenght (cm)	Aerial biomass (kg/plant)
RECDt	14.46 a	14.76 b	0.71 a
RTCDt	13.26 a	17.40 a	0.67 a
SRDt	10.10 b	12.96 b	0.43 b
RECDe	10.53 a	11.40 b	1.10 a
RTCDe	10.10 a	11.10 a	0.63 a
SRDe	9.80 b	11.20 b	0.39 b

* Values in the same collumn followed by equal letters are not statisticlly different ($P > 0.05$).

a. Treatments are described in Table 1.

Conclusions

- With the application of supplemental irrigation, *D. trífida* increased 78.9% the tuber production and *D. esculenta* 92.9%, in comparison to the control treatment without water.
- The RTC treatment (888 mm of water at the critical stage of the crop) shows that the irrigation in the yam crop should be done at the critical stage of the crop.
- The starch yield per hectare in *D. trífida* with irrigation surpass in 13.4% the ones *D. esculenta*.

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