doi: http://dx.doi.org/10.15446/acag.v64n1.43935 e-ISSN 2323-0118

Response of two cassava (*Manihot esculenta* Crantz) cultivars (CM 3306–4 and MCOL 2215) to irrigation under different water conditions

Respuesta de dos cultivares de yuca (*Manihot esculenta* Crantz) (CM 3306–4 y MCOL 2215) a la aplicación de riego en condiciones hídricas diferentes

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Acep.: 25.07.2014 Rec.: 26.08.2014

Abstract

This study assessed the yield of cassava cultivars MCO L2215 and CM 3306–4 in a silty clay soil under different water conditions: (1) rainfed conditions from planting to harvest (nine months) with a rain offer of 841mm; (2) with supplemental irrigation from planting to harvest and total water supply of 1247mm, this treatment had the higher starch content in the field (27.45%), height (249 cm) and yield (30 t/ha) and (3) irrigated from the fourth month and a water supply of 998mm. The cultivar CM 3306–4 presented higher mean in yield (26.4 t/ha), height (249 cm) and starch content (26.64%) under the different treatments evaluated, showing significant differences from the other cultivars. The irrigation increased the yield of cassava, with significant differences between water condition and the parameters assessed. There was not significant difference between cultivars and starch content. This study shows the importance of irrigation in cassava production and serves as a reference for supply of irrigation technologies and future research.

Key words: Irrigation, *Manihot esculenta*, dry matter content, starch content, CM3306–4, MCOL 2215.

Resumen

En el estudio se evaluó el rendimiento productivo de los cultivares de yuca CM 3306–4 y MCOL 2215, cultivados en un suelo arcillo–limoso, bajo diferentes condiciones hídricas: (1) H1 = en secano desde la siembra hasta la cosecha (9 meses) con una precipitación de 841 mm; (2) H2 = riego complementario desde la siembra hasta la cosecha y una precipitación de 1247 mm; y (3) H3 = riego a partir del cuarto mes y una precipitación de 998 mm. El diseño utilizado fue parcelas subdivididas con tres repeticiones. En el tratamiento H2 el contenido de almidón en campo (27.45%), el rendimiento de almidón (8.23 t/ha), la altura de planta (249 cm) y el rendimiento de yuca fresca (30 t/ha) fueron más altos que en los tratamientos H1 y H3. El cultivar CM 3306–4 presentó los mayores incrementos promedio en rendimiento (26.4 t/ha), altura (249 cm) y contenido de almidón (26.64%) en los diferentes tratamientos ($P < 0.05$) en relación con el cultivar MCOL 2215. El riego incrementó el rendimiento del cultivo de yuca, presentando diferencia significativa entre la condición hídrica y los parámetros evaluados; igualmente se encontraron diferencias en contenido de almidón entre variedades.

Palabras clave: Riego, *Manihot esculenta*, yuca, contenido de materia seca, contenido de almidón, CM 3306–4, MCOL 2215.

Introduction

Cassava (*Manihot esculenta* Crantz) is a tuber root with high energy content, used as food for both animal and humans. Its roots are rich in carbohydrates and the leaves have proteins, vitamins and minerals (Aguilera, 2012). The cassava plant grows on a wide range of tropical conditions, from the wet and warm tropics of the lowlands, passing to the medium high tropics up to the subtropics with cold winters and rain in summer. Although it grows in fertile soils, its comparative advantage with other more profitable crops, is to grow well on acid soils with low fertility, scarce rains or long drought periods. However, it does not tolerate flooding nor saline conditions in the soil (Sharkawy and Cadavid, 2000).

This plant is appreciated for its suitable adaptation to different ecosystems, high tolerance to drought and pest attacks and, easy storage (Giraldo, 2006). Although it is a lowland crop, the cassava does not economically produce under water deficit conditions, even though under these conditions, the plants can grow and produce small amount of roots (Finagro, 2012).

Information on cassava water requirements is scarce. The current experience suggests that it requires water for germination and development, increasing its demand between the fourth and fifth month after sowing. It has also been estimated that frequent irrigation can produce an excessive growth of the aerial part and reduce it root biomass. Some experimental works show that the distribution of the cassava roots are responsive to irrigation (Caraballo *et al.*, 1997); if after sowing there is a severe drought during the first two months of development, the cassava plants stop growing, defoliate and start a latent state; however at the onset of the rainy season it uses the carbohydrates of the roots and stem to produce new leaves (López, 2002).

In Colombia, producers, industrials and researchers have tried to promote the cassava crop and increase its productivity, implementing technologies in which the irrigation is vital to increase the productivity of this crop (Caraballo *et al.*, 1997). In the country the producer communities use cassava roots as food security, industrial use and very little for animal food. Additionally, it can be grown in different geographical conditions, therefore it is an important alternative when the harvest of other crops are not complete, being the varieties Venezolana (MCOL 2215) and ICA-Negrita (CM 3306-4) the most cultivated in the Caribbean region of Colombia, due to its high dry matter contents and use in double purpose systems for fresh and/or industrial consumption (Aguilera, 2012). In this study the yield of the cassava cultivars ICA-Negrita CM 306-4 and Venezolana MCOL 215 under different water conditions and application of additional irrigation was evaluated.

Materials and methods

In this study were used the cassava cultivars MCOL 215 and CM 3306-4 from the Breeding Program of the International Center of Tropical Agriculture (CIAT), which were evaluated in the town of San Antonio de Palmitos (9° 19' 35" N and 75° 31' 1" W), Department of Sucre, Colombia. The experimental site was located at 85 MASL, with an average annual temperature of 30 °C, 83% of relative humidity and an average annual precipitation of 1585 mm, with climate classified as tropical sabana (Aw) according to Köppen. The evaluated water conditions were (Table 1): (1) H1, on the 9 months crop cycle, between May and January, the crop did not get any irrigation and grew under the regional conditions; (H2), the crop was developed under the water conditions of the region and got additional irrigation and; (3) H3, the crop got additional irrigation from the fourth till the ninth month. The harvest was done on a single season at the end of January.

Data collection on the variables: root weight, dry matter content, starch content in the field and, plant height, was done for nine month after sowing till finishing the crop. The methods and procedures used for the physical, chemical and mineralogical analysis of soil were proposed by the Instituto Geográfico Agustín Codazzi (IGAC, 2006); for gravimetric water at field capacity (CC) and humidity deficit (DH); Silva´s methodology (2002) was used, in the field and in the lab the pressure chamber method at three water tension points was used (Table 2).

For calculation of the applied water lamina the following equation was used (Ortiz, 2000):

$$LR=[(CC-DH)\times Da]\times Pf$$

where, *LR* is the irrigation lamina (mm), *CC* is the gravimetric humidity (%) at field capacity, *DH* is the water deficit (%), *Da* is the bulk density of the soil (g/cm^3), and *Pf* is the effective depth of the root system (m) and it was the zone where 80 to 90% of the plant roots are located.

Table 2. Physical and chemical characteristics of the soil till 25 cm of depth in the experimental site.

Parameters	Value
Chemical	
pH (1:1)	7.5
OM (%)	4.68
Texture	Sandy loam
Relación Ca/Mg	2.12
P (ppm)	14.52
K (meq/100 g)	0.21
CEC (meq/100 g)	23.4
Physical	
Da (g/cm^3)	1.24
CC (%)	31.6
DH (%)	20.3
Moisture at 0.05 atm. (%)	40.2
Moisture at 0.33 atm. (%)	36.5
Moisture at 15 atm. (%)	16.7

To control water application in the plots, the irrigation system used was by sprinkling sector. The soil moisture was determined with field tensiometers (Irrometer – SR #224). Every eight days an average lamina of 22 mm was applied for 63 min in average, taking into account the consumptive use of the cassava at its different phenological stages (Allen *et al.*, 2006).

To measure moisture and dry matter in the root, the Icontec 2002 methodology was used; in the first case it was used a balance Precisa XM 60 and a drying oven Precision Scientific Thelco 130D. To determine the

Table 1. Total water (rain plus irrigation, mm) during the development of the cassava crop under the evaluated water conditions.

Period of development	Treatments		
	H1	H2	H3
From sowing till the third month of the crop.	253	502	253
From the fourth till the ninth month of the crop.	588	745	745
Total	841	1247	998

starch content of the roots it was used the technique of Mestres *et al.* (1993), based on the starch dispersion on aqueous medium, followed by partial enzymatic hydrolysis to obtain dextrin with the thermostable α–amylase enzyme and, completing the hydrolysis with amyl glucosidase to get glucose as an end product that was quantified by the DNS method (Miller, 1959) for reducing sugars.

The statistical design used was a random block split-plot with three replicates, where the irrigation treatments were the plot and the cultivars the sub-plot. The experimental unit area was 30 m² with a sowing density of 10,000 plants/ha at 1 m between rows and plants, considering the irrigation as source of variation. The statistical analysis of data was done with the SAS® v. 9.1 software. For mean comparison the Tukey´s test with 5% probability was used.

Results and discussion

During the development of the experiment the available water lamina was registered for the crop. The H2 plots had additional irrigations between May and July, exceeding the other two treatments in 249 mm; from August till January, critical stage for water demand in the crop, the irrigated plots (H2 and H3) had 175 mm more water than the non-irrigated (H1). This was reflected in the cassava production, being 56% (11 t/ha) and 43% (8 t/ha) higher in the treatments H2 and H3, respectively, in comparison with the H1 treatment (Table 3).

In all the treatments the yields were higher than the ones registered for the cassava crop in the Colombian Caribbean, which is 10.2 t/ha (Aguilera, 2012). Caraballo and Velázquez (2000) in Venezuela obtained an increment of 60% when irrigating the cultivars 104-64, Venezuela-7 and 107-35; Mogaji *et al.* (2011) found also an increase in cassava production from 8.45 t/ha (lowland) up to 21.87 t/ha with the supplemental irrigation during all the cycle of the TMS 30572 hybrid.

The relations between water conditions vs. yield, dry weight, starch content in the field and plant height at harvesting, showed significant differences ($P < 0.01$), which indicates that the water offer has an effect on the production of the evaluated cultivars (Table 3). In this Table is observed that the productions of dry matter and starch were similar in the H2 and H3 treatments but, were higher than in the H1 treatment. With the application of additional irrigation the starch yield was 71.4% higher ($P < 0.05$) in the treatments with irrigation than in the ones with no supplemental water. Both irrigation treatments coincide from the fourth month till harvesting, time when the tuber formation, thickening and starch accumulation in the cassava roots happens. It is also important to highlight that from the tuber formation phase the roots start to accumulate starch (photosynthesis products) but, it is during the accumulation phase where this potential is developed (Cadavid, 2008).

In relation to the cultivar performance, the CM 3306-4 showed higher yield and

Table 3. Effect of the water treatments on yield, dry matter percentage and starch content and plant high of cassava roots.

Water treatment	Yield (t/ha)	Dry matter (%)	Starch in the field (%)	Starch in the field (t/ha)	Plant heigh (cm)
H1	19.2 c*	39.72 a	24.93 b	4.80 c	227 c
H2	30.0 a	34.57 b	27.45 a	8.23 a	249 a
H3	27.4 b	35.30 b	26.95 a	7.38 b	245 b

*Averages with different letters inthe same collum are statistically different ($P < 0.01$) according to Tukey´s test. H1 = under lowland conditions from sowing till harvesting (9 months) with rainfall of 841 mm. H2 = additional irrigation from sowing till harvesting and rainfall of 1247 mm. H3 = irrigation from the fourth month and rainfall of 998 mm.

Table 4. Yield, dry matter content and starch in the field of two cassava cultivars evaluated under different water conditions.

Variety	Yield (t/ha)	Dry matter (%)	Starch		Height (cm)
			(%)	(t/ha)	
CM 3306-4	26.4 a*	35.21 b	26.64 a	7.09 a	249 a
MCOL 2215	24.6 b	37.84 a	26.24 a	6.51 b	232 b

* Averages with different letters in the same column are statistically different ($P < 0.01$) according to Tukey´s test.

plant height in comparison with the MCOL 2215 cultivar ($P < 0.05$), however the starch content was similar (Table 4). The last one produced 2.63% more dry weight than the first one ($P < 0.05$); as it is known this content depends on the variety, crop age at harvesting, soil, weather conditions and plant health (Cock, 1989).

Water conditions and irrigation application favor taller plants. Caraballo and Velázquez (2000) had similar results to the ones found here; Araujo *et al.* (2013) found a positive lineal increment in the cassava plant height when the water availability in the soil was increased. Without irrigation the plants reached 227 cm of height, being 9.7% higher than in the H2 treatment (with irrigation) than on the H1 treatment (without irrigation).

Conclusions

- The higher root yield in the field (30 t/ha) was obtained when the cassava plants had 502 mm of available water on the first four months of the crop and 745 mm of water from the fourth till the ninth month. With these treatments, the cassava crop increased the yield in 56% in comparison with the treatment without supplementary irrigation.
- The variety CM 33064 showed higher increments in yield, height and starch content than the variety MCOL 215 in the different evaluated treatments.
- The water availability during the crop positively affects the yield, starch content and plant height of the cassava varieties studied.

Acknowledgments

To the Young Research Program of Colciencias and to the Universidad de Sucre for their collaboration on the development of the activities of this research.

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