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Yield and oil content of castor oil plant (*Ricinus communis* L.) accessions grown with fertigation in a semiarid zone

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ABSTRACT

Objective: To evaluate seed, dry matter, and oil content yield in five accessions of castor oil plant (*Ricinus communis* L.) in the Altiplano Potosino Zacatecano high plateau regionof Mexico, grown with a fertigation system.

Design/Methodology/Approach: Castor was established under a fertigation system on agricultural land. Three levels of fertilization were tested. A completely random experimental design was used, with a 5×4 factorial arrangement (accessions×fertilization levels) and three repetitions, for a total of 60 experimental units.

Results: The following accessions showed an outstandingly favorable response to fertilization: ZACS2C1 (Orito Zac) which had the greater seed yield (735 g) and oil content (%) (50.30±5.23); and SLPS11C1 which had the greater weight per 100 seeds (g) (56.77±2.35) and dry matter (1600 g). The best fertilization level for the above mentioned accessions was obtained with the low nutrient solution, while other accessions showed a variable and inverse response to the fertilization level.

Limitations/Implications of the study: The study did not imply limitations.

Results/Conclusions: The castor oil plant accession from El Orito showed a favorable response to fertilization levels and achieved a higher yield (number of seeds and their oil content), even in the absence of fertilization; consequently, it is a promising accession for agro-industrial crops use.

Keywords: accessions, fertigation, nutrition, productivity, *Ricinus communis*.

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INTRODUCTION

The castor oil plant (*Ricinus communis* L.) species can be found from sea level up to 2,500 m.a.s.l. (Naik, 2018). Its water requirement ranges from 75 to 1,178 mm, depending on the soil type, the irrigation method, and its location (Ramanjaneyulu *et al.*, 2013). It is basically a long-day plant, but it can be adapted to a very wide range of daylight, with lower yield and a wide range of photoperiods (Naik, 2018). Its seed produces an oil that is used for a wide range of industrial purposes (Kallamadi *et al.*, 2015). The main differences between the diverse varieties lay on the color and shape of their stems, leaves,

Image by Alejandro Sánchez

and seeds; they grow as perennial plants in tropical and subtropical regions (frequently growing above 7 m tall) and as annual plants in temperate climates. The main producers of castor oil plant seeds worldwide are: India (1.2 million t), Mozambique (85,000 t), China (27,000 t), Brazil (14,000 t), and Ethiopia (11,000 t) (FAOSTAT, 2018; the figures are approximations). According to SIAP (2019), the main castor oil plant producers in Mexico are: Sonora (12,194 t/11,553 ha), Sinaloa (1,620 t/1,000 ha), and Nayarit (1,695 t/660 ha), with estimated production values of $83.8, $5.6, and $17.5 million Mexican pesos, respectively. The demand for castor oil in Mexico has increased during recent years (Trademap, 2019); various industries use it as an additive or raw material for their products, including the automotive, cosmetics, pharmaceutical, lubricant, paint, and ink industries. However, the low supply offered by the Mexican industry has forced the industrial sector to import crude or refined oil from India, Spain, Brazil, Germany, and the United States, among others. Overall, the production of castor oil plants includes wild, semi-wild, intermediate, and hybrid populations (Velasco *et al.*, 2015). Insufficient P and K levels slow down the initial growth of the plant and may lead to a considerable productivity reduction (Severino, 2006). Additionally, the growth and production of castor oil plant requires high N doses; a deficiency of this element leads to few leaves and small-sized plants (Araujo *et al.*, 2009). On general terms, reports mention 860 kg/ha yields (Rivera and Hernández 2016). Therefore, this work tested six promising samples of genotypes of castor oil plant (*Ricinus communis* L.) with various fertilization levels, in order to determine their viability as a systematic crop.

MATERIALS AND METHODS

Plant material and location of the experiment

The castor oil plant (*Ricinus communis* L.) accessions belong to a germplasm bank obtained at the influence area of the CP Campus San Luis (Table 1). The experimental castor oil plant cultivation was established at 101° 22' 33" N and 22° 43' 51" W, at an altitude of 2,100 m.a.s.l., in the Vicente Guerrero town, Salinas de Hidalgo municipality, San Luis Potosí. According to the data obtained by the COLPOS-SLP weather station, the rainfall accumulated during this research amounted to 467 mm and the average temperature was 15.5 °C.

Table 1. Origin of the *Ricinus communis* L. accessions.

Identification key	Accession Name	Latitude (N)	Length (O)	Altitude (msnm)
ZACS2C1	El Orito, Zacatecas	22° 45' 07.8"	102° 35' 36.4"	2,399
JALS2C1	Encarnación Díaz, Jalisco	21° 31' 12.8"	102° 14' 47.1"	1,811
SLPS11C1	Salinas San Luis Potosí	22° 37' 28.9"	101° 42' 52.3"	2,083
SLPS1C1	Ranchería de Guadalupe, San Luis Potosí	22° 19' 42.0"	101° 12' 04.6"	1,861
SLP*	San Luis Potos	-	-	-

* Castor oil plant seed with varietal origin, collected in three Mexican states.

Preparation of plant material for cultivation

To grow the seedlings, the seeds were put 40 days in 2.5-L black bags with a substrate made of a mixture of sand, tezontle, and compost (in equal parts), using a 4-L h^{-1} localized dripping irrigation system. During the said period, most plants had 5 leaves. Afterwards, they were transplanted into a plot where the land had been previously turned over (using a chisel plough and a harrow) and the soil had been levelled. Sixty plants were distributed in a 240 m^2 plot, 1.5 m apart from each other. Likewise, to prevent the border effect, a row of plants was sown on the border of the study accessions.

Soil fertigation system

Four 1,000-L water tanks were used for the fertilizer doses and a 4-L/h dripper was used per plant. The Penman-Monteith formula was used to estimate irrigation, based on the data obtained from the COLPOS-SLP weather station, located 2 km away from the study site. Water application was controlled with three control drippers. In the final stages of the evaluation, the soil was irrigated twice a day, in 30- and 40-min application periods.

Fertilization levels

The following NPK (ppm) fertilization levels were applied (Table 2): without fertilization (control), low (140:50:150), medium (210:80:250), and high (280:110:350). The combinations were prepared in independent containers. Each nutrient solution was complemented with secondary nutrients and micronutrients (Fe, Zn, Cu, and B). Additionally, monoammonium phosphate and monopotassium phosphate were used to prepare the nutrient solution, during the growth and reproductive stages, respectively.

Study variables and experimental design

The following variables were evaluated during the research: seed yield (g $plant^{-1}$), dry matter production (g $plant^{-1}$), and oil content. The latter was determined according to the methodology described by Loreto *et al.* (2012), using a Soxtec oil

Table 2. Nutrient solution used in the soil (g/1,000 liters of water) to grow castor oil plant.

Nutrients	Fertilization levels		
	Low level	Medium level	High level
KNO_3	487.50	600.00	650.0
$Ca(NO_3)_2$	412.50	562.50	550.0
H_6NO_4P *	187.50	232.50	250.0
KH_2PO_4**	187.50	232.50	250.0
$MgSO_4$	90.00	90.00	120.0
$C_{18}H_{16}FeN_2NaO_6$	8.20	8.20	11.0
$CuSO_4$	0.60	0.60	0.8
$ZnSO_4$	0.52	0.52	0.7
H_3BO_3	1.35	1.35	1.8

Note: * Monoammonium phosphate used during the growth stage. ** Monopotassium phosphate used during the fruiting stage.

and fat extraction system (USA). The weight of 100 seeds was determined using an Ohaus analytical balance (Ref. Explorer Pro, with a ± 0,0001 g accuracy), according to Makkar *et al.* (1998). A completely random experimental design was used, with a 5×4 factorial arrangement (accessions×fertilization levels) and three repetitions, for a total of 60 experimental units.

RESULTS AND DISCUSSION

Castor oil plant seed yield

Overall, a high fertilization level resulted in a greater seed yield (Figure 1). The highest results were obtained with accession ZACS2_C1 (753 g plant^{-1}), followed by SLP11_C11 (644 g plant^{-1}). These yields are lower than the results reported by Solís *et al.* (2010) for 10 varieties improved by INIFAP, obtained from Chiapas, State of Mexico, and Michoacán, with a 0.297-1.106 kg plant^{-1} weight.

Clearly, the SLPS1_1 accession showed a better yield when medium and low fertilization levels were applied. This means that this genotype might have low fertilization requirements, a possibility that requires further research. However, accession AZCS2_C1 showed remarkable responses to the fertilizers applied and might therefore be a genotype with high production requirements. The lower production may have been caused by differences in weather conditions between the regions where the crop was grown and the previous genetic selection work that was carried out. Consequently, the next activity should be a cost-benefit economic analysis, in order to determine if investing in seed yield is convenient.

Dry matter (g plant^{-1})

The greatest amount of dry matter was produced by accession SLPS11_C1 with all fertilization levels; the amount was significant between accessions and fertilization levels.

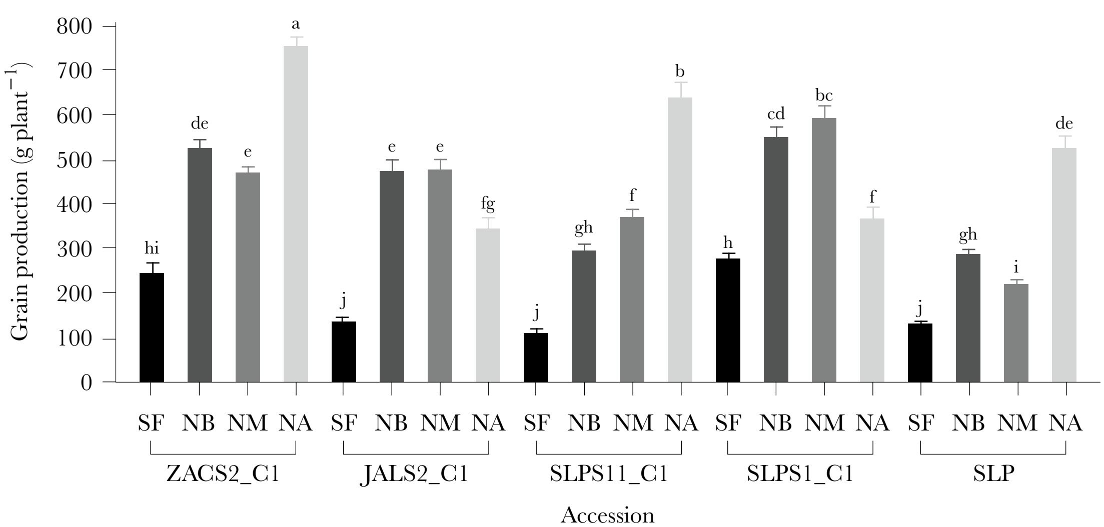

Figure 1. Seed yield of *R. communis* L. accessions per fertilization level.
SF: without fertilizer, NB: low level, NM: medium level, NA: high level.

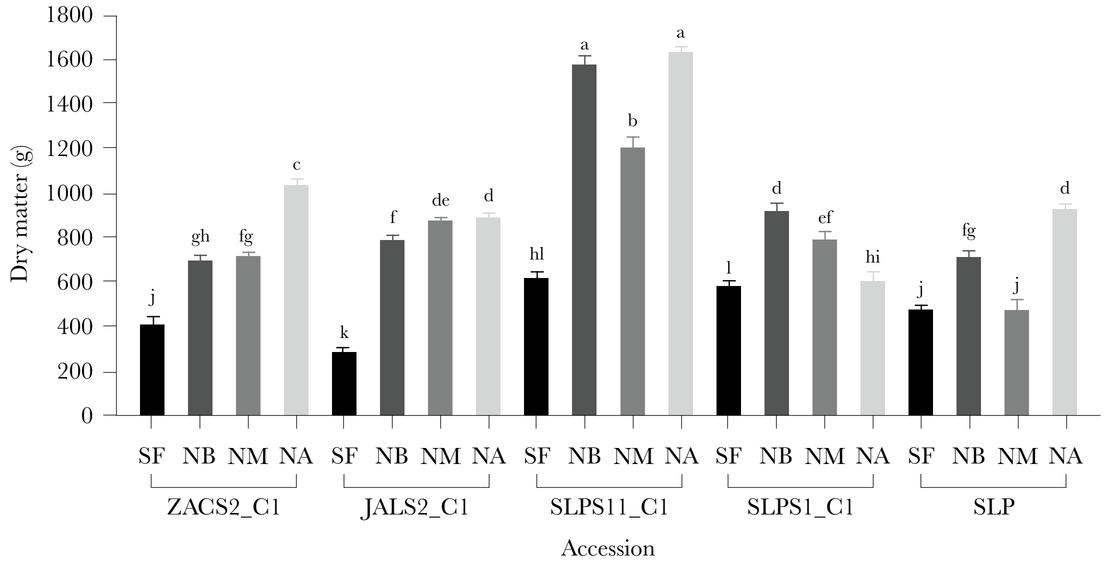

Figure 2. Dry matter behavior (g plant^{-1}) of castor oil plant (*R. communis* L.) accessions about fertilization levels. SF: without fertilizer, NB: low level, NM: medium level, NA: high level.

In accessions ZACS2_C1 and JALS2_C1, dry matter increases in relation to the increase of fertilization levels. Accession SLPS1_C1 had an inverse trend about fertilization levels. Accesion SLP had a highly illogical trend about the fertilization level. No relation was found between seed yield and the accession that produced more dry matter. A higher dry matter yield would provide the producers with an additional economic benefit, as the output could be used as fodder and/or soil conditioner. The average plant height ranges from 156 cm (accession from Ranchería de Guadalupe) to 249 cm (accession from Salinas); similar heights have been reported in other studies carried out in similar environments.

Accession JALS2_C1 showed low response to the fertilizers used.

Weight of one-hundred seeds (g)

Seeds from accession SPLS11_C1 grown without fertilizer achieved the highest weight (56.77 g±2.35), with a diminishing trend at greater fertilization (Table 3). The seed weight of accession SLP showed a homogeneous stability, probably due to the selection

Table 3. Weight of one-hundred seeds (g) of the *Ricinus communis* L. accessions.

Accession	Without Fertilizer	Low level	Medium level	High level
ZACS2_C1	11.50±1.20^{f}	12.70±0.70^{f}	12.83±0.65^{f}	12.40±0.50^{f}
JALS2_C1	30.47±1.05^{e}	33.07±1.55^{e}	31.0±1.30^{e}	32.20±1.80^{e}
SLPS11_C1	56.77±2.35^{a}	55.07±0.75^{ab}	46.33±1.25^{c}	40.7±2.10^{d}
SLPS1_C1	11.37±1.15^{f}	11.73±0.55^{f}	10.60±0.4^{f}	11.0±0.70^{f}
SLP	51.20±1.81^{b}	52.07±1.55^{b}	54.30±1.9^{ab}	51.37±1.15^{b}

The results are set forth as the mean of three replications±standard deviation. Different letters in the same column show significative differences ($p<0.05$) in Tukey's test.

process it has been subjected to and which has allowed it to retain uniform characteristics; regrettably, it produces little dry matter and only responds to high fertilization levels. The differences between accessions are fundamentally nutrition-related and/or the result of the plant's intrinsic conditions (particularly, its genetic composition). The seed weight of the accessions is higher than the weight reported by Vasco *et al.* (2018) for a crop under controlled conditions (54.23 g). Perdomo *et al.* (2013) reported very low values (13.2-40 g) in accessions from the state of Queretaro. According to Beltrão *et al.* (2001), the weight of one-hundred castor oil plant seeds ranges from 10 to 100 g. The mean in dwarf-sized cultivars is 30 g and, in medium-sized cultivars, it ranges from 45 to 75 g, under cultivation conditions. Accessions with low-weight seeds produce more seeds per plant; this would seem to be one of the species' survival strategies.

Oil content in the *R. communis* L. accessions

The oil content of the various castor oil plant accessions with the different fertilization levels fluctuated between 22.75 and 50.30% (Table 4); accession ZACS2_C1 recorded the highest content (50.30% with a high fertilization level). In this regard, Vasco *et al.* (2017) reported similar high results for other wild regional accessions: ZACS2C1, JALSC1, and SLP11C1, with 48.84, 50.14, and 51.04% values, respectively. Therefore, a new formulation of the fertilization levels should be discussed. This work confirmed that more oil was obtained from the accession with the highest number of seeds and the lowest seed weight.

CONCLUSIONS

The castor oil plant accession from El Orito showed a favorable response to fertilization levels and achieved a higher yield (number of seeds and their oil content), even in the absence of fertilization; consequently, it is a promising accession for agro-industrial use crops. A full use would require the use of SLPS11_C1 which has an outstanding seed weight and dry matter volume per plant.

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Table 4. Oil content with soil fertilization levels of *R. communis* L. accessions.

Accession	Without Fertilizer	Low level	Medium level	High level
ZACS2_C1	35.60±7.92^{abcd}	41.00±5.66^{abcd}	42.35±1.63^{abc}	50.30±5.23^{a}
JALS2_C1	34.65±2.19^{abcd}	36.15±4.88^{abcd}	33.45±1.48^{abcd}	32.75±7.85^{abcd}
SLPS11_C1	31.35±0.78^{abcd}	22.75±0.49^{d}	36.30±1.13^{abcd}	34.05±4.60^{abcd}
SLPS1_C1	32.25±6.01^{abcd}	39.10±2.12^{abcd}	26.55±7.57^{cd}	38.75±1.63^{abcd}
SLP	41.20±7.64^{abcd}	48.00±3.82^{ab}	24.95±4.03^{cd}	45.60±1.84^{ab}

The results are set forth as the mean of three replications±standard deviation. Different letters in the same column show significative differences ($p<0.05$) in Tukey's test.

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