Article

Evaluation of two castor bean cycles in Morelos, Mexico: sowing and regrowth

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Abstract

In Mexico grows the interest of castor oil plant production for the production of castor oil and biodiesel. There are few varieties released in Mexico, most are imported at a high cost, so the evaluation of elite materials that could be used for planting is of great importance. The objective of the present study was to evaluate the agronomic behavior of sixteen materials (T) of castor oil plant in a seed cycle with respect to regrowth under conditions of the dry tropics in Morelos, Mexico. In the seed cycle, the flowering of early genotypes occurred 40 days after sowing (dds) and the later ones at 72 dds. The T8 genotype had high values in plant height (4 m) and stem diameter (8.3 cm); on the contrary, T10 showed low values: 2.3 m and 4.1 cm, respectively. The T1 presented fruits with greater width and length, 2.7 and 2.5 cm and seeds of 1.8 and 1.4 cm. In the seed weight per plant, T1 obtained the highest value with 866.6 g and T12 the lowest, with 171.1 g. The materials T1, T2, T3 and T4 obtained better results in the regrowth cycle, showed little reduction for plant height, stem diameter, number of shoots, length and width of fruit and seed, number of bunches and fruits, weight of one hundred seeds, total weight of fruits and seeds per plant. The average of the regrowth cycle with respect to the seed cycle decreased 19.3% in the registered variables. The best production cycle was obtained in the first harvest from seed.

Keywords: agronomic characteristics, bioenergetic crops, genetic variability.

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Introduction

The castor oil plant (*Ricinus communis* L.), a species of use as bioenergetic, also called palma cristi, castor bean, infernal fig, tartago, fig or castor bean, is a shrub that grows wild in most of the tropical, arid regions and semi-arid ones of the world (Govaerts *et al.*, 2000). More than 95% of the production of castor oil in the world is concentrated in countries such as India, China and Brazil (Sailaja *et al*., 2008).

Tolerance to drought and its wide adaptation in different climates of the planet, are two of the main advantages for its cultivation (Weiss, 1983). The oil is not considered edible; however, it has multiple qualities, among the most important, it has high density and it keeps its viscosity at different temperatures and only freezes at -10 ºC (Durham and Wood, 2002; Jeong and Park, 2009). The plant has several uses, at least 700 applications, among them: stems used to make paper, but the seeds are the most economically important, from which the castor oil or “aceite de ricino” is extracted (Niembro, 1990). The castor cake does not serve as animal feed due to the presence of toxins and allergenic substances, but as organic fertilizer (Arango, 1990).

The first investigation with castor oil plant in Mexico was made in 1962, in the Experimental Field of Rio Bravo, Tamaulipas of the National Institute of Agricultural Research (INIA), four dwarf varieties were evaluated and it was found that the best grain yields were achieved with Lynn (1 908 kg ha^{-1}) and Hale (1 888 kg ha^{-1}) (Robles, 1980). In Mexico, the genetic variability existing in castor oil plant (Pecina-Quintero *et al*., 2013) is known, hence its importance in the evaluation of wild genotypes (Goytia *et al*., 2011); however, it is necessary to carry out research to evaluate and determine the potential of each material collected, to select the best genotypes with characteristics of agronomic or industrial importance, which will give rise to outstanding genotypes.

The genotypes evaluated during several cycles can be proposed as promising, according to the degree of stability and interaction with the environment (Figueiredo-Neto *et al*., 2004). When validating the agronomic behavior of a commercial hybrid of castor oil plant at three locations in southern Jalisco, it was found that the material reached yields 3 t of grain per hectare, with an average plant height of 2.75 m, beginning flowering at 51 days after sowing and reached the physiological maturity of the last cluster at 180 days (González, 2009a). In another evaluation of commercial varieties and hybrids available in the market, the best yield was 2 994 t ha^{-1} and 52.34% seed oil with the CSR-6.2 hybrid (González, 2009b).

The genotypes collected in Mexico are perennial, so that periodic harvests can be made and could be a viable production option as a crop, unlike the annual cycle. On the other hand, in other species you can greatly save many crops, seed, planting and obtain another crop cycle as is done in some crops such as rice where the regrowth or soca is used (Geraldo, 2001).

For this purpose, the National Institute of Forestry, Agriculture and Livestock Research (INIFAP) has collected genotypes of castor oil plant that could be used for this purpose. Therefore, the objective of the present study was to evaluate the agronomic behavior of sixteen (T) castor oil plant materials in a seed cycle with respect to regrowth in dry tropical conditions in Morelos, Mexico.

Materials and methods

Location of the experiment

The work was carried out during the autumn-winter (AW) 2009-2010, spring-summer (SS) 2010 agricultural cycles in the INIFAP Zacatepec Experimental Field, located at km 0.5 of the Zacatepec-Galeana highway, at 18° 39' 16" north latitude and 99° 11' 54" west longitude and altitude of 911.8 m. The site presents Aw_0climate, subhumid warm, 800 mm of average annual rainfall recorded in summer and average annual temperature of 24 °C (García, 1988).

Establishment of the crop

During the AW cycle 2009-2010 sixteen genotypes (T) of castor oil plant were collected, collected in the states of Jalisco, Michoacán and Chiapas (whose geographical coordinates are presented in Table 1. A randomized block design was established with four replications, for a total of 64 experimental units, each experimental unit with six plants. The planting in the field was carried out on November 26, 2009, placing two seeds per point is sown, with a separation of 1.5 m between plants and 3 m between rows (approximate population of 2 222 plants ha^{-1}).

In the SS 2010 cycle the re-sprouting of the materials was evaluated, which began at the beginning of the rainy season during the months of June to July.

Table 1. Origin data of sixteen castor bean genotypes evaluated during two production cycles in the Zacatepec Experimental Field, Morelos during the years 2009 and 2010.

Genotypes	State	Municipality	Location	Latitude N	Longitude W	Altitude (m)
T1 (C1)	Chiapas	Cacahoatán	Ejido Unión Roja	15°02'48"	92°13'00"	519
T2 (C3)	Chiapas	Cacahoatán	Ejido El Progreso	15º05'20"	92º11'33"	1 020
T3 (C10)	Chiapas	Union Juárez	Union Juárez	15º03'55"	92º04'36"	878
T4 (C19)	Chiapas	Villacorzo	Ejido Sierra Morena	16º09'08"	93º35'11"	1 070
T5 (C26)	Chiapas	Jaltenango La Paz	Jaltenango La Paz	16º00'34"	92º50'21"	576
T6 (C29)	Chiapas	Villaflores	La Garza	16º23'5"	93º17'5"	605
T7 (C39)	Chiapas	Tapachula	Rancho Rialfer, Viva Mexico	14º53'54"	92º19'25"	87
T8 (C230)	Jalisco	Zapotlan el grande	Rancho la Herradura	19º41'42"	103º30'28"	1 588
T9 (C231)	Jalisco	Without registration				
T10 (C234)	Michoacán	Cointzio	Cointzio	19º38'23"	101º16'04"	1 907
T11 (C270)	Chiapas	Tuxtla chico	CERI-INIFAP	14º56'	96º46'	435
T12 (C271)	Chiapas	Cacahoatán	Periferico Cacahotán	14º59'27"	92º10'27"	475
T13 (C272)	Chiapas	Cacahoatán	Cobach Cacahoatán	15º00'48"	92º09'18"	495
T14 (C273)	Chiapas	Cacahoatán	Ejido Guatimoc	15º00'48"	92º09'10"	809
T15 (C274)	Chiapas	Union Juárez	San Jerónimo Unión Juarez	15º02'48"	92º08'13"	776
T16 (C275)	Chiapas	Unión Juárez	Casa Grande Santo Domingo	15º01'56"	92º06'12"	873

The number in parentheses is the identification of the material within the germplasm bank.

Crop management

The emergency began seven days after sowing (dds). A rolled irrigation of aid was carried out 24 dds and fertilization with triple formula 17 (N-P-K) three days after irrigation. Subsequently, the development of the plants occurred under rainfall. The thinning was 56 dds and the growth of one plant was allowed per planting point. The weeding was done every fifteen days, three in total after sowing and before the first harvest; subsequently, plant shading reduced weed growth. In 2010, at the end of the harvest of each experimental unit in its entirety, pruning was carried out at a height of one meter above the ground. The regrowth of the castor bean genotypes grew naturally and without agronomic management, only a weeding at the beginning of rains, which was established during the month of June. It was decided to do this practice due to what was observed in other evaluations, where there is a good regrowth of the castor plants, and this can greatly save many labors of cultivation, seed, sowing and obtain another crop cycle as it is carried out in some crops such as rice where the regrowth or soca is used (Geraldo, 2001).

Days at the beginning of flowering

This variable was only registered in the plantation from seed, taking as reference the release of pollen from male flowers, emitted in the basal part of the inflorescence. The days elapsed from the planting date to the emission of the first floral cluster in the plants were counted, when the first basal (male) flowers were open.

Harvest

The first harvest of the genotypes ended in March 2010. The harvest of bunches for both evaluations (seed and regrowth), was performed at 30% visual maturity of the fruits of the cluster, identifying a change of hue from green to brown. The dehiscent materials were identified to avoid shattering in the field. Then the number of bunches per plant and number of fruits per bunch was counted. Post-harvest handling consisted of drying fruits placed in paper bags outdoors, under the sun, for three to five days, depending on the degree of maturity. Afterwards, width and length of fruit and seed were measured in a random sample of ten fruits per plant, in the six plants of each material and in the four blocks. For the measurements of the seeds, ten were taken at random per plant, from the six plants of the four replications. At the end of the harvest the total weight of seed and fruit per plant in each block was recorded. In addition, the weight of 100 seeds taken at random in five samples of each accession per block was evaluated.

Morphological measurements

Variables such as stem diameter, number of lateral buds and plant height were measured, this in sowing by seed; however, in the regrowth cycle these were numerous from the base of the stem at ground level, so the bud with intermediate size was chosen to perform the measurements, this due to standardize the measurements in each of the experimental units, and not take the larger outbreak strictly.

Percentage of reduction of the regrowth cycle with respect to seed

To compare the seed cycle and the regrowth cycle, although it was expected that the regrowth was more sacrificed or of lower yield, for this reason, the data from the seed cycle was considered 100% and the regrowth was determined in comparison to those values expressed in percentage of reduction of some variables, with this refers to the maximum that could be in the case of 100% would be taken from the seed data.

Statistical analysis

The individual and combined (factorial) analysis was done through a randomized block design in SAS (2004), as well as the Tukey test ($p\leq 0.05$) for the comparison of means between materials.

Results

The start of the emergence of the majority of the genotypes occurred seven days later, although T6, T11 and T13 had low germination percentage (50%), so a reseeding had to be carried out ten days after sowing.

Morphological variables of castor in two evaluation cycles: plant height, stem diameter and number of lateral shoots

On average, plant height, stem diameter and number of lateral shoots of all genotypes were reduced by 23.5, 22.7 and 19.6%, respectively (Table 2). In the seed and regrowth cycles, highly significant differences were found ($p\leq 0.01$) for plant height, stem diameter and number of shoots. The average plant height was 2.4 m in the regrowth; while for the seed cycle, it was 3.1 m. The average diameter of stem was 5 cm in the regrowth and 6.4 cm in the seed cycle, similar values were reported in a study where the thickness was 6, 7 and 10 cm for different castor materials 120 days after of sowing (Machado *et al*., 2012). The number of outbreaks recorded was 7.2 for the seed cycle and 5.4 for regrowth.

The reduction of height of plant (23.5%), stem diameter (22.7%) and the number of shoots (19.6%) in the seed cycle and regrowth, are results coinciding with what was reported by other authors (Rodríguez and Duche, 2010; Machado *et al*., 2012). On the other hand, it is mentioned that the fructification period increases in genotypes with greater branching (Moshkin, 1986), a situation that was also observed in the genotypes studied in this work, since most of the materials produced a high number of branches. Also in this study, it was observed that successive generations of branches of different age in the plant, caused the heterogeneous formation of bunches with ripe, immature and flowering fruits, a phenomenon that causes the fruiting and harvesting period to be prolonged (Baldanzi *et al*., 2002). On the other hand, it has been observed that the castor plant having a greater number of branches presents the possibility of having an increase in yield (Severino, 2010).

In Brazil, (Soares *et al*., 2006) fertilized the BRS Nordestina variety with doses of 0, 25, 50 and 100 kg ha^{-1}, obtained plants of 2, 2.6, 2.6 and 2.3 m in height, which are less than records obtained with the materials evaluated in the present work, favorable difference possibly due to the environment and genetic improvement to which this Brazilian variety has been subjected, to minimize the management problem. On the other hand, Severino (2010) mentions in relation to the castor plant that having a greater number of branches presents the possibility of having an increase in yield.

In the seed cycle, the evaluated germplasm showed a height that varied from 2.7 to 4 m, which caused difficulties for the manual harvest. During the regrowth cycle, the evaluated genotypes reduced their productive capacity, which was reflected in the variables evaluated. The materials that reduced the plant height in greater percentage were T5 and T10 with a value higher than 30%, on the contrary, T1, T11 and T13, presented only 20% in the reduction of plant height. Stem diameter was reduced in greater proportion in genotypes T1, T14, T12 and T15 which was greater than 30%, on the contrary, T7 and T8 only reduced the diameter of their stem by 15%. The number of outbreaks was greater than 8 in the seed cycle for T3, T5, T6, T7, T11 and T15; while, in the regrowth cycle T14, T11, T5 and T3 obtained values above seven. T1, T7, T8 and T10 reduced the emission of lateral shoots in the regrowth by 25%, T14 and T3 only 15%. The highest plant height in the seed cycle was obtained by T8, T6 and T11 with 4, 3.4 and 3.4 m. In the regrowth cycle T8 and T11 reached the highest height with 3 and 3.1 m each. The largest diameter of the stem in the seed cycle was for T11 and T8, with 8.3 cm and thus they remained in the regrowth cycle with 6.8 and 7.3 cm, respectively (Table 2).

Table 2. Height of plant (AP), stem diameter (DT), lateral shoots per plant (NB), of sixteen elite genotypes of castor oil plants evaluated in Zacatepec, Morelos, in the autumn-winter 2009-2010 and spring-summer cycles 2010.

Genotype	Plant height (m) (AP)		%R-AP	Stem diameter (cm) (DT)		%R-DT	Num. of buds (NB)		%R-NB
	Se	Re		Se	Re		Se	Re	
T1 (C1)	3.2 b	2.6 b	18.8	6.6 b	4.5 c	31.8	6.9 a	5.1 b	26.1
T2 (C3)	3.1 b	2.4 b	22.6	6.6 b	5.1 b	22.7	7 a	5.8 a	17.1
T3 (C10)	3.3 b	2.4 b	27.3	7.3 a	5.9 b	19.2	8.3 a	7.2 a	13.3
T4 (C19)	2.9 b	2.3 c	20.7	5 c	3.7 d	26	4 b	5 b	15
T5 (C26)	3.3 b	2.3 c	30.3	7.2 a	5.8 b	19.4	8.5 a	7.1 a	16.5
T6 (C29)	3.4 b	2.7 b	20.6	6.6 b	5.6 b	15.2	8.7 a	6.8 a	21.8
T7 (C39)	3.2 b	2.3 c	28.1	7 a	6.3 a	10	8.7 a	5.7 a	34.5
T8 (C230)	4 a	3.1 a	22.5	8.3 a	7.3 a	12	7.1 a	5.1 a	28.2
T9 (C231)	2.8 c	2 c	28.6	5.4 c	4.2 c	22.2	7.3 a	5.8 b	20.5
T10 (C234)	2.3 c	1.6 d	30.4	4.1 d	3.3 d	19.5	5.8 b	4.3 b	25.9
T11 (C270)	3.4 b	3 a	11.8	8.3 a	6.8 b	18.1	9.3 a	7.6 a	18.3
T12 (C271)	2.8 c	2.4 b	14.3	5.7 b	3.7 d	35.1	5.6 b	4.5 b	19.6
T13 (C272)	2.8 c	2 c	28.6	5.6 b	4.1 c	26.8	6.5 a	4.9 b	24.6
T14 (C273)	2.9 b	2.3 c	20.7	6 b	4.1 c	31.7	7.8 a	7.1 a	9
T15 (C274)	3.2 b	2.5 b	21.9	7 a	4.9 c	30	8.6 a	7.3 a	15.1
T16 (C275)	2.7 c	1.9 d	29.6	5.9 b	4.5 c	23.7	4.9 c	4.5 b	8.2
DHS	0.6	0.4		1.6	1.2		3.1	2.5	
CV (%)	16.6	14.5		22.6	14.2		18	18.7	
Average	3.1	2.4	23.5	6.4	5	22.7	7.2	5.4	19.6

Se= coming from seed; Re= coming from regrowth; DHS= significant honest difference of Tukey ($p \leq$ n0.05); CV= coefficient of variation; (%) R-AP= reduction of plant height of the first cycle with respect to the first (%); (%) R-DT= reduction of stem diameter (%); (%) R-NB= reduction in the number of outbreaks (%).

Harvest

The genotypes T3, T4, T6, T9, T10 and T14 showed indehiscence, the capsules remained closed, even after harvest, the moderately indehiscent were T1, T5, T12, in this case, only some fruits were opened while others they remained closed; and the dehiscent ones: T2, T7, T8, T11, T13, T15 and T16 that at the beginning of the fruit maturity the capsules burst releasing the seed. To avoid the loss of seed of this last group, the bunches were harvested when they showed 20 and 30% of total fruit maturity. The maturity allowed to differentiate indehiscent or dehiscent genotypes, evaluated by the rupture of the capsule and explosive dispersion of the seed (Hocking, 1982). The fruits can be dehiscent or indehiscent, depending on the variety, temperature and humidity of the air, but this characteristic is determined mainly by the thickness of the pericarp at the junction of the lobes. In the genetic improvement of INIFAP castor oil plant, a high degree of indehiscence is preferred, so that the seed remains enclosed within the capsule to avoid its loss in the field (Solis *et al*., 2011).

In the genetic improvement of castor oil plant, a degree of high indehiscence is preferred, so that the seed remains enclosed within the capsule to avoid loss of seeds in the field.

Variables evaluated on average of two cycles

Length and width of fruit and seed

The analysis of variance showed highly significant differences ($p\leq 0.01$) for length and width of fruit and seed. The averages for fruit were 1.9 cm long and 2 cm wide, and for seed 1.4 and 1 cm long and wide, respectively. The coefficients of variation for length and width of fruit were 13.9 and 18.6 cm, and length and width of seed were 16.4 and 11.2 cm, respectively. The T1 genotype presented long fruits of 2.5 cm, followed by T3 and T15, with 2.4 cm, while T8, T14 and T11 presented short fruits with 1.5, 1.5 and 1.6 cm, respectively. The materials T1 and T15 presented wide fruits with 2.7 and 2.6 cm, however, the genotypes T7, T8, T9, T10 and T13 formed fruits with smaller width (1.6 cm). The seeds with greater length were T1 and T15, with 1.8 cm and shorter length were T12, T7, T8, T11 and T14, while the seeds of greater width were T1, T3, T4 and T15 with 1.4 cm and instead T7, T8, T10, T12 and T13 had seeds of smaller width with 0.8 cm (Table 3). Authors have reported seed sizes of 0.5 to 1.5 cm in length (Rzedowski and Rzedowski, 2005), in this study seeds were found with predominantly oval shape, with length and width superior to that reported. Other investigations have reported an average of 1.35 cm, with a minimum value of 1.07 cm and a maximum of 1.94 cm in the length of the seed (Manzzani and Rodríguez, 2009). In Colombia, seeds have been described in a range of 1.1 to 1.33 cm long and 0.57 to 0.83 cm wide, with averages of 0.89 and 0.62 cm, respectively (Cardozo-Conde and Posada-Tique, 2013).

Weight of one hundred seeds

There were highly significant statistical differences for the weight of 100 seeds in the seed cycle and regrowth. This variable was the one that showed the greatest difference between the accessions evaluated. The weight of 100 seeds varied from 21.8 to 91.6 g and the average 47.4 g. The materials with the highest weight of 100 seeds were T3 and T1, with 91.6 and 83.4 g, on the contrary, the lowest weight was for T8 with 21.8 g (Table 3). Like this study, other works show a significant variation in the weight of 100 castor bean seeds. There have been variations between 19 and 95 g in the weight of castor bean seed (Mazzani, 2007); in a similar work, we found weights in 100 seeds of 29.37 g with a minimum value of 14.76 g and a maximum of 67.94 g with a coefficient of variation of 51.72% (Manzzani and Rodríguez, 2009). Other studies found that this was one of the variables with the greatest difference, registering weights from 7 to 123.6 g, when they characterized 151 accessions of castor bean collected in Chiapas, Mexico (Goytia *et al*., 2011). In Cuba, it was reported that the weight of 100 seeds of castor bean collections was between 13.8 and 81.5 g (Machado *et al*., 2012).

Table 3. Characteristics of fruit and seed of sixteen genotypes of castor oil plants evaluated in two sowing cycles (2009-2010) and regrowth (2010). Zacatepec, Morelos.

Genotypes	LF (cm)	AF (cm)	LS (cm)	AS (cm)	NR	NF	P100S (g)	PS (g)	PF (g)
T1 (C1)	2.5 a	2.7 a	1.8	1.4a	14.2 a	293.8 b	83.4 a	866.6 a	1562.7 a
T2 (C3)	2.1 a	2.1 c	1.3	1 b	14.3 a	394.4 a	53.3 c	427.9 b	798.2 c
T3 (C10)	2.4 a	2.5 a	1.7	1.4 a	14.2 a	313.8 b	91.6 a	696.9 a	1223.9 b
T4 (C19)	2.3 a	2.5 a	1.7	1.4 a	9.3 a	196.1 c	78.7 a	708.3 a	1181.4 b
T5 (C26)	2.1 a	2.2 b	1.4	1 b	9.3 a	256.3 b	57.1 c	402.5 b	814.4 c
T6 (C29)	1.9 b	2.1 c	1.4	0.9 b	7 b	194 c	40.1 d	315.6 b	418 d
T7 (C39)	1.6 b	1.6 d	1.2	0.8 b	9.4 a	282.6 b	25.3 e	372.3 b	676.3 d
T8 (C230)	1.5 c	1.6 d	1.2	0.8 b	7.8 b	236.1 c	21.8 e	222.3 c	296.7 e
T9 (C231)	1.8 b	1.6 d	1.3	1 b	8.8 b	164.9 c	31.4 e	290.9 b	415.7 d
T10 (C234)	1.8 b	1.6 d	1.4	0.8 b	14.5 a	164.4 c	32.8 e	336 b	491.7 d
T11 (C270)	1.6 b	1.8 c	1.2	0.9 b	5.2 b	144.9 d	33.8 e	618.9 a	1182.6 b
T12 (C271)	1.7 b	1.8 c	1.1	0.8 b	4.3 b	174 c	24.6 e	171.1 c	369 e
T13 (C272)	1.7 b	1.6 d	1.3	0.8 b	8.7 b	433 a	32.8 e	295.9 b	890.6 c
T14 (C273)	1.5 c	1.7 d	1.2	0.9 b	11.2 a	277.5 b	31.9 e	180 c	274.9 e
T15 (C274)	2.4 a	2.6 a	1.8	1.4 a	10.4 a	217 c	78.6 a	352.5 b	605 d
T16 (C275)	1.9 b	2.1 c	1.4	1.1 a	5.3 b	196 c	41.9 d	288.9 b	490.7 d
DHS ($p\leq 0.05$)	0.5	0.3	0.3	0.4	3.8	91.5	14.1	304.1	288.1
CV (%)	13.9	18.6	16.4	11.2	20.4	12.3	17.3	16.4	21.1
Average	1.9	2	1.4	1	9.6	246.2	47.4	409.1	730.7

DHS= significant honest difference of Tukey ($p\leq 0.05$); CV= coefficient of variation. LF= length of fruit; AF= fruit width; LS= seed length, AS= seed width; NR= number of bunches per plant, NF= number of fruits per plant; P100S= weight of one hundred seeds, PS= total weight of seeds; PF= weight of the fruits.

The best materials evaluated were T1, T2 and T4 since they obtained more bunches per plant, greater weight of fruit and seed which affects the final yield of the crop. The T1 material presented the highest weight of seed and fruit, as well as greater length and width of fruit and seed; however, also highlights T4, the second best material in terms of seed weight. The material T14, followed by the T8 and T12, presented lower weight of seed and fruit, as well as weight of 100 seeds and number of fruits per plant in the two evaluated cycles.

There was high variability in the characteristics of the genotypes evaluated; also, materials with high potential in performance were detected. The effect of the pruning caused a decrease in the yield of the materials during the cycle evaluated as regrowth in comparison with the one of seed.

It was observed that in castor oil plants the number of bunches, number of fruits per cluster, the size of the seed and its weight are components that result in a high final yield, which is why they are of great importance when looking for a genotype high potential for a region.

Number of bunches, number of fruits, weight of fruits and total weight of seed per plant

In the genotypes evaluated, the average number of bunches was 9.6, the materials T1, T2 and T3 had a higher number of bunches, with an average above 14, while the lowest number was obtained by T12 and T11, with averages of below five clusters (Table 3).

The statistical analysis showed highly significant differences ($p\leq 0.01$) in number of bunches, number of fruits, total weight of fruit and total weight of seed in the two cycles evaluated. The number of bunches is one of the factors that directly affect the yield of the grain, in relation to the castor oil plant indicates that having a greater number of branches presents the possibility of having an increase in the number of inflorescences (Severino, 2010).

Percentage of reduction in the evaluated variables

The characters evaluated in the genotypes showed high variability, in terms of reduction in the regrowth cycle. The T1 genotype showed good regrowth capacity, which was reflected in the low reduction percentage for some variables of greater interest such as P100S, PS and PF, followed by T3 and T2, not so for LF, LS and NF. That is, in these materials the effect of the regrowth cycle did not significantly affect the performance in the present study, but some other variables evaluated as NR, AF and AS were affected (Table 4).

Table 4. Percentage of reduction in the evaluated variables of sixteen elite genotypes of castor oil plants in two cycles, one of sowing seeds (2009-2010) and one regrowth (2010). Zacatepec, Morelos.

Genotypes	LF	AF	LS	AS	NR	NF	P100S	PS	PF
T1 (C1)	18.5	10.7	15.8	7.1	9.4	33.2	5.1	12	15
T2 (C3)	4.8	9.1	14.3	10	23	25.9	8.5	20.1	11.8
T3 (C10)	8	14.8	11.1	7.1	19.1	31.1	3.1	13.9	11.3
T4 (C19)	12.5	11.5	11.1	7.1	27.8	45.2	5.8	15.2	13.1
T5 (C26)	9.1	13	13.3	10	19.4	39.5	9.2	34	14.6
T6 (C29)	15	4.8	7.1	20	35.3	48.5	13.5	20.1	31.3
T7 (C39)	17.6	17.6	8.3	12.5	19.2	35.6	15.7	20.3	20.2
T8 (C230)	23.5	11.8	0	12.5	22.7	38.8	14.1	19.5	27.1
T9 (C231)	20	22.2	7.7	0	20.4	52.5	11.1	24.6	30.8
T10 (C234)	20	27.8	7.1	22.2	18.8	51.2	15	30.2	20.6
T11 (C270)	27.8	20	8.3	11.1	32.3	59.5	14.6	22.5	13.3
T12 (C271)	16.7	20	16.7	22.2	20.8	52.8	16.4	26.2	26.6
T13 (C272)	21.1	22.2	14.3	12.5	29.4	24.8	9.6	22.8	20.9
T14 (C273)	23.5	11.1	8.3	11.1	16.4	34.9	7.8	28.3	38.6
T15 (C274)	15.4	11.1	15.8	7.1	32.3	44.4	6	25.9	23.7
T16 (C275)	19	9.1	13.3	9.1	31.7	48.5	8	31.7	24.2
Average (%)	17	14.8	10.8	11.4	23.6	41.7	10.2	22.9	21.5

DHS= significant honest difference of Tukey ($p\leq 0.05$); CV= coefficient of variation; LF= length of fruit; AF= fruit width; LS= seed length, AS= seed width; NR= number of bunches per plant, NF= number of fruits per plant; P100S= weight of one hundred seeds, PS= total weight of seeds; PF= weight of the fruits.

The genotypes that showed the greatest reduction in yield correspond to T10, T11 and T12. The average reduction percentage was 19.3% in the variables evaluated for the 2010-2011 cycle, compared to the 2009-2010 cycle, on average they were 17% for fruit length, 14.8% fruit width, 10.8% seed length, 11.4% seed width, 23.6% for number of bunches, 41.7% number of fruits per plant and 10.2% for weight of 100 seeds.

Conclusions

According to the obtained if it is potentially viable to obtain a regrowth cycle with good yields in castor, saving the work of sowing and seed. It was observed that the sprouts emerge mainly from the base of the plants.

The regrowth cycle was the one that showed lower yields, the variables most affected are the number of bunches (NF), the number of fruits (NS), seed weight (PS) and fruit weight (FP), all of these by the order of 20%.

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