Article

Productivity of castor oil plant (*Ricinus communis* L.) in the north of Sinaloa

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Abstract

To determine the productivity of castor oil plant in Sinaloa, the influence of two sowing dates, water availability and two planting densities on the grain yield of four castor oil plant hybrids were evaluated, the trial was established at Valley of Fuerte Experimental Field. During the autumn-winter agricultural cycles with sowing date of December 10, 2015 and spring-summer 2015-2016 with sowing date of February 18, 2016. A randomized complete block design with four replications was used, the plot experimental was four furrows of 20 m long, with a separation of 0.80 m, equivalent to 64 m^2, two population densities were managed: 23 000 and 26 000 plants ha^{-1}, and two irrigation regimes per test. The statistical analysis indicated that hybrids 2B-5, Chinatan and HB-8, were higher in yield and without statistical differences, with days at maturity from 145 to 152, so they are considered normal cycle; the average height was 20 m, considered average. The cycle that most favors the development of the crop for HB-8 and 2B-5 is A-W with density of 23 000 plants ha^{-1} and three irrigation of aid for spring-summer, four irrigation of aid is recommended, density of 23 000 plants ha^{-1} and hybrids of better response were HB-8 and Chinatan with yields higher than 3 000 kg ha^{-1}.

Keywords: biofuel, efficiency indices, fatty acids, water stress, yield.

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Introduction

The profitability of castor oil plant cultivation depends on the planning of the sowings, the diversification and the purity of the material that is offered to the producer. Production costs are increased by factors that affect profitability; among the main stand out the combat of weeds and the manual or mechanized harvest, in addition to aspects of agronomic management such as inadequate choice of land, date, density of sowing, use and efficient management of irrigation water, pests and diseases, among others (Toledo *et al*., 2006; Rico *et al*., 2011).

Due to the lack of crop diversity adapted to the irrigated and temporary regions, migration to large cities has been caused in search of income alternatives, so it is important to promote agricultural activities that generate jobs and allow a sustainable use of the phytogenetic resources that can be adapted to the region, strengthening agricultural production and expanding alternative crop options in Mexico.

The productivity of a crop is determined by its genetic potential and the impact of the environment on its growth capacity and partition of dry matter to reproductive destinations on the other hand changes in the date of planting in bioenergy crops modify the response of grain yield and oil content. Temperature is one of the most important physical factors that directly influences the growth and length of the plant during its vegetative cycle (Msaakpa, 2014).

The castor oil plant is a tropical perennial shrub that originated in Africa is an oleaginous plant characterized by its rapid growth and adaptation to different climatic zones (Pabon, 2010), requires 140 to 180 days of growing season natural cross pollination, it is a monoecious species (Chan *et al*., 2010). The main product of the castor oil plant cultivation is the grain from which the oil is extracted, also called castor oil or “aceite de ricino” and has numerous industrial applications since it is used for the production of plastics, synthetic fibers, inks, enamels, lubricants, cosmetology, chemistry, fertilizers, pesticides, aeronautics, medical, energy, among others (Cardona, 2009).

The castor oil plant has high oil content, between 45 and 55%, compared with sunflower that contains between 38 and 48%, soybean that has between 40 and 47% and cotton that contains between 15 and 19%, characteristic that makes the plant very attractive (Solis *et al*., 2011; Rafael and Alfredo, 2013) for the extraction of this product. Castor oil plant is considered as raw material in the production of bioenergy and industrial oils, bioenergy is that energy generated by biomass or material of biological origin that is on the surface (Pabon, 2010; Goytia *et al*., 2011).

It is currently cultivated in many tropical and subtropical regions around the world. The cultivated area of castor oil plant worldwide in 2009 was 1 473 751 ha, with a total production of 1 499 111 t of seed. The most important producing countries are: India with 840 000 ha, China 210 000 ha, Brazil 159 205 ha, Paraguay 11 000 ha, with a seed production of 109 8000 t, 190 000 t, 90 384 t, 13 000 t, respectively (FAOSTAT, 2011). Mexico is a country with large oil reserves is also a country where agriculture plays a very important role in the generation of food for the population and raw materials for the industry.

Within the national territory there are regions with great potential for the production of different crops useful for the production of biofuels such as biodiesel and bioethanol. In Mexico there is great interest in validating the castor oil plant yield in different entities. The castor oil plant can be found widely distributed in a wild way, next to the road, on slopes of drains and irrigation canals, which shows that this species is fully adapted to the climatic conditions of the country (Machado *et al*., 2012).

On the other hand, Falasca *et al*. (2012) mentioned that castor oil plant can be an alternative production for producers and the energy market, taking into account that it is a crop that adapts to water stress conditions under an efficient water use system. So also Rodríguez and Zamarripa (2011) indicated a high competitiveness of the castor oil for biofuel in relation to current crops in Oaxaca. Studies on performance components provide guidance for optimal production, since they are interdependent and change in response to environmental conditions.

Negative correlations between performance components are very frequent (Machado *et al*., 2009; Rafael *et al*., 2013; Rivera-Brenes y Hernández-López, 2016). Some authors also point out that for the selection of highly productive castor oil plant varieties, emphasis should be placed on the number of bunches and fruit weight, as well as the length of bunches and weight of seeds (Machado *et al*., 2009, 2014; Goytia *et al*., 2011).

With the objective of evaluating the agronomic behavior of castor oil plant elite materials in Morelos, obtaining highly significant differences for all the variables analyzed, therefore the objective of this work is to determine the productivity of castor oil plant (*Ricinus communis* L.), the influence of two sowing dates, density of plants and also the availability of water in grain yield, which will generate information that can serve as a basis for the selection of genotypes that can be used for the establishment of bioenergy crops of this species.

Materials and methods

Location of the study area

The present research was developed in the agricultural cycles autumn-winter 2015-2016 and spring-summer 2016, two irrigation schedules and two planting densities, for each cycle. Experimental lots were established in the Valley of Fuerte Experimental Field-INIFAP, with geographic location at 25° 46’ 492’’ north latitude and 108° 48’ 181’’ west latitude with an altitude of 4 masl (www.inegi. org.mx). Its climate is generally humid warm, and has an average annual temperature of 25.9 °C. There is a minimum annual temperature of 18 °C and an annual maximum of 33.9 °C, the hottest season being from May to October. In the reference period, the average rainfall is 383 millimeters per year, being the rainiest months from July to October (http://www.weatherbase.com).

Experiment management

Genotypes evaluated. The hybrids used were: Maravilla, Chinatan, HB-8, and 2B-5, plus four commercial controls: Olga, Eva, K-93 and Zoya (Table 1), from China and Argentina , which were planted and harvested manually in the Valley of Fuerte Experimental Field (Guasave, Sinaloa), during the autumn-winter 2015-2016 and spring-summer 2016 cycles.

Table 1. Genotypes evaluated.

Treatments	Control
Maravilla	Olga
Chinatan	Eva
HB-8	K-93
2B-5	Zoya

Experimental design

A factorial design with four repetitions was used, with four levels of observation: genotypes, two agricultural cycles, two planting densities and two irrigation schedules.

Variables evaluated

The plant characteristics considered were plant height (AP, cm), days to flowering (DF, days), end of flowering (FDF, days), days to maturity (DM, days), bunch length first generation (LRG1), bunch weight per generation (PRG, g), weight of a thousand seeds (PMS, g) and grain yield (REND, kg ha^{-1}), as established by Goytia *et al*. (2011).

Data analysis and experimental model

An analysis of variance of a factorial design was performed with an arrangement in divided plots using the SASv9.4 program (2015), and the Tukey test ($p \leq 0.05$) for the comparison of means between the genotypes.

Results and discussion

Combined factor analysis

Significance was found in hybrids, irrigations and dates in seven evaluated plant variables, the interaction hybrids by dates of reading was significant for beginning of flowering, end of flowering, days to maturity, weight of bunch in first generation, bunch length in first generation and yield (Table 2).

According to the analysis of the information in relation to hybrids, density, irrigations and dates, interactions H∗F, D∗F or R∗F.

Differences were detected in seven evaluated plant variables, irrigation was only significant for yield and for dates it was days to flowering, end of flowering and physiological maturity of the evaluated hybrids, the hybrid interaction by date was significant for six variables, of which two of them have a significant impact on yield, such as bunch length in 1st generation and bunch weight in the 1st generation (LRG and PRG (Table 2).

Table 2. Relationship between sources of variation and plant morphological characteristics, mean squares and significance.

FV	GL	Days to flowering	End of flowering	Days to maturity	Plant height (cm)	Bunch length in 1st generation	Bunch weight in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
Hybrid	7	1922.09**	1691.6**	1224.02**	30264.1**	1400.86**	3259829.45**	83985.9	2728043.73**
Density	1	4.5	1.32	10.12	17.25	52.53	80601.12	532.19	164953.32
Irrigation	1	3.12	1.75	1.53	14770.5	603.78	1637145.12	736.32	5204747.82**
Dates	1	604**	779.65**	1714.54**	7146.61	240	2464706.45	296.38	653133.65
Error	116	3.46	4.37	1.56	1178.02	82.6	324750.71	251.89	286135.6
H*F	7	73.32**	22.78**	231.13**	5133.59	490.83**	2538458.5**	1224.56	1388594.89**
D*F	1	0.5	9.57	10.12	1960.94	30.03	3070861.53	815.07	32416.95
R*F	1	6.125	1.75	1.53	297	205.03	629161.53	689.13	2732829.76
CV		2.55	2.34	0.81	13.97	14.43	23.1	4.12	18.06
R2		0.97	0.97	0.99	0.69	0.64	0.58	0.95	0.68

**= significant differences at $\leq$ 0.05 probability.

Variation of plant morphological characteristics between hybrids

In terms of days to flowering of the hybrids, 2-B5, Chinatan and HB-8 were earlier with days to flowering ranging from 64 to 69, days respectively. In fact, the difference of days from the beginning of flowering to harvest was 76 days for both Maravilla and HB-8, and 88 for 2B-5. For Chinatan it was 84 days, which indicates that HB-8 has a higher grain filling rate (TLLG, greater accumulation of grams per day, Maravilla= 34 g day and HB-8= 42 g day 2B-5= 37g day), it could be considered that this material is precocious, since precocity is a relative characteristic and it is necessary to consider it within the production cycle, in places where the normal cultivation cycle goes from 140 to 180 days for the crops that are established in the area, this material shows to be of medium size with an average of two meters in length and a cycle of 140 days, its average yield is 3 205 kg ha^{-1}.

It is also clearly observed the division into two groups according to their precocity at the days of maturity where the following is shown: early cycle (138-143) medium cycle (151-166). For plant height, they are classified as low for the witnesses, Olga, Eva, K-93 and Zoya (100-162 cm), medium height with a height ranging from 230 to 236 for hybrids HB-8, Chinatan and 2B- 5. The tall one was Maravilla with 309 cm height, whose characteristic complicate the tasks of data collection and cutting (Table 3).

The variables involved with the yield, such as the fruit weight of the first bunch or generation one, the length of the first cluster and the weight of one thousand seeds showed values that reflect the potential of the materials 2B-5 and HB-8 which responded with favorable yields in both evaluated cycles, densities and schedules of irrigation under study were relevant to identify their adaptability when subjected to water stress and increased plant competition.

In some studies, the number of seeds per bunch is broken down into the number of fruits per bunch and the number of seeds per fruit; however, these two components are preferably analyzed together because there is an insignificant variation in the number of seeds per fruit (Machado *et al*., 2009). The individual weight of the seeds plays an important role, they reported yields of 3 569 kg ha^{-1} for the Durango region.

On the other hand, Machado *et al*. (2009) reported 34 to 143 fruits per bunch. In Morelos they found ranges of days to flowering from 40 to 72 dds. The results found in this investigation were, ranges of DF fluctuated from 99 to 149 dds, the differences reside in the altitudinal level and climate, being Morelos of warmer and dry climate (Table 3).

Table 3. Comparison of means of the morphological characteristics of eight castor oil plant hybrids.

Hybrid	Days to flowering	End of flowering	Days to maturity	Plant height (cm)	Bunch length in 1st generation	Bunch weight in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
Maravilla	90[a]	106[a]	166[a]	309[a]	48[bc]	3 010[a]	496[a]	2 615[ab]
2B-5	64[e]	82[d]	152[b]	236[ab]	58[abc]	2 109[ab]	374[b]	3 249[a]
HB-8	69[d]	84[cd]	145[c]	230[bc]	70[a]	2 656[ab]	340[cb]	3 205[ab]
Chinatan	67[d]	86[cd]	151[b]	235[ab]	73[ab]	2 326[ab]	352[b]	3 028[ab]
Olga	83[b]	92[b]	138[d]	137[d]	43[bc]	1 523[bc]	315[cd]	2 025[b]
Eva	78[c]	86[cd]	143[c]	157[cd]	61[ab]	2 232[ab]	243[bc]	2 234[ab]
K-93	69[de]	76[e]	138[d]	162[cd]	40[c]	1 790[abc]	296[d]	2 909[ab]
Zoya	81[b]	88[bc]	138[d]	100[d]	46[bc]	567[c]	196[e]	629[c]
Average	75	88	146	208	55	200	327	2 487
CV	2.55	2.34	0.81	13.97	14.43	23.1	4.12	18.06
DMS	27.97	18	17.22	7 722	20.45	1 282.2	3 571	1 203.6

Variation between hybrids by dates in combined analysis

In relation to the number of fruits (CFR) and grains in each bunch (CGR), a similar trend was observed in the first generation of bunches; therefore, this correlation is a consequence of the fact that each fruit contains three carpels that can originate the same number of grains; however, sanitary, genetic and environmental factors can regulate the final amount of grain per bunch. (Falasca *et al*., 2012).

According to the work done by Amorim *et al*. (2001); Moshkin (1986a) and Weiss (1983), extreme conditions, cold (<14 °C) and heat (>41 °C), limit the formation and maturation of seeds, due to flower abortion and sexual reversion, increase the ratio of male flowers to female ones. However, the results obtained indicate that, under the conditions where the research was conducted and for the varieties evaluated, the maximum and minimum temperatures of the environment did not affect the formation or filling of the grain, as discussed above. The cycle that most favors the development of the crop for HB-8 and 2B-5 is A-W with a density of 23 000 plants ha^{-1} and three irrigation risks (Table 4).

Table 4. Relations between sources of variation and plant characteristics in the CEVAF.

Cycle	Days to flowering	End of flowering	Days to maturity	Plant height (cm)	Bunch length in 1st generation	Bunch weight in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
1er FS	78	95	162	258	2259	54	389	3449
23 000	78^a	94^b	161^b	248^b	2324^a	53^a	400^a	3494^a
26 000	78^b	96^a	163^a	268^a	2185^a	54^a	378^b	3409^a
3 R. AUX	77^a	95^b	161^b	244^b	2170^a	52^a	378^b	3314^b
4 R. AUX	78^b	95^a	163^a	273^a	2358^a	55^a	401^a	3601^a
average	78	95	162	258	2259	54	389.2	3453
2nd FS	68	83	143	233	64	2674	380	2473
23 000	67^a	83^a	141^b	230^a	63^a	2459^a	376^b	2464^a
26 000	67^a	82^a	143^a	237^b	63^a	2914^b	384^a	2482^a
3 R. AUX	67^a	83^a	141^b	216^b	59^a	2456^b	375^b	2137^b
4 R. AUX	67^a	82^a	143^a	252^a	68^a	2918^a	384^a	2850^a
Average	67	83	142	234	63	2684	380	2481

Mean squares and significance, of two sowing dates fall-winter and spring summer of 2015-2016.

Variation between risks by dates

The evaluated materials behaved in a favorable way to the irrigation schedules applied, since they were maintained with yields above 3 000 kg ha^{-1}, the commercial controls for their part, the highest in yield was OLGA with 2 681 kg ha^{-1} and the lowest performing ZOYA with 359 kg ha^{-1}.

Density

Variability was found in hybrids of castor oil plant, in terms of the morphological characteristics of the plant, as well as in plant height, beginning of flowering, physiological maturity and above all in yield. This allowed to differentiate groups, which presented different production potentials overcoming the witnesses involved; According to the height of the plant, Silva (2005) grouped the castor oil plant in three categories: low plants (<1.5 m), medium (1.5-2.5 m) and tall (> 2.5 m) therefore, in accordance with the results obtained in this investigation showed that the height in the experimental lot with low density (23 000 plants ha^{-1}) the range of height was much wider where it is oscillating between 113 to 268 cm in length; however, when increasing the density to (26 000 plants ha^{-1}) it was reduced to a lower range ranging from 201 to 302 cm in height (Figure 1), it did not show significant effects in yield since higher density favors competition by light, nutrients; that is, it reduces the accumulation of biomass in the vegetative organs, decreasing the possibility of nutrients to supply the demand generated by spikes, capsules and growing grains (De Souza *et al*., 2011).

The height of the vegetable is important, since according to Weiss (1983), manual or mechanical harvesting is difficult, as the clusters of higher orders are emitted at higher heights.

Similar results were found by Beltrão *et al*. (2001), who found, when comparing two locations with different altitudinal levels (27 and 500 masl), that as the height above sea level increased, the evaluated varieties presented greater size or size of the plant. As indicated by Tavora (1982); Weiss (1983); Moshkin (1986a); Amorim *et al*. (2001); Falasca *et al*. (2012), on the effect of the temperature and the limit altitude for the development of the plant and seed production, the results obtained in the present work, showed that the castor oil plant was adapted to thermal ranges below and above those that, traditionally, have been considered propitious for their cultivation; likewise, in relation to altitudinal elevation, it is evident that castor oil plant can be planted up to 2 120 meters above sea level, with the use of materials adapted to that environment, without affecting its performance.

Analysis by agricultural cycle

First planting date autumn-winter 2015-2016

Table 5 and 6 shows high significance among hybrids for all the characters evaluated; however, for the interaction hybrids by density only difference in yield was observed which indicates that some hybrids tend to be affected by the high density.

Table 5. Relations between sources of variation and morphological characteristics of the plant in the CEVAF.

FV	GL	Days to flowering	End of flowering	Days to maturity	Height of plant (cm)	Bunch weight in 1st generation	Bunch length in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
Rep.	3	0.291667	0	0	1878.7	225 659.81	56.02	6727	84188.8
Density	1	1	9	0	1173.06	10782222.64	1.56	1332.2	171 810.25
Irrigation	1	0.25	0	0	5 439.06	118 250.02	52.56	1 425.06	197 358.06
Hybrids	7	1276.23^{**}	997.9^{**}	1191.3^{**}	24984.3^{**}	5090182.96^{**}	612.1^{**}	46913.9^{**}	1996726.19^{**}
Hybrids/ density	3	1.8	9	0	781.06	544 400.8	185.85	309.6	233533.04^{**}
CV		0.4	1	1	11.72	26.8	19.5	3.9	15.7
R^2		0.9	0	0	0.81	0.67	0.47	0.96	0.52

Mean squares and significance, first planting date autumn-winter 2015-2016.

Table 6. Relations between sources of variation and plant characteristics in the CEVAF.

Cycle	Days to flowering	End of flowering	Days to maturity	Height of plant (cm)	Bunch weight in 1st generation	Bunch length in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
1er FS	78	95	162	258	2259	54	389	3 449
23 000	78^a	94^b	161^b	248^b	2324^a	53^a	400^a	$3\,494^a$
26 000	78^b	96^a	163^a	268^a	2185^a	54^a	378^b	$3\,409^a$
3 R. AUX	77^a	95^b	161^b	244^b	2170^a	52^a	378^b	$3\,314^b$
4 R. AUX	78^b	95^a	163^a	273^a	2358^a	55^a	401^a	$3\,601^a$
Average	78	95	162	258	2259	54	389.2	3 453

Mean squares and significance, first planting date autumn-winter 2015-2016.

In the comparison of means for this cycle it is observed that the hybrids HB-8 and 2B-5 resulted with higher yield in this upper cycle 3 000 kg ha^{-1}, the most outstanding witness is Olga with yield of 2 681 kg ha^{-1}. Regarding the evaluation of plant height, it is observed that there are variations between hybrids, the highest observed height is in the Maravilla hybrid with 347 cm, while the average height is HB-8, Chinatan and 2B-5 which oscillates between 229 to 239 cm, however, the four controls were kept low in height with heights of 107, 160, 177 and 184 cm (Table 7, 8 y 9).

Table 7. Comparison of means of the morphological characteristics of the plant and index of selection of castor oil plant varieties in the CEVAF.

Hybrid	Days to flowering	End of flowering	Days to maturity	Height of plant (cm)	Bunch weight in 1st generation	Bunch length in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
Maravilla	97^{a}	113^{a}	180^{a}	347^{a}	49^{a}	3 226^{a}	504^{a}	3 349^{ab}
T. Eva	86^{b}	92^{b}	145^{d}	177^{ab}	63^{a}	3 511^{a}	344^{b}	2 669^{ab}
T. Zoya	86^{b}	92^{b}	145^{d}	107^{b}	49^{a}	81^{a}	135^{c}	359^{b}
T. Olga	85^{b}	92^{b}	145^{d}	160^{b}	45^{a}	1 154^{a}	306^{b}	2 681^{ab}
HB-8	75^{c}	90^{b}	150^{c}	239^{ab}	45^{a}	2 539^{a}	346^{b}	3 782^{a}
T. K-93	72^{c}	80^{b}	145^{d}	184^{ab}	32^{a}	685^{a}	294^{b}	1 894^{ab}
Chinatan	70^{c}	92^{b}	162^{b}	239^{ab}	56^{a}	1 971^{a}	358^{b}	3 406^{ab}
2B-5	68^{c}	88^{b}	162^{b}	229^{ab}	45^{a}	1 522^{a}	382^{b}	3 647^{a}
Average	80	92	154	263	48	1 836	334	2 723

First planting date autumn-winter 2015-2016. Second planting date spring-summer 2016.

Table 8. Relations between sources of variation and morphological characteristics of the plant in the CEVAF.

FV	GL	Days to flowering	End of flowering	Days to maturity	Height of plant (cm)	Bunch weight in 1st generation	Bunch length in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
REP	3	29.45	54.01**	0.45	1 248.5**	186.85	315 931.5	727.8	860 360.89
Density	1	4	1.89	20.25	805.1	81	2 073 240	15.01	25 560.02
Irrigation	1	9	3.51	3.06	9 628.5	756.25	2 148 056	0.39	7740219.52**
Hybrids	7	727.7**	710.5**	235.7**	5844.42**	1 226.35**	467 260	36636.4**	2011367.65**
Hybrids/ Density	3	18.79	7.8	7.1	1 512.55	69.58	460 108	291.26	553 311.14
CV		3.19	2.8	1.2	11.7	10.37	19.36	4.01	20.6
R^2		0.95	0.94	0.92	0.77	0.82	0.48	0.95	0.65

Mean squares and significance, second planting date spring-summer 2016.

Table 9. Relations between sources of variation and plant characteristics in the CEVAF.

Cycle	Days to flowering	End of flowering	Days to maturity	Height of plant (cm)	Bunch weight in 1st generation	Bunch length in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
1ª FS	68	83	143	233	64	2674	380	2473
23000	67[a]	83[a]	141[b]	230[a]	63[a]	2459[a]	376[b]	2464[a]
26000	67[a]	82[a]	143[a]	237[b]	63[a]	2914[b]	384[a]	2482[a]
3 R. AUX	67[a]	83[a]	141[b]	216[b]	59[a]	2456[b]	375[b]	2137[b]
4 R. AUX	67[a]	82[a]	143[a]	252[a]	68[a]	2918[a]	384[a]	2850[a]
Average	67	83	142	234	63	2684	380	2481

Mean squares and significance, second planting date spring-summer 2016.

In Table 10 it is observed that the Maravilla, chinatan and 2B-5 hybrids were more yielding than Maravilla and HB-8 for this spring summer cycle; however, they did not surpass the K-93 control who showed a yield of 3 924 kg ha^{-1}. However, it is necessary to specify that the excessive growth of the hybrid Maravilla, caused difficulties for the manual harvest, since the height of the seed collection, aspect that was indicated by Rodríguez and Duque (2010).

Table 10. Comparison of means of morphological characteristics of the plant and index of selection of castor oil plant varieties in the CEVAF.

Hybrid	Days to flowering	End of flowering	Days to maturity	Height of plant (cm)	Bunch weight in 1st generation	Bunch length in 1st generation	Weight of a thousand seeds	Yield (kg ha^{-1})
Maravilla	82[a]	98[a]	151[a]	270[a]	45[a]	2792[a]	488[a]	1851[a]
T. Eva	70[a]	79[bc]	140[ab]	136[a]	58[a]	953[a]	341[bc]	1799[a]
T. Zoya	76[a]	83[abc]	130[b]	93[a]	43[a]	1052[a]	256[c]	899[a]
T. Olga	81[a]	91[ab]	130[b]	113[a]	41[a]	1891[a]	324[bc]	1368[a]
HB-8	62[a]	78[bc]	140[ab]	241[a]	74[a]	2772[a]	339[bc]	2628[a]
T. K-93	65[a]	71[c]	130[b]	139[a]	48[a]	2895[a]	297[bc]	3924[a]
Chinatan	64[a]	79[bc]	140[ab]	230[a]	69[a]	2679[a]	344[bc]	2649[a]
2-B5	60[a]	76[bc]	141[ab]	241[a]	69[a]	2695[a]	366[b]	2850[a]
Average	70	82	137	183	56	2216	344	2246

Second sowing date spring-summer 2016.

This is considered a common condition for most of the plants of castor oil to medium height to high and although the commercial varieties reach between 0.9 and 3 m (Flemming and Jongh, 2011), many producers prefer dwarf varieties that grow at an average height 1.6 m, with periods of sowing to harvest from 120 to 130 days, as well as the medium varieties that grow from 2 to 2.5 m, with periods of sowing to harvest of 150 to 240 days (Rodríguez and Duque, 2010), aspect that should be paid attention.

Conclusions

The cycle that most favors the development of the crop for HB-8 and 2B-5 is A-W with a density of 23 000 plants ha^{-1} and three irrigation aid, for S-S four irrigation assistance is recommended, density of 23 000 plants ha^{-1} and the hybrids with the best response were HB-8 and Chinatan.

It is concluded that *R. communis* studied have agronomic characteristics that differentiate them from each other, at the same time that they demonstrated the existence of particularities relevant to the production of oil depending on the content of their seeds, the production per plant and the estimated per unit area. Therefore, it is considered, *R. communis* represents a good option in terms of its use for the production of oil, which can be used for the production of biodiesel, as well as other derivatives.

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