Article

Physiological and numerical components of canola yield affected by density and sowing system

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Abstract

In the present work, the physiological and numerical components of canola yield affected by density and sowing system were evaluated. Two spring canola genotypes were evaluated: Hyola 61 (hybrid) and Bioaureo 2486 (open pollination) under three densities (50, 75 and 90 seeds m^{-2}), during the 2019-2020 winter-spring cycle. The treatments were established under a randomized complete block design with four repetitions, in each of the two systems, FBS (flat bed system) and DRBS (double-row bed system), that were considered as environments. The FBS presented the highest yield (4.9 t ha^{-1}) on average. Changes in seed yield were associated with a higher biomass production at maturity. Bioaureo 2486 exceeded by 7% the number of seeds obtained by Hyola 61 in the density of 90 plants m^{-2}. The number of seeds per m^2 was positively associated with the number of siliques per m^2. However, the increase in plant density decreased the number of branches.

Keywords: *Brassica napus* L., biomass, number of seeds, population density.

Reception date: January 2022
Acceptance date: March 2022

Introduction

Canola (*Brassica napus* L.) is an oilseed recognized for the quality of its edible oil, whose essential fat content can prevent heart diseases (Kirkegaard *et al*., 2016). The world area sown with this crop is 37 579 575 ha, with a production of more than 75 million tonnes and an average yield of 1.9 t ha^{-1} (FAOSTAT, 2018). In Mexico, during 2018, 2 058 ha were harvested, with a production of 1 473 t and an average yield of 0.715 t ha^{-1} (CONASIPRO, 2019). The most outstanding states in the production of canola in this year were Tamaulipas, State of Mexico, Tlaxcala, Hidalgo and Jalisco, with Tamaulipas standing out with 91% of the area sown and volume of production; however, this entity has had the lowest yields (0.6 t ha^{-1}), while the State of Mexico and Hidalgo obtain the highest (2.5 t ha^{-1}) (CONASIPRO, 2019).

Population density has an important effect on canola growth and yield, and it strongly depends on the spatial arrangement (distance between plants and between rows) and the type of cultivar (free-pollinated populations or hybrids) (Rathke *et al*., 2006). Worldwide, different population densities have been evaluated in canola, which range from 8 to 190 plants m^{-2}, observing a differential effect between the factors that influence the yield, such as: the distance between rows, distance between plants, environmental factors and fertilization dose, etc.

For example, Hosseini *et al*. (2006) concluded that an increase in plant density significantly reduces the length of the main inflorescence and the total number of siliques per plant, but increased the plant height, these authors found that the highest seed yield was obtained with 190 plants m^{-2} and claim that the optimal plant density increases the competitive capacity of canola against weeds. In the same way, Mobasser *et al*. (2008) observed that an increase in plant density decreased plant height, stem diameter, number of siliques per plant, silique length and seed yield. The highest seed yield occurred with a density of 80 plants m^{-2}.

Similarly, Kazemeini *et al*. (2010) determined that 90 plants m^{-2} is the optimal density for canola cultivation, stating that this density positively influences the seed weight of secondary siliques, which contributes to improving seed yield and biomass production. On the other hand, Li *et al*. (2014) observed that increases in density reduce plant height, the number of branches and siliques per plant and the harvest index; however, a higher density of plants can improve the adaptability of canola by regulating plant structure.

Similarly, Wang *et al*. (2015) concluded that the increase in plant density complemented with an adequate spatial arrangement between plots and rows can be considered as an optimal practice for increasing canola yield. On the other hand, there is evidence that, in the cultivation of canola, with low densities, it is possible to obtain seed yields comparable to those obtained with high densities (Gan *et al*., 2016; Rondanini *et al*., 2017), which may be attributable to changes in plant morphology (number of branches). The variability in the results obtained in previous studies shows that there is a need to understand the effects of genotype, plant density and sowing system on yield, in order to better channel agronomic management strategies aimed at increasing the productivity of the crop.

In the region of the high valleys of Mexico, there is no record of works where these factors are compared, so it is important to elucidate their effect on the physiological and numerical components of the yield, which allow optimizing management practices aimed at increasing the production levels of this crop and expanding their adoption in potential agricultural areas. Based on the above, the present work was carried out with the aim of evaluating the effect of two sowing systems, three densities and two genotypes on the physiological and numerical components of seed yield in canola cultivation.

Materials and methods

Location of experimental work

The experiment was carried out in the 2019-2020 winter-spring cycle at the Faculty of Agricultural Sciences, dependent on the Autonomous University of the State of Mexico, located 18 km north of the city of Toluca, with geographical coordinates of 19° 15’ 33” north latitude, 99° 39’ 38” west longitude and at an altitude of 2 640 masl. The predominant climate is type C (w2) (w) b (i), which corresponds to a subhumid temperate climate, the most humid of the subhumid climates, with rainfall in summer and little rainfall in winter (5%), little thermal oscillation, average annual temperature of 12.8 ºC and average annual rainfall of 900 mm.

The predominant soil of the region is of the pelic vertisol type of volcanic origin, it has a mineral horizon with a low content of organic matter that ranges from 1.01 to 2.36%. The color of the dry surface horizon is dark grayish-brown or dark gray with clay contents of 20 to 36.4%. In the soil profile, a horizon with tillage disturbances showing compaction due to plow floor can be distinguished, the amount of organic matter is very low, it ranges from 0.07 to 1.01 (Gil *et al*., 2014).

Treatments and experimental design

Two sowing systems were evaluated, DRBS: double-row bed system (24 plots) and FBS: flat bed system (24 plots). The treatments derived from the factorial arrangement of two canola genotypes, Hyola 61 (hybrid) and Bioaureo 2486 (open pollination), and 3 densities were established under a randomized complete block design with four repetitions in each of the aforementioned systems (two serial experiments) considering the two sowing systems.

General conditions of the experiment

The sowing was carried out on December 7, 2019, in two sowing systems, the first made up of plots of 3 m in length with three beds 80 cm apart with two rows, each 20 cm apart (7.2 m^2) double-row bed system (DRBS), while the second had plots of 5 rows of 3 m in length and separated from each other at 0.3 m (4.8 m^2) flatbed system (FBS). Three sowing densities were used, 50, 75 and 90 seeds m^{-2}. To ensure the three sowing densities, the seed was placed on biodegradable paper tapes at a distance that would guarantee the required density. The crop was kept with moisture at field capacity during its cycle and without nutritional restrictions, so it was fertilized with a formula of 150-60-30 (NPK), using urea as source of nitrogen, triple calcium superphosphate as a source of phosphorus, potassium chloride as a source of this element.

Biomass production, yield and its components

At physiological maturity, the plants in a linear meter of the central furrow of each plot were cut and separated into branches and main stem, separating the siliques of each stratum. The dry matter of each stratum (branches, main stem and siliques) was determined after drying in a forced air oven for 72 h at 60 °C. The siliques of each stratum were counted and threshed separately to obtain the dry weight of seed (yield). The number of siliques, the number of seeds per silique and the number of seeds per m^2 were determined. The weight of 1 000 seeds was determined by counting and weighing 1 000 seeds of each experimental unit.

Statistical analysis

The response variables of the experiment were subjected to a combined analysis of variance and when the F test of the analysis of variance was significant, the mean test was performed using the honest minimum significant difference (HMSD) or Tukey test at a significance level of 5% (Palaniswamy and Palaniswamy, 2006), using the statistical package R for Windows version 4.0.5 based on the following model: $y_{ijkl}= \mu+\alpha_i+\beta_j(\alpha_i)+\gamma_k+\tau_l+\alpha\gamma_{ik}+\alpha\tau_{il}+\gamma\tau_{kl}+\alpha\gamma\tau_{ikl}+\epsilon_{ijkl}$. Where: μ is the general mean, α_i is the effect of the i-th system, $\beta_j(\alpha_i)$ is the effect of the j-th block within systems and was the error term used to test systems, γ_k is the effect of the k-th density, τ_l is the effect of the l-th genotype, $\alpha\gamma_{ik}$ is the effect of the interaction of the k-th density on the i-th system, $\alpha\tau_{il}$ is the effect of the i-th system on the l-th genotype, $\gamma\tau_{kl}$ is the effect of the k-th density on the l-th genotype, $\alpha\gamma\tau_{ikl}$ is the interaction of the i-th system in the k-th density in the l-th genotype and ϵ_{ijkl} is the general error term. The relationships between variables were determined by linear regression and the association between them by correlation analysis (Jandel, 1991).

Results and discussion

Climatic conditions

The climatic conditions during the development of the experiments are shown in Figure 1, in which it is observed that the emergence occurred 14 days after sowing. On the other hand, it can be seen that the beginning of the reproductive period in both genotypes coincided with favorable temperatures for the crop. It should be noted that precipitation during the reproductive period was very scarce, but this was not a limitation since the crop was established under irrigation conditions. Towards physiological maturity, an increase in the recorded precipitation levels was observed, which did not affect the development of the experiment. In general, factors such as precipitation and temperature were favorable for the development of the experiment.

The results of the analysis of variance presented in Table 1 show that for the factor sowing system, highly significant differences ($p< 0.01$) were only observed for the variables biomass, weight of 1 000 seeds and number of branches. On the other hand, for genotypes, highly significant differences ($p< 0.01$) were observed in biomass, weight of 1 000 seeds and number of branches and significant differences ($p< 0.05$) were only observed for harvest index. For the interactions, no significant effects were observed for most of the variables, except for the interaction system x density x genotype, which showed highly significant effects ($p< 0.01$) for number of siliques. Finally, the coefficients of variation ranged between 1.2 and 20.8, which correspond to the variables weight of 1 000 seeds and biomass at physiological maturity, these coefficients are considered acceptable given the nature of the experiment.

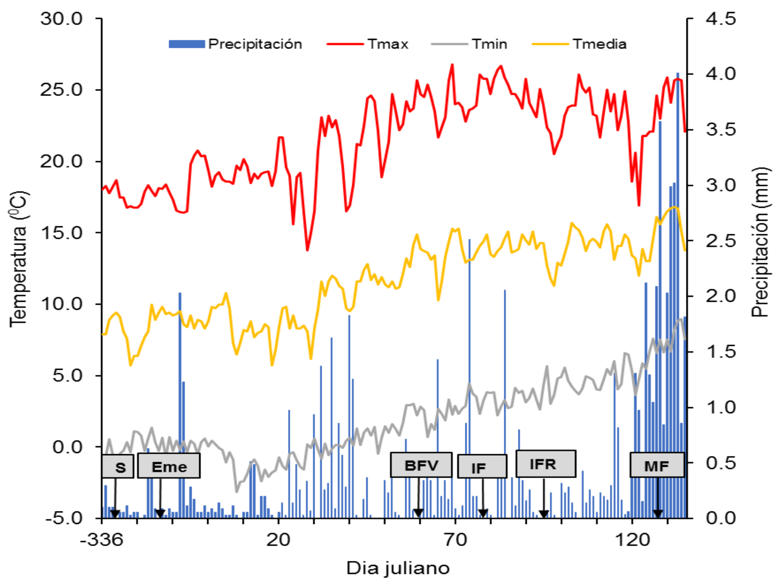

Figure 1. Agroclimatic conditions occurred during the conduct of the experimental work. (S= sowing; Eme= emergence; BFV= visible flower bud; IF= beginning of flowering; IFR= beginning of fruiting; MF= physiological maturity).

Table 1. F values and their statistical significance for the variables evaluated in the two sowing systems, three densities and two canola genotypes in Toluca, Mexico.

Source of variation	df	YIELD ($g\ m^{-2}$)	BIOM ($g\ m^{-2}$)	HI	NG (m^2)	W1000S (g)	NS (m^2)	NSPS	NB
Systems(S)	1	0.4 ns	13.2 **	3 ns	0.1 ns	24.7 **	3.6 ns	1.3 ns	15.7 **
Blocks (System)	6	2.5 *	0.9 ns	0.6 ns	2.5 *	0.1 ns	0.9 ns	1.4 ns	2.5 *
Densities (D)	2	9.7 **	7.6 **	1.1 ns	9.3 **	0 ns	108.1 **	0.4 ns	22 **
Genotypes (G)	1	1.3 ns	8.2 **	4.6 *	0.9 ns	7.4 **	2.5 ns	0 ns	20.8 **
S x D	2	0.2 ns	0.6 ns	0.9 ns	0.1 ns	0.6 ns	2.9 ns	1.5 ns	3 ns
S x G	1	3.5 ns	0.4 ns	0.5 ns	3.5 ns	0 ns	0.3 ns	0 ns	1.3 ns
D x G	2	0.3 ns	0.9 ns	1.1 ns	0.3 ns	0.2 ns	0.7 ns	0.5 ns	2.5 ns
S x D x G	2	0.1 ns	0.5 ns	0.9 ns	0.1 ns	1.2 ns	13.6 **	0.3 ns	1 ns
CV (%)		17.4	20.8	20	17.5	1.2	8.6	14.1	10

BIOM= biomass at maturity; HI= harvest index; NG= number of seeds per m^2; W1000S= weight of 1 000 seeds; NS= number of siliques per m^2; NSPS= number of seeds per silique; NB= number of branches; *= significant at 0.05; **= significant at 0.01; ns= not significant and df= degrees of freedom.

Table 2 shows the comparison of means for the variables evaluated, where the flat bed system (FBS) was significantly higher than the double-row bed system (DRBS) in biomass production, weight of 1 000 seeds and number of branches per plant, for the rest of the characters both sowing systems were statistically the same. The superiority of the flat bed system over the double-row bed system lies in the fact that, in the first, the separation of the rows was 30 cm, while in the second, the separation was 20 cm, but in beds 80 cm apart. Evidence in the literature shows that a smaller spacing between rows produces a higher seed yield as a result of a higher number of siliques and seeds per m^2 (Shahin and Valiollah, 2009; Uzun *et al*., 2012).

Table 2. Mean values of the variables evaluated in two sowing systems, three densities and two canola genotypes in Toluca, Mexico.

	YIELD (g m^{-2})	BIOM (g m^{-2})	HI	NG (m^2)	W1000S (g)	NS (m^2)	NSPS	NB
System								
FBS	493.3 a	2 609.7 a	0.19 a	128549 a	3.8 a	2 117.8 a	19.6 a	5.5 a
DRBS	467.6 a	2 115.6 b	0.2 a	124135 a	3.7 b	2 216.7 a	20.7 a	4.5 b
Mean	480.4	2 362.6	0.15	126342	3.7	2 167.2	20.1	5
Density								
D90	552.4 a	2 692.7 a	0.2 a	145007 a	3.8 a	2 541.8 a	19.7 a	4.4c
D75	463.8 b	2 381 ba	0.18 a	122060 b	3.8 a	2 343.1 b	20.1 a	5 b
D50	425.2 b	2 014.2 b	0.2 a	111958 b	3.8 a	1 616.9 c	20.6 a	5.6 a
Mean	480.4	2 362.6	0.16	126341	3.8	2 167.2	20.1	5
Genotype								
Hyola 61	466.3 a	2 158.6 b	0.21 a	123181 a	3.7 b	2 124.3 a	20.2 a	4.7 b
Bioaureo 2486	494.6 a	2 566.6 a	0.18 b	129502 a	3.8 a	2 210.2 a	20 a	5.3 a
Mean	480.4	2 362.6	0.19	126341	3.7	2 167.2	20.1	5

BIOM= biomass at maturity; HI= harvest index; NG= number of seeds per m^2; W1000S= weight of 1 000 seeds; NS= number of siliques per m^2; NSPS= number of seeds per silique; NB= number of branches. Means with the same letter within columns do not differ significantly from each other, at a significance level of 0.05 of the Tukey test.

Increases in plant density are reflected in higher biomass production and seed yield, as a result of a higher number of seeds per m^2 (Shahin and Valiollah, 2009; Uzun *et al*., 2012). The data reveal that D90 (90 plants m^{-2}) was statistically higher than D75 (75 plants m^{-2}) and D50 (50 plants m^{-2}) in most of the variables evaluated, except for the harvest index, weight of 1 000 seeds and number of seeds per silique.

The genotypic effect on population density in canola has been analyzed in many studies, where differences in seed yield have been minimal (Różyło and Pałys, 2014), while others mention that differences in yield may be due to the different structure of the plant (Waseem *et al*., 2014). In this sense, our data show that Hyola 61 was statistically higher (14%) than Bioaureo 2486 in harvest index, while Bioaureo 2486 was statistically higher than Hyola 61 in biomass production (18%), weight of 1 000 seeds (3%) and number of branches (11%) (Table 2). The differences in some characteristics between both cultivars may be due to the different plant structure that exists between them since Hyola 61 produces fewer branches than Bioaureo 2486.

The production of biomass at maturity and the harvest index are very important characteristics to reach high yields in grain crops and particularly in canola (Zhang and Flottmann, 2016). The contribution of both characters to seed yield strongly depends on the type of cultivar (hybrid or open pollination), but usually biomass production largely explains changes in seed yield (Li *et al*., 2016). The data indicate that, when considering sowing systems, densities and genotypes, seed yield was mainly explained by the changes observed in biomass production at maturity (r^2= 0.81, p< 0.001) and not by the harvest index (Figure 2), apparently the latter was more stable, as has been reported in other grain crops such as triticale (Estrada *et al*., 2012) and wheat (Parry and Hawkesford, 2010).

It has been established that the distance between rows is a very important management factor since it affects the seed yield and the components of the yield in individual plant in canola (Uzun *et al*., 2012; Różyło and Pałys, 2014). Our data revealed that when densities and genotypes are considered, the flat bed system (5 rows to 30 cm) obtained a higher biomass production compared to the double-row bed system (Table 3; Figure 2a).

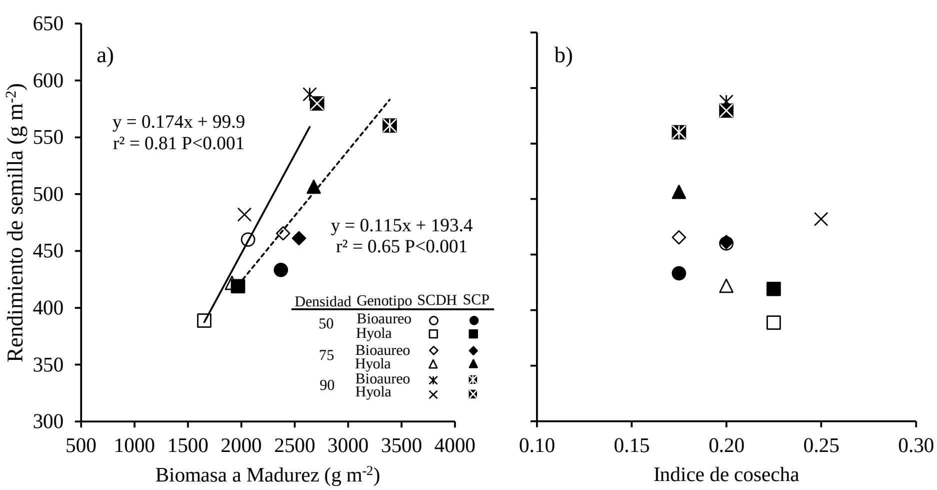

Figure 2. Relationships between seed yield and biomass produced at maturity (a) and with harvest index (b) for two canola cultivars grown under three plant densities and in two sowing systems in Toluca, Mexico. Solid and dashed lines in the graph are the regression models fitted for DRBS (SCDH) and FBS (SCP), respectively.

On the other hand, increases in sowing density significantly increased seed yield in both sowing systems, with increases of 22 and 20% when going from 50 to 90 plants m^{-2} in Bioaureo 2486 and Hyola 61, respectively, for the double-row bed system. While in the flat bed system, the increases in yield, when going from 50 to 90 plants m^{-2}, were 23 and 28% for Bioaureo 2486 and Hyola 61, respectively (Table 3).

Table 3. Mean values of the variables evaluated for system, density and genotype in canola cultivation in Toluca, Mexico.

Density	Genotype	YIELD (g m^{-2})		BIOM (g m^{-2})		HI		NG (m^2)	
		DRBS	FBS	DRBD	FBS	DRBS	FBS	DRBS	FBS
50	Bioaureo	460bA	433bA	2 063aA	2370bA	0.20aA	0.17aB	121992aA	112509bA
	Hyola	388bA	419bA	1 653bA	1969cA	0.22aA	0.22aA	103026bA	110304bA
75	Bioaureo	465aA	461aA	2 392aA	2540bA	0.17bB	0.20aA	122524aA	119953bA
	Hyola	422bA	506aA	1 913aB	2677aA	0.20aA	017aB	113408bA	132354aA
90	Bioaureo	587aA	560aA	2 641aB	3390aA	0.20aA	0.17aB	155491aA	144541aA
	Hyola	482aA	579aA	2 029aB	2709aA	0.25aA	0.20aB	128366aA	151628aA
		467A	493A	2 115B	2609A	0.20A	0.19A	124135A	128549A
		W1000S (g)		NS (m^2)		NSPS		NB	
50	Bioaureo	3.8aA	3.9aA	1 724A	1 538cB	21.5aA	19.2aA	5.7aA	6.0aA
	Hyola	3.8aA	3.8aA	1 662A	1 543cA	22.1aA	19.8aA	5.0aB	5.7aA
75	Bioaureo	3.8aA	3.9aA	2 620B	2 119bA	22.3aA	19.0aB	4.5bB	6.0aA
	Hyola	3.7aA	3.8aA	2 292A	2 340bA	20.0aA	19.1aA	4.2bB	5.5aA
90	Bioaureo	3.8aA	3.9aA	2 385B	2 873aA	18.6aA	19.9aA	4.7aA	5.2bA
	Hyola	3.8aA	3.8aA	2 616B	2 291bA	20.0aA	20.4aA	3.2cA	4.5bB
		3.7A	3.8A	2 216A	2 117A	20.7A	19.A	4.5B	5.5A

BIOM= biomass at maturity; HI= harvest index; NG= number of seeds per m^2; W1000S= weight of 1 000 seeds; NS= number of siliques per m^2; NSPS= number of seeds per silique; NB= number of branches; S= system; D= density; G= genotype. Means with the same uppercase letter are not different between systems and with the same lowercase letter within columns, the means do not differ significantly from each other, at a significance level of 0.05 of the Tukey test.

Positive effects in reducing the distance between rows have been reported in numerous studies, for instance, Shahin and Valiollah (2009), when evaluating three distances between rows (12, 18 and 24 cm), found significant increases in seed yield in rows 12 cm apart. On the other hand, Uzun *et al*. (2012), when evaluating different spacings between plants (5, 10, 15 and 20 cm) and between furrows (10, 20, 30 and 40 cm), found a higher yield with distances between plants of 5 to 10 cm and separation between furrows of 10 cm. In the same way, Różyło and Pałys (2014), when evaluating different spacings between furrows, found that greater separation decreased both biomass production and yield per m^2. Recently, French *et al*. (2016), when evaluating densities between 7 and 180 plants m^{-2}, found that the optimal average density was 32 plants m^{-2} and as the density increased there was a positive effect on yield.

The analysis of the numerical components of yield in grain crops has shown that the most important component in determining yield is the number of grains per m^2 (Cheng-dong *et al*., 2019). As expected, changes in seed yield, when considering sowing systems, densities and cultivars, were explained by the number of seeds per m^2 (r^2= 0.99, p< 0.001; Figure 3a), since no degree of association was observed for individual seed weight (Figure 3b). Between both cultivars, it was observed that the increase in sowing density positively affected the number of seeds per m^2, mainly in the double-row bed system, however, this did not statistically affect the individual seed weight (Figure 3b).

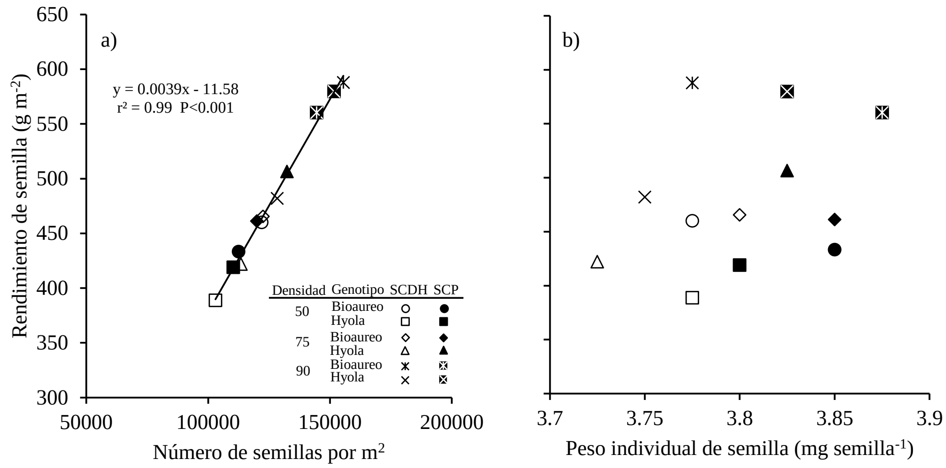

Figure 3. Relationships between seed yield and number of seeds per m^2 (a) and with individual seed weight (b) for two canola cultivars grown under three population densities and in two sowing systems in Toluca, Mexico. The solid line in the graph represents the regression model fitted for both systems.

It should be noted that the number of seeds per m^2 had a moderate and positive association with the number of siliques per m^2 (r^2= 0.41 p< 0.05) (Figure 4a) when considering the joint effect of sowing systems, densities and cultivars, while for the same number of seeds per silique, changes in the number of seeds per m^2 were observed (Figure 4b). These results highlight the importance of the number of siliques as a characteristic strongly associated with seed yield through the number of seeds (Shahin and Valiollah, 2009). The number of siliques per plant depends on the number of branches, number of flower clusters and how many of these siliques set (Shahin and Valiollah, 2009; Assefa *et al*., 2018) and is a character that compensates for losses in yield due to low density in potentially good environments, because a greater number of siliques per productive branch is achieved when the sowing density is reduced (Assefa *et al*., 2018).

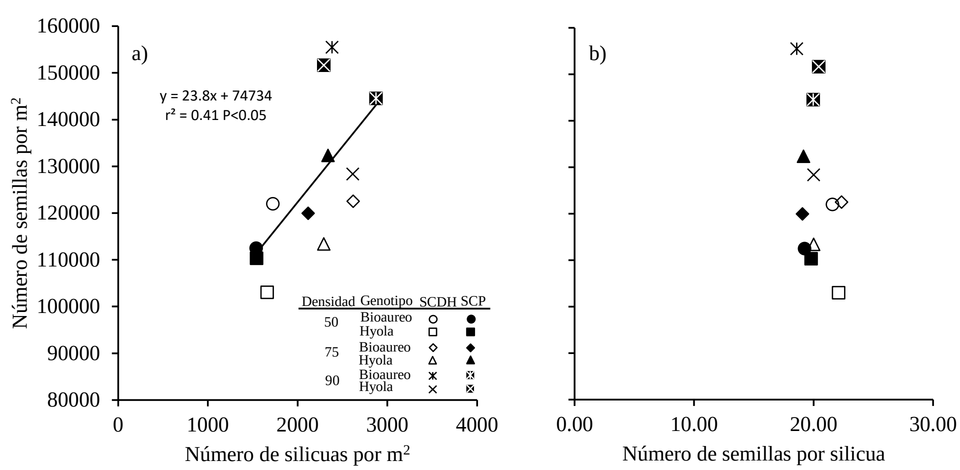

Figure 4. Relationships between the number of seeds per m^2 with the number of siliques per m^2 (a) and with the number of seeds per silique (b) for two canola cultivars grown under three population densities and in two sowing systems in Toluca, Mexico. The solid line in the graph represents the regression model fitted for both systems.

The number of productive branches in canola is a characteristic that is largely associated with seed yield, and it also responds significantly to changes in the environment and management practices (Shahin and Valiollah, 2009; Hua *et al*., 2014). In this sense, reductions in the number of branches are observed when the sowing density is increased (Uzun *et al*., 2012; Vincze, 2017) or when there are delays in the sowing date (Hua *et al*., 2014; Vincze, 2017). Our data reveal that the number of siliques per m^2 was associated with the changes observed in the number of productive branches, mainly in the flat bed system (r^2= 0.83, p< 0.01) (Figure 5).

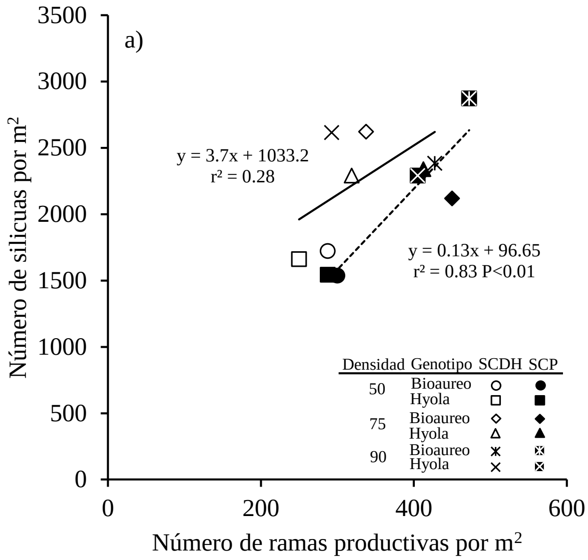

Figure 5. Relationship between the number of siliques per m^2 and the number of branches per m^2 for two canola cultivars grown under three population densities and in two sowing systems in Toluca, Mexico. Solid and dashed lines in the graph are the regression models fitted for DRBS (SCDH) and FBS (SCP), respectively.

Seed yield was positively associated with biomass production at physiological maturity, with the number of seeds per m^2 and with the number of siliques per m^2 (Table 4), which is consistent with numerous studies in the literature that indicate that these attributes are defining in canola seed yield (Shahin and Valiollah, 2009; Uzun *et al*., 2012; Mamun *et al*., 2014; Yang *et al*., 2014). On the other hand, the biomass at physiological maturity was positively correlated with the number of seeds, with the weight of 1 000 seeds and with the number of siliques per m^2, while a negative association was observed with the harvest index.

As expected, the number of seeds per m^2 was positively correlated with the number of siliques per m^2, which indicates the great influence of the number of siliques in the determination of the number of seeds and the yield in canola, coinciding with previous evidence in the literature (Shahin and Valiollah, 2009; Kazemeini *et al*., 2010). On the other hand, there was a negative association between the number of siliques per m^2 and the number of branches. This is a very important aspect to consider when varying density, since the number of productive branches tends to be affected both by density and by delays in the sowing date (Kazemeini *et al*., 2010; Vincze, 2017; Assefa *et al*., 2018). The weight of 1 000 seeds showed a positive association with the number of branches.

Table 4. Coefficients of correlation between the evaluated characters.

	YIELD	BIOM	HI	NG	W1000S	NS	NSPS
Biom	0.708**						
HI	0.029	-0.453**					
NG	0.997**	0.68**	0.048				
W1000S	0.188	0.473**	-0.257	0.117			
NS	0.468**	0.502**	-0.098	0.468**	0.025		
NSPS	-0.106	-0.178	-0.067	-0.091	-0.211	-0.02	
NB	-0.099	0.14	-0.218	-0.13	0.448**	-0.444**	-0.06

**= Highly significant at 0.01. YIELD= seed yield (g m^{-2}); BIOM= biomass at physiological maturity (g m^{-2}); HI= harvest index; NG= number of seeds per m^2; W1000S= weight of 1 000 seeds (g); NS= number of siliques per m^2; NSPS= number of seeds per silique; NB= number of productive branches per plant.

Conclusions

In terms of physiological components, seed yield was explained by the changes observed in biomass production at maturity and not by the harvest index. The highest seed yield was obtained with the flat bed system, the genotype Bioaureo 2486 and a sowing density of 90 plants m^{-2}. With the flat bed system (5 rows at 30 cm), a higher biomass production was obtained compared to the double-row bed system. The two cultivars showed differences in their plant structure, Hyola 61 produced fewer branches than Bioaureo 2486.

Acknowledgements

The author G. García-Hernández would like to thank the National Council of Science and Technology (CONACYT, for its acronym in Spanish) for the scholarship that allowed him to complete his Master's degree in Agricultural Sciences and Natural Resources. The present work was part of the project 'Ecophysiological attributes of biomass yield and production in grain crops modified by population density and sowing system' with registration number in the UAEMex.

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