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Article

Desi chickpea forage production at different sowing dates and densities

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Abstract

Desi chickpeas are a legume with forage potential due to their high protein and energy content. It has been observed that the sowing date and density affect their yield; however, there is a lack of information to optimize their production under irrigation in arid areas. This study aimed to evaluate the effect of sowing date (October 22, December 22 and January 22), sowing density (27, 41 and 55 kg ha^{-1}), and *Desi* chickpea varieties (El Patrón, Pénjamo, and San Antonio 05) on forage yield (FY), grain yield (GY), and harvest index (HI). The experimental design used was randomized complete blocks arranged in subsplit plots and three replications, the experiment was replicated in two agricultural cycles (2018-2019 and 2019-2020). The data were analyzed by means of an analysis of variance, with comparison of means using mutually orthogonal contrasts. The sowing date of December 22 favored FY and GY with values of 12.9 and 3.5 t ha^{-1}. The density of 27 kg ha^{-1} excelled by achieving values of 11.4 t ha^{-1}, 3.41 t ha^{-1}, and 32.65% in FY, GY, and HI. The best variety in FY was El Patrón with 12 t ha^{-1}, while San Antonio 05 stood out in GY and HI with values of 3.4 t ha^{-1} and 34.8%. This study highlights the importance of defining an optimal level in the factors evaluated for their influence on the yield of *Desi* chickpea varieties under irrigated conditions.

Keywords:

Cicer arietinum L., chickpea straw, forage yield, ruminant nutrition.

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Introduction

Chickpeas (*Cicer arietinum* L.) are one of the most important crops worldwide (Merga and Haji, 2019) as they are a valuable source of proteins, minerals, and vitamins that plays a prominent role in the human diet in many regions of the world; additionally, they represent an alternative source of food rich in protein and energy for the livestock industry (Bampidisa and Christodoulou, 2011). The whole plant or the grain of the forage or *Desi* chickpeas is in great demand in some areas of Mexico as livestock feed due to its high protein content, which reduced dependence on high-cost balanced feeds (Soltero *et al*., 2008).

It has been observed that the date and density of sowing directly influence the growth and development of the chickpea crop, maturity time, and pod and seed production, which affects its yield and quality (Husnain *et al*., 2015; Yeasin *et al*., 2018). Several studies have been carried out on the effect of plant density on the crop. Some assessments noted a positive relationship between plant density and grain yield potential (Jettner *et al*., 1999; Regan *et al*., 2003; Bahar, 2007), while others reported a lack of significance in this factor (Ali and Singh, 1999).

Therefore, it is necessary to develop research work on sewing seasons. Regan *et al*. (2003) concluded that there was a strong relationship between optimal economic plant density and seed yield potential; in higher yield situations, lower plant densities will produce the greatest profit. In this sense, no research work has been carried out in Mexico on the aforementioned factors and their influence on chickpea forage production. The objective of this work was to evaluate the effect of sowing date and density on forage yield in *Desi* chickpea varieties.

Materials and methods

The study was conducted at the facilities of the Valle de Santo Domingo Experimental Site of the National Institute of Forestry, Agriculture and Livestock Research (INIFAP, for its acronym in Spanish), located at 25° 00' 36" north latitude, 111° 39' 49" west longitude, at 48.3 masl. The climate at the site is very dry, with precipitation and average annual temperature of 200 mm and 22 °C, respectively (CONAGUA, 2018). The soil texture is sandy clay loam, with 0.23% organic matter, pH of 8.9 and electrical conductivity of 0.76 dS m^{-1}.

An experimental design was established in randomized blocks arranged in subsplit plots with three replications in each of the autumn-winter agricultural cycles, 2018-2019 and 2019-2020. As a large plot, three sowing dates were evaluated: October 22, December 22, and January 22; the medium plot considered three sowing densities (SDe): 27, 41, and 55 kg ha^{-1} of viable pure seed (equivalent to 10, 15, and 20 seeds per meter of row) and in the small plot, three varieties of *Desi* chickpeas were evaluated: El Patrón, Pénjamo, and San Antonio 05. Each experimental unit consisted of six furrows spaced at 0.8 m by 5 m in length (24 m^2).

Weed control was carried out with oxyfluorfen at a dose of 240 g of ai. ha^{-1} in pre-sowing. The seed was treated with carboxin + thiram at doses of 80 g per 100 kg of seeds. Irrigation was applied with 6-thousandth gauge drip tape with emitters 20 cm apart. The total irrigation sheet was 35 cm. It was fertilized with the dose 120-70-00, with the sources UAN 32® and phosphoric acid. Nitrogen was fractionated in equal parts and applied at 15, 30 and 50 days after sowing and phosphorus at 15 days after sowing.

To determine the forage yield, three meters in length were harvested manually from two internal furrows of each experimental unit (4.8 m^2), and the samples were cut at a height of 5 cm from the ground 130 days after sowing. The following was determined: forage yield (FY) in t ha^{-1} dry matter, grain yield (GY) in t ha^{-1} adjusted to 10% moisture, and harvest index (HI) in percentage (%) using the formula HI= (grain production/biological yield) *100 (Kohashi *et al*., 1980). For the analysis of the variables, the general linear model procedure (GLM procedure) was used in the SAS software (2014), and the main factors and significant interactions were analyzed by mutually orthogonal contrasts.

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Results

Within the factors of agricultural cycle, sowing dates, and varieties, the three variables under study presented statistical differences (Table 1). In the case of the sowing density factor, only the GY and HI variables showed statistical differences (Table 1).

Table 1. Analysis of variance for productive variables of *Desi* chickpeas established on three sowing dates and densities in the 2018-2019 and 2019-2020 agricultural cycles.

Source of variation	Model	Agricultural cycle	Rep (agricultural cycle)	SD	Agricultural cycle*SD	Error a	SDe
df	81	1	4	2	2	8	2
FY	7.25	20.34**	0.77	140.36**	60.69**	1.39	0.86
GY	0.79	23.81**	1.2	2.79**	1.14**	0.45	1.14**
HI	90.57	88.64*	98.68	667.28**	443.75**	35.62	88.43**
	SD*SDe	Agricultural cycle*SDe	Agricultural cycle*SD*SDe	Error b	Var	SD*Var	SDe*Var
df	4	2	4	24	2	4	4
FY	4.47**	6.15**	4.98**	0.96	27.52**	1.83*	0.53
GY	0.04	0.43	0.15	0.16	3.34**	1.38**	0.24
HI	29.66	152.69**	68.56**	14.06	996.44**	145.12**	20.17
	SD*SDe*Var	Year*Var	Year*SD*Var	Year*SDe*Var	Error c	CV	Total
df	8	2	4	4	80		161
FY	0.46	0.21	1.32	0.5	0.65	7.12	
GY	0.12	0.3	0.42	0.13	0.19	13.49	
HI	17.2	53.57*	41.3*	17.35	14.45	12.19	

df= degrees of freedom; SD= sowing dates; SDe= sowing density; Var= varieties; CV= coefficient of variation; **= (p< 0.01); *= (p< 0.05); FY= forage yield in t ha^{-1} dry matter; GY= grain yield in t ha^{-1} grain adjusted to 10% moisture; HI= harvest index in (%). The values of each column in each response variable correspond to mean squares error.

Agricultural cycles

The productive behavior of chickpeas varied between agricultural cycles (Table 2). During the 2018-2019 cycle, chickpeas performed better in FY, GY and HI (Table 2).

Table 2. Comparison of means of productive variables of *Desi* chickpeas between sowing cycles.

Variable	Agricultural cycles		DBT	Significance‡
	2018-2019	2019-2020		
FY	11.678	10.969	0.709	**
GY	3.635	2.868	0.767	**
HI	31.911	30.432	1.479	*

**= p< 0.01; *= p< 0.05; DBT= difference between treatments; FY= forage yield in t ha^{-1} of dry matter; GY= grain yield in t ha^{-1} grain adjusted to 10% moisture; HI= harvest index in (%). ‡= Mutually orthogonal contrast test.

Varieties, sowing densities and dates

There were highly significant differences (p< 0.01) among varieties. El Patrón had the highest FY, but the lowest GY and HI, whereas San Antonio 05 showed the highest GY and HI, but the lowest FY (Table 3). Between sowing densities, there were significant differences (p< 0.05) for GY and HI, and highly significant differences (p< 0.01) in the density of 27 kg ha-1 vs 55 kg ha-1 for GY and HI. The density of 27 kg ha-1 was higher than the average for high densities in GY and HI (Table 3).

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For the yield characteristics (FY and GY), highly significant differences ($p < 0.01$) were found between sowing dates; on the date of December 22, the yield was higher than that of the rest of the dates, whereas the HI was higher on the date of January 22. The sowing date of October 22 showed the lowest GY (Table 3).

Table 3. Mutually orthogonal contrasts between varieties, sowing densities and dates for productive variables of *Desi* chickpeas.

Variable	Varieties		DBT	Sig‡	Sowing densities		DBT	Sig‡	Sowing dates		DBT	Sig‡
	Pénjamo *vs* El Patrón and San Antonio				**SDe41 *vs* SDe27 and SDe55**				**22-Dec *vs* 22-Oct and 22-Jan**			
FY	11.356	11.308	0.048		11.179	11.396	-0.217		12.936	10.518	2.418	**
GY	3.386	3.184	0.202	**	3.144	3.306	-0.162	*	3.501	3.127	0.374	**
HI	32.271	30.622	1.649	*	30.298	31.608	-1.31	*	28.672	32.444	-3.772	**
	El Patrón *vs* San Antonio				SDe27 *vs* SDe55				22-Oct *vs* 22-Jan			
FY	12.022	10.595	1.427	**	11.408	11.385	0.023		11.324	9.712	1.612	**
GY	2.965	3.403	-0.438	**	3.417	3.194	0.223	**	3.056	3.198	-0.142	
HI	26.433	34.811	-8.378	**	32.641	30.575	2.066	**	29.705	35.183	-5.478	**

** = $p < 0.01$; * = $p < 0.05$; DBT= difference between treatments; Sig= significance; FY= forage yield in t ha^{-1} of dry matter; GY= grain yield in t ha^{-1} grain adjusted to 10% moisture; HI= harvest index in (%); ‡= mutually orthogonal contrast test.

Interaction between showing dates *vs* densities, and dates *vs* varieties

The main interaction between sowing dates and densities ($p < 0.01$) was observed between the date of October 22 and the density of 27 kg ha^{-1} for the FY and, to a lesser degree ($p < 0.05$), with the density of 41 kg ha^{-1}. On the other hand, the main interaction between sowing dates and varieties occurred between the first sowing date (October 22) and the Pénjamo variety, which reduced FY and GY. For this same date, El Patrón decreased the GY and HI (Table 4).

Table 4. Mutually orthogonal contrasts of the interaction between sowing date *vs* densities and date *vs* varieties for the evaluated productive variables.

Source of variation	df	Variable FY	Source of variation	df	Variables FY	GY	HI
22-Oct. x SDe27 *vs* 22-Oct. x rest of densities	1	11.25*	22-Oct. x Pénjamo *vs* 22-Oct. x rest of varieties	1	11.21**	3.01*	29.47
22-Oct. x SDe41 *vs* 22-Oct. x rest of densities	1	10.74*	22-Oct. x El Patrón *vs* 22-Oct. x rest of varieties	1	12.11	2.59**	22.91**
22-Dec. x SDe27 *vs* 22-Dec. x rest of densities	1	13.1	22-Dec. x Pénjamo *vs* 22-Dec. x rest of varieties	1	13.38	3.77	29.7*

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Source of variation	df	Variable FY	Source of variation	df	Variables FY	GY	HI
22-Dec. x SDe41 *vs* 22-Dec. x rest of densities	1	13.29	22-Dec. x El Patrón *vs* 22-Dec. x rest of varieties	1	13.36	3.32**	26.33**
Total	4			4			

** = $p < 0.01$; * = $p < 0.05$; FY= forage yield in t ha^{-1} of dry matter; GY= grain yield in t ha^{-1} grain adjusted to 10% moisture; HI= harvest index in (%); df= degrees of freedom.

Discussion

Effect of cycles and sowing dates

In this study, there was 21% difference in GY between agricultural cycles; FY and HI were 6.4 and 5.7% higher, respectively, during the 2018-2019 cycle. In both cycles, the most productive performance occurred on the sowing date of December. There is no conclusive evidence in arid areas of Mexico on FY or GY of *Desi* chickpeas; nevertheless, sowing dates from November 25 to December 25 are recommended for these areas for white or Kabuli chickpeas (Guía técnica, 2010).

It was observed that sowing outside this date reduces FY and GY by 19 and 11%, respectively. In addition, the January showing date showed the highest HI. In this sense, it has been shown that both late (Parmar *et al*., 2015) and early (Ray *et al*., 2020) sowings significantly reduce the yield and quality of chickpea grain. On the other hand, Sethi *et al*. (2016) noted that early sowings allow for increased root and nodule growth, leading to vigorous vegetative growth through taller plants and increased accumulation of dry matter and branches per plant.

Sowing density effect

The sowing density of 27 kg ha^{-1} presented on average 7% and 6% more GY and HI compared to the rest of the densities. On the other hand, the lowest SDe represents seed cost savings of 25 and 50% compared to the densities of 41 and 55 kg ha^{-1}, respectively. Regan *et al*. (2003) mention that the most profitable density is that of 25 plants m^{-2} additionally, Swi-Kwong (2005) found that this density produces higher quality seeds.

The results generated in this work contrast with those presented by Jettner *et al*. (1999); Bahar (2007), who observed that the yield of *Desi* chickpea seed responded positively to an increase in the sowing rate of up to 120 kg ha^{-1}, but they also perceived that the number of pods per plant, the seed size, and the harvest index decreased. In a more recent study, developed in India by Choudhary *et al*. (2022), when testing sowing rates of 48, 64, and 80 kg ha^{-1}, they found a higher harvest index, number of branches and pods per plant in sowings with 48 kg ha^{-1} and higher seed and straw yield with sowings of 60 and 80 kg ha^{-1}.

Variety effect

Of the factors under study, the varieties showed the greatest variation in the parameters evaluated, either as a main effect or in combination with the sowing date, and to a lesser degree with density. The El Patrón variety exhibited the highest FY (12 t ha^{-1} dry matter), San Antonio 05 presented an FY of 10.59 t ha^{-1}, enough to feed around 30 animal units month^{-1}. This amount of feed can be used during the dry season in areas where forage availability decreases significantly. Sotelo and Pérez (2006) report yields of between 5 and 7 t ha^{-1}, below those reported in this study.

The area sown with chickpeas in Mexico for 2020 was 96 000 ha, with a GY of 2.1 t ha^{-1} and an estimated average of 186 000 tons in the last 10 years (SIAP, 2021). Regarding the GY of

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the varieties evaluated, San Antonio 05 and Pénjamo produced an average of 3.4 t ha^{-1}, like that reported by Sotelo and Pérez (2006) for the San Antonio 05 variety (2.4 to 3.5 t ha^{-1}) under irrigated conditions.

Research by Gutierres *et al*. (2017) obtained yields higher than 2.6 t h^{-1} for the El Patrón and Pénjamo varieties. In the present study, although no differences were observed in the GY compared to the studies carried out by Sotelo and Pérez (2006) and Gutierres *et al*. (2017), the HI was lower due to the higher production of straw; therefore, even if vegetative growth is modified, the amount of grain is not modified due to the negative correlation that exists between FY and HI.

Effect of the interaction between sowing date and density

Although it has been mentioned in this work that the sowing density of 27 kg ha^{-1} did not present a statistical difference in FY compared to the rest of the densities, for the sowing date of October 22 in combination with the different sowing densities, significant differences were observed, which are the lowest values obtained between the different interactions. The FY shows the lowest yield in October, while the HI is the highest for this density; in contrast, the sowing date of December 22 presented the highest FY and the lowest HI when the sources of variation are analyzed separately. Therefore, for the first sowing date, it is not advisable to use the density of 27 kg ha^{-1}.

Effect of the interaction between sowing dates and varieties

The productive response (FY and GY) and the HI of the varieties were dependent on the sowing date; on the sowing date of October 22, the Pénjamo variety was the one with the lowest productive performance in FY (11.21 t ha^{-1}), whereas the El Patrón variety, which had the highest FY (12.11 t ha^{-1}), limited its GY (2.59 t ha^{-1}) and its HI (22.91%) to a greater degree. On December 22, both varieties presented the same performance in FY, whereas El Patrón presented lower GY (3.32 t ha^{-1}) and HI (26.33 t ha^{-1}).

The variable behavior of varieties at sowing dates has been reported by Ali *et al*. (2018); Kumar *et al*. (2023), who have linked a better response in forage and grain yield in those genotypes established in adequate environmental conditions for their growth and development. Thus, evaluating different varieties on different sowing dates allows the expression of genotypes in different environments, which is valuable when issuing recommendations of the most suitable varieties for specific production and management systems (Richards *et al*., 2020).

Conclusions

The sowing date and density as well as the genotype influenced the productive behavior of forage chickpeas. The best productive performance was achieved on the sowing date of December 22. It is recommended to use the sowing density of 27 kg ha^{-1} of viable pure seed. The El Patrón variety had the highest forage yield, whereas the San Antonio 05 variety presented the highest grain yield. For future work, it is recommended to assess the quality of chickpea forage in response to the factors under study to define the best agronomic practices, considering the potential productive response of livestock to forage consumption and productivity per unit area, that is, kilograms of meat or liters of milk per hectare for future work.

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