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AGRONOMIC FEASIBILITY OF GROWING CHIA IN NORTHWESTERN RIO GRANDE DO SUL

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ABSTRACT
The aim of this work was to evaluate the development of Chia at different sowing times and plant spacings. The experiment was conducted in a commercial area located in the Northwest Region of RS in the municipality of Novo Machado. The experiment was conducted in a bifactorial arrangement with 2 spacings and 3 sowing times, with four replications. The factors analyzed were three different sowing times (January 15 and 30, and February 15) combined with two spacings (17 and 45 cm). The following parameters were evaluated: mean plant height, ear length, yield, weight of one thousand seeds, germination and first germination test count. The variable percentage of germination and its derivations were transformed into arcsin $(X/100)^{1/2}$. The study showed that chia can be cultivated in the region, achieving good results for the parameters evaluated, mainly for grain yield. Sowing carried out in January and at the spacing of 17 cm between rows provided the best results.

KEYWORDS: Spacing; sowing time, plant density, *Salvia hispânica*, crop rotation.

VIABILIDADE AGRONÔMICA DO CULTIVO DA CHIA NO NOROESTE DO RIO GRANDE DO SUL

RESUMO
O objetivo deste trabalho foi avaliar o desenvolvimento do cultivo da Chia através de diferentes épocas de semeadura e espaçamento entre plantas. O experimento foi conduzido em área comercial localizada na Região Noroeste do RS no município de Novo Machado. O experimento foi conduzido como um bifatorial composto por 2 espaçamentos x 3 épocas de semeadura com quatro repetições. Os parâmetros analisados foram semeadura em três épocas diferentes (15 e 30 de janeiro e 15 de fevereiro) combinados com dois espaçamentos (17 e 45 centímetros). Foram avaliados os seguintes parâmetros: altura média das plantas, comprimento de espigas, produtividade, peso de mil sementes, germinação e primeira contagem do teste de germinação. A variável germinação e suas derivações foram transformadas em arco seno $(X/100)^{1/2}$. A chia pode ser cultivada na região estudada onde obteve bons resultados nos parâmetros estudados em destaque para produtividade de grãos. O período de semeadura que obteve melhores resultados foi referente as semeaduras realizadas no mês de janeiro no espaçamento de 17 cm entre linhas.

PALAVRAS-CHAVE: Espaçamento, época de semeadura, densidade de plantas, *Salvia hispanica*; rotação de culturas.

1 INTRODUCTION

Chia (*Salvia hispanica* L.) is native to southwestern Mexico and northern Guatemala and has attracted interest in recent years because the concentration of proteins, lipids, carbohydrates and fiber in seeds is significantly higher than other important grains and cereals such as rice, oats, corn, wheat and barley. In addition, chia proteins lack gluten, being an alternative to celiacs and a good source of vitamins, minerals and antioxidants. Interest in growing chia derives from the health benefits of their grains to human body. Chia contains omega-3 fatty acids, antioxidants and fiber, which contribuite to delay cellular aging and prevent cardiovascular diseases (Ixtaina et al., 2010; Zavalia et al., 2011). In Brazil, chia had not been recognized as a safe food for commercialization until 2013 by the Brazilian legislation, and can only be commercialized in pharmaceutical stores, even with all the benefits reported in the international literature (Coelho & Sallas-Mellado, 2014).

In its center of origin, chia is grown between the 20º and 30º latitudes and there are reports on research and production in the province of Santa Fe, Argentina, 33º14' S latitude, in altitudes from sea level to 2000 meters and in the most diverse types of soil. These environmental conditions allow sowing chia in the same latitudes of the northwest of Rio Grande do Sul, aiming at providing an alternative crop and a new source of income for farmers (Busilacchi et al., 2013).

Farmers' interest in growing chia has come ahead of research and happens in a disorderly manner and based on the seed market value in face of the possibility of financial return compared with conventional crops, whose profit margin decreases at each harvest. Sowing is done based on information from neighboring countries that already cultivate chia, arriving through relatives and friends who in the past migrated to Argentina and especially Paraguay. Thus, commercial planting of chia takes place in Bolivia, Colombia, Guatemala, Mexico, Peru, Argentina and Paraguay (Ayerza & Coates, 2007).

Chia seed is composed of proteins (15-25%), lipids (30 to 33%), fibers (18-30%), carbohydrates (26-41%), ashes (4-5%), minerals, vitamins and dry matter (90-93%). It contains a high number of antioxidants (Ixtaina et al., 2008; Ayerza & Coates, 2011) such as beta-carotene, tocopherol, chlorogenic acid, caffeic acid and flavonoids (quercetin, myricetin and kaempferol). Chia prevents rancidity in unsaturated fatty acids present in foods (Reyes-Caudillo et al., 2008). Another key characteristic of chia seed is that it does not contain gluten (Bueno et al., 2010). The moisture content of the seed is approximately 6 to 8% (Ayerza, 2009; Ixtaina et al., 2010; Jimenez et al., 2013).

With the goal of increasing the number of alternative crops and providing a new source of income to farmers because of the highly valued market of chia, there is a need to evaluate its cultivation in the Northwest region of Rio Grande do Sul as well as to propose suitable crop management techniques to achieve a better economic return of the farm economic activity. There is little technical information on growing chia in the Portuguese language and more specifically in Brazil. In this way, the existing literature focuses on Spanish-speaking countries in the Central and South America, where the crop has great historical, cultural and economic importance.

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Considering the potential for diversification of the productive matrix of Northwestern Rio Grande do Sul with chia, studies are required to investigate the possible adaptation and production up to the parallel 33º14' S (Busilacchi et al., 2013), with emphasis on the ideal time for sowing to provide the development and fruit setting of the crop before the first frosts forecasted for these latitudes in July (Wrege et al., 2004). Frost episodes have been reduced in the last six decades, averaging 0.9 days in autumn and 2.3 days in winter (Berlato & Althaus, 2010), with the risk of frost damage decreasing in autumn, at harvest time. At latitudes greater than 39º 11' S, the incidence of frost occurring before flowering prevents chia from producing.

Since chia is a short-day plant, it is necessary to plan the sowing time so that a good vegetative development occurs before flowering, avoiding a small and less productive plant and having as critical photoperiod between 12 and 13 hours for the crop implementation. Controlled environment trials showed that chia can flower with day length below14 hours (Jamboonsri et al., 2012). Field experiments showed that the best sowing time at latitude 26º S is between January 20 and February 12 (Zavalia et al., 2011), coinciding with maize harvesting in Northwestern RS and the possibility of planting a new agricultural crop, thus providing a new alternative for crop rotation.

In this context, the objective of this study was to evaluate the effects of different sowing times and line spacings on the development of chia.

2 MATERIAL AND METHODS

The experiment was conducted in a commercial area located in the northwest Region of RS, in the municipality of Novo Machado, 27º54' South latitude and 54º29' West longitude, 220 m altitude, from January to June 2015. The soil is classified as a Dystrophic Red Latosol (Santos et al., 2006) Typic Hapludox (Soil Survey Staff, 2010) with clay content above 60%. The climate is classified as Cfa, sub-tropical humid, by the Koppen (1948) classification. During the period of the experiment the average temperature was 21.5 °C; January was the warmest month with average temperature of 25.8 °C, and June was the coldest month with average of 15.5 °C. A total of 934 mm of rainfall was recorded over the experimental period; Figure 1 shows the rain distribution. The laboratory analyses were carried out at the University of Cruz Alta.

Sowing of chia was carried out after the harvest of the corn crop, in no-tillage system, without fertilizers or other soil correctives, so the new crop could remove the remaining nutrients of the previous crop from the soil and from the straw degradation. A soil analysis was performed after the corn harvest, with data shown in Table 1.

Table 1: Soil chemical characteristics after maize harvest in the 0-20 cm depth layer

Clay[1] (g kg^{-1})	pH H_2O[2]	MOS[3] (%)	P[4] (mg dm^{-3})	K[4]	Al[5]	Ca[5] (cmol$_c$ dm^{-3})	Mg[5]	CTC
660	5.7	3.3	6.1	134	0.0	7.3	2.7	14.2

[1]Determined by densitometry; [2]determined by potentiometry; [3]soil organic matter determined by the Walkley-Black method; [4]determined by Mehlich-1 solution; [5]determined by extraction with KCl (1 mol L^{-1}).

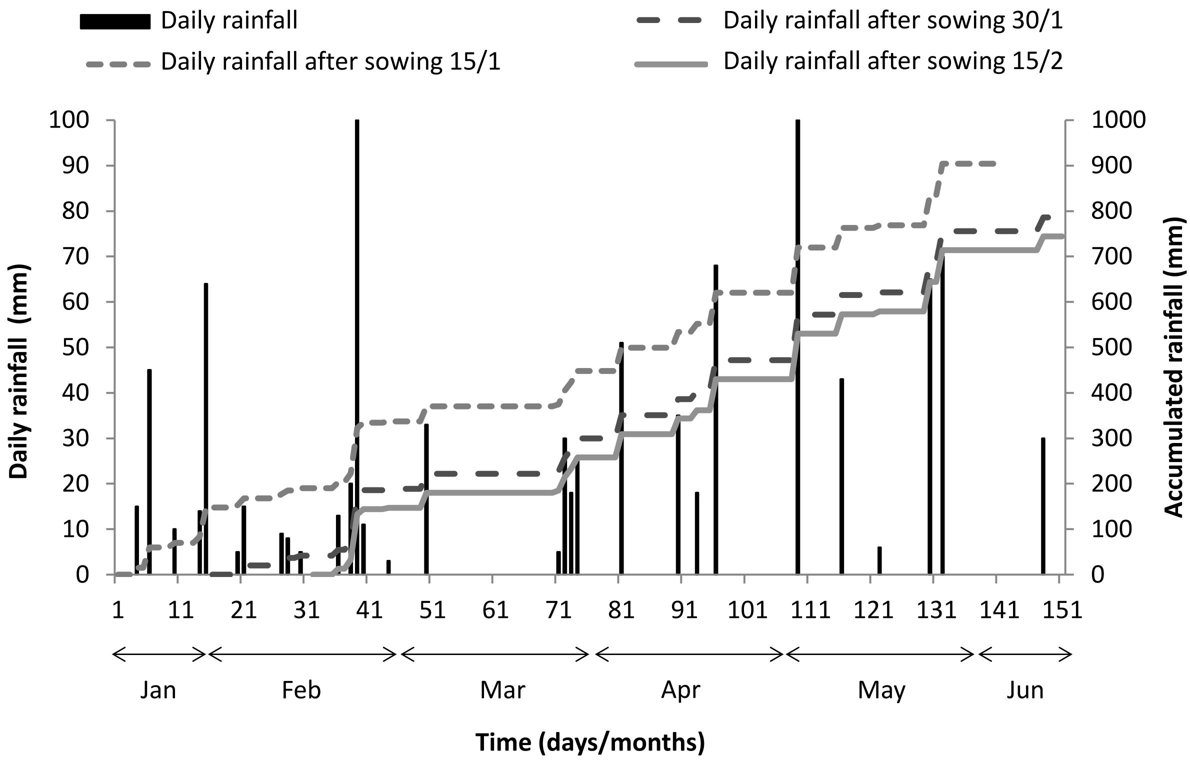

Figure 1: Daily and accumulated rainfall during the chia crop cycle for the three sowing times

The experiment was conducted in a bifactorial arrangement with 2 spacings and 3 sowing times, with four replications. The factors analyzed were sowing in three different times (January 15 and 30 and February 15) combined with two spacings (17 and 45 cm).

The spacings were chosen for being the same that were used in wheat (17 cm) and corn and soy (45 cm). The plots were (1) 3.15 m wide (the planter width) by 4 meters in length, with total area of 12.6 m^2, and 45 cm between rows; and (2) 2.55 m wide (planter width of 15 rows by 4 m in length), with total area of 10.2 m^2, and 17 cm between rows. For the field parameters evaluated, 4 m 2 were considered, scoring the rows of the border.

Planting was carried out using 5 kg of seeds per hectare in all sowing times and spacings, providing an approximate population of 4 million plants per hectare. The following characteristics were evaluated:

Mean plant height: plant height was measured in 20 plants selected at random per repetition, when plants were at 30% bloom and at harvest, using a millimeter measuring tape.

Spike length: length was measured in 20 plants selected at random per repetition, directly on the plants before harvest.

Yield: it was calculated based on hand picking of 4 m^2 in the plot, eliminating border rows. The result was expressed as kg ha^{-1} and corrected to 13% moisture.

Thousand seed weight: it was calculated based on eight samples of 100 pure seeds as described in the Guide for Seed Analysis (Brazil, 2009). The weight was corrected to 13% moisture.

Germination: the germination tests were carried out using eight samples of 100 seeds, on two sheets of blotting paper that had been moistened to 2.5 times the dry substrate weight, in a germinator at 25 °C, with the first evaluation at 7 days and the second evaluation at 14 days (Brazil, 2009). The results were expressed as percentage of normal seedlings.

First count of the germination test: it was performed together with the germination test by considering the first count at seven days as the vigor test. The results were expressed as percentage of normal seedlings.

The experiment in the field was arranged in a randomized blocks design and the the variables of germination in a completely randomized design, both with four repetitions. The experimental data were examined by analysis of variance, and the means were compared by the Tukey test at 5%. The variable germination and its derivations were transformed into arcsin $(X/100)^{1/2}$.

3 RESULTS AND DISCUSSION

Plat height is a variable dependent on varietal characteristics and is expressed with the interaction of the cultivar genotype with the environment, with highlight to rainfall regime, temperature, altitude, photoperiod, evapotranspiration, sunlight, relative humidity, and wind. Significant differences in plant height were observed by delaying sowing in relation to January 15 at both spacings (17 cm and 45 cm). The longer the sowing delay, the smaller the plant size. This finding was verified in both moments of the evaluation (Table 2), which agrees with the findings of Ayerza & Coates (2007).

Table 2: Plant height when plants were at 30% bloom and at harvest as a function of sowing time and row spacing

Spacing cm	Sowing time 15/1	30/1	15/2	Mean
	Plant height 30% bloom (cm)			
45	95.26Ab*	91.64Ba	36.67Cb	74.52
17	104.85Aa	90.88Ba	44.62Ca	80.12
Mean	100.06	91.26	40.64	
CV %	4.04			
	Plant height at harvest(cm)			
45	118.08^{ns}	105.35	48.08	90.50b
17	128.66	117.21	56.91	100.93a
Mean	123.37A	111.28B	52.49C	
CV %	3.35			

* Means followed by capital letters in the row are not significantly different by the Tukey test at 5% significance. Means followed by small letters in the column are not significantly different' by the Tukey test at 5% significance. The interaction between the factors sowing time and spacing was not significant.

In general, higher average heights were found at the spacing 17 cm between rows. These higher values resulted from a better plant distribution, plant nutrient utilization, and

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plant light search, while at the spacing 45 cm, there is a greater competition in the sowing line and lower pressure in the search for energy (light) because of the larger spacing, considering that the plant population was the same at the two spacings (Table 2). Similar results were found by Zavalia et al. (2011). However, there are reports showing that chia spacing can range from 80 to 200 cm (Migliavaca et al., 2014).

The spike length, in Table 3, is a yield component, in which larger spikes have a higher yield potential. The mean spike length of sowings in January were significantly different from the sowing in February, that is, the spikes were higher in the two sowing seasons in January. Larger spikes were also found at the spacing 17 cm indicating a higher productive capacity and corroborating with the results obtained by Zavalia et al. (2011) in Argentina. The authors point out that chia produces similar amounts of inflorescences per m² at different spacings.

Table 3: Spike length, yield and one thousand seed weight of chia as a function of sowing time and row spacing

Spacing cm	Sowing time			Mean
	15/1	30/1	15/2	
	Spike length (cm)			
45	5.48^{ns}	5.54	4.30	5.11b
17	6.72	6.48	4.73	5.98a
Mean	6.10A	6.01A	4.52B	
CV %	6.16			
	Yield (kg ha^{-1})			
45	594.17Ab*	557.08Ab	405.01Bb	518.75
17	768.75Aa	633.75Ba	531.25Ca	644.58
Mean	681.46	595.42	468.13	
CV %	5.23			
	One thousand seed weight (g)			
45	1.131^{ns}	1.007	0.987	1.042b
17	1.199	1.145	1.032	1.125a
Mean	1.165A	1.076B	1.010B	
CV %	5.42			

* Means followed by capital letters in the row are not significantly different by the Tukey test at 5% significance. Means followed by small letters in the column are not significantly different' by the Tukey test at 5% significance. The interaction between the factors sowing time and spacing was not significant.

As Table 3 shows, the yield recorded for the spacing 45 cm is similar for both sowings carried out in January (01/15 and 01/30), but was significantly different from the sowing on February 15, with a decrease in yield, that is, decreasing yield with the delay in sowing. The behavior at spacing 17 cm is similar, however, there is significant difference among the three sowing times, with the highest yield recorded in the first sowing and the lowest yield in the last sowing, with a decrease in yield with delay in sowing time. Similar behavior was reported by Zavalia et al. (2011) and Busilachi et al. (2013) in studies with chia.

From the data in Table 3, it is apparent that the yield is higher at spacing 17 cm then at 45 cm, showing a positive interaction of sowing at earlier time with the spacing 17 cm, with a

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greater increase in production for these factors. Sowing chia at smaller spacings provides a better spatial distribution and less competition for water, nutrients, and sun light in the planting line. Zavalia et al. (2011) found similar results in the province of Tucuman, Argentina, at similar latitude and photoperiod.

From Table 3, we can see that at spacing 17 cm and sowing in January, the yield was above 600 kg ha^{-1}. Farmers from the Northwest region of Argentina have obtained yields from 258 kg ha^{-1} to 1262 kg ha^{-1}. However, the average yield is 606 kg ha^{-1} in mechanized harvest (Ayerza & Coates, 2007). After 20 years of experiments in the same locality, experimental trials on sowing densities have reached yields of up to 1700 kg ha^{-1} and means of 1400 kg ha^{-1} (Lobo et al., 2011).

As shown in Table 3, thousand seed weight is significantly different between sowing times and spacing, with the best results recorded for the first sowing time with the smaller spacing, ranging from 1.165 to 1.125 grams. There are reports of thousand seed weight ranging from 1.21 grams to 1.31 grams, in field trials in Argentina (Rovati et al., 2012).

Table 4 shows that there is significant difference for the means of the first germination test and the first count of the germination test between the sowing in January and the sowing in February. The shorter period of vegetative development and accumulation of reserves may have contributed to this difference. The means of the treatments at spacing 17 cm were significantly higher than those at 45 cm, possibly due to a better population arrangement, a root distribution providing a better use of nutrients, and a better use of sun light. Stefanello et al. (2015), in studies to test chia germination, reported higher values for first count of the germination (73%) and germination (77%).

Table 4: First count of germination and germination test of chia seeds as a function of sowing time and row spacing

Spacing	Sowing time			Mean
cm	15/1	30/1	15/2	
	First count of germination (%)			
45	60.75^{ns}	58.50	57.75	59b
17	64.25	64.5	60.5	63.08a
Mean	62.5A	61.5AB	59.12B	
CV %	3.66			
	Germination (%)			
45	70.25Ab*	67.50ABb	66.00Bb	67.92
17	73.50Aa	74.50Aa	66.75Ba	71.58
Mean	71.88	71.00	66.37	
CV %	3.06			

* Means followed by capital letters in the row are not significantly different by the Tukey test at 5% significance. Means followed by small letters in the column are not significantly different' by the Tukey test at 5% significance. The interaction between the factors sowing time and spacing was not significant.

During storage, seed deterioration cannot be prevented, however, the speed of the process can be minimized by appropriate procedures in production, harvesting, drying, processing, transport, and storage. Seed deterioration comprises a sequence of biochemical and physiological changes initiated shortly after physiological maturity, which leads to reduced vigor and consequent loss of germination capacity (Sá et al., 2011). The deterioration process is affected by internal, external or environmental factors, nevertheless, conservation without loss of germination qualities and vigor can be achieved for a longer time (Luz et al., 2014). Despite the considerable increase in knowledge regarding the use of chia seeds for medicinal and spice purposes, information on the seed germination process of this species is still scarce and insufficient when compared to ornamental and vegetable species (Stefanello et al., 2015).

The best results obtained for the sowing in January, especially at the spacing 17 cm for plant height (Table 2), ear length, yield, one thousand seed weight (Table 3) and germination tests can be attributed to an early induction of flowering because chia is a short-day species (Busilacchi et al., 2013). Experiments in a greenhouse with controlled environment showed that chia was induced to flowering when the length of the day was less than 14 hours (Jamboonsri et al., 2012), indicating for the -27º54' Latitude, location of this experiment, a critical photoperiod from 12 to 13 hours, resulting in early flowering induction and later sowing, which was proved in the field, resulting in smaller size of plants sowed later compared with the first date of sowing. However, early sowing can result in excessive vegetative growth, up to 2.0 meters in height (Migliavaca et al., 2014), which may cause lodging. By having its vegetative development affected and reduced by the induction of the reproductive stage, the plant will be smaller with less productive potential. In this study, the chia cycle was reduced by delaying sowing to February, directly affecting the variables studied.

Chia is not resistant to frost, which restricts the sowing season in places with risks of losing production (Migliavacca et al., 2014). The sowing time determines the period of vegetative growth and flowering induction, directly influencing the production, biomass, and yield of the crop. Earlier sowings produce better results than delayed sowings. Despite the different sowing times, plants can flower at the same time and the difference in yield is probably due to the longer period of vegetative growth.

4 CONCLUSIONS

Chia can be cultivated in the region of study, in which the parameters evaluated showed good results, particularly the seed yield.

The best results for spacing and sowing time were found for sowing in January at the spacing 17 cm between rows.

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