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Anjali Jingar
ASCO, RSSOCA, Jodhpur, Rajasthan, India

Manpreet Singh Preet
School of Agriculture, GEHU, Dehradun, Uttarakhand, India

Dr. Moola Ram
Department of Agronomy, Agriculture University, Jodhpur, Rajasthan, India

Corresponding Author:
Anjali Jingar
ASCO, RSSOCA, Jodhpur, Rajasthan, India

Interaction effect of date of sowing and plant geometry on yield attributes of chia (*Salvia hispanica* L.)

Anjali Jingar, Manpreet Singh Preet and Dr. Moola Ram

Abstract
The experiment consisted of two factors, date of sowing (Factor A), crop geometry (Factor B) which were replicated three times under factorial randomized design to see the outcome their interactive effect on yield attributes of Chia. Experimental station of Agricultural University, Jodhpur basically known as Agriculture Research Station, Mandor was the designated place for execution of experiment in 2016-17 year. Different dates of sowing are 25th October (D_1), 05th November (D_2), 15th November (D_3) and 25th November (D_4) which come under factor A while as the crop spacing *viz*., 30 cm x 30 cm (P_1), 45 cm x 30 cm (P_2), 60 cm x 45 cm (P_3) and 90 cm x 45 cm (P_4) falls under factor b i.e. plant geometry. Observations on biological yield revealed that interaction between D_1 x P_1 recorded significantly higher biological yield (21169.98 kg ha^{-1}) per hectare than rest of the interactions. Consequently, data on seed and husk yield per hectare revealed that interaction between D_1 x P_2 recorded significantly higher seed yield (685.44 kg ha^{-1}) and husk yield (272.79 kg ha^{-1}) per hectare than rest of the interactions except D1x P1 (658.15 kg ha^{-1} & 262.10 kg ha^{-1}) respectively.

Keywords: Chia, Date of sowing, Plant geometry, biological yield, seed yield and husk yield

Introduction

Chia (*Salvia hispanica* L.) being an annual plant belongs to Lamiaceae family has its centre of origin from Mexico and Guatemala (Ixtaina *et al.*, 2008) [4]. It falls under the category of super-division of phanerogams, as well as kingdom Plantae. Morphometrical characters in terms of plant height reaches up to 1 meter tall and depicts opposite arranged leave pattern. The flowering morphology depicts white or purple flowers. Size of the chia crop flower ranges from (3-4 mm) which are well enough to promote high rate of self-pollination in fused flowers with small corollas. Colour of the seeds show variation from black to grey, and black spotted to whitish, while as the appearance is observed as oval and size ranges from 1-2 mm (Bresson *et al.*, 2009) [2]. However, from the commercialization point of view black spotted chia is more popular followed by the of white seeds with increasing trend (Ayerza and Coates, 2005) [13].

Nutritionally Chia seed is rich in protein (15 - 25%), polyunsaturated fat (30 - 33%), CHO (26 - 40%), huge digestable fiber (18 - 31%), ash (4 - 5%), important vitamins and minerals, and dry matter (90 - 94%). It has a rich wealth of antioxidants as well (Ixtaina *et al*., 2008) [4]. Due to the presence of omega -3-fatty acid it has been recommended for the human consumption because of its nutritional enrichness (Vuksan *et al*., 2010) [11]. It is being cultivated as a potential source of α-linolenic acid. It is reported that Oil content chia seeds weather whitish or blackish touches 33.8% and 32.7%, respectively (Suri S. *et al*., 2016) [10]. Similarly Yeboah (2014) [12] depicted that there is about 35% oil enrichment in chia seeds. Due to the existence of high levels of polyunsaturated fatty acids (PUFAs) in Chia seeds, it has regained popularity of being the main oil sources.

Adoption of chia by the farmers have proved to be an emerging innovative crop in the tropical region like Rajasthan. Diversification of the chia crop cannot only provide a wider choice in oil seed *crop* production but also it will help in fetching out *higher* net returns per unit of land it has been proved earlier that the exploitation of new crops varieties and their genotypes leads to new horizons in crop cultivation practices. The potential of the crop needs to be checked under the parameters like optimum sowing time and plant geometry in a particular agroclimatic zone. Because it has been observed that yield attributes and their quality characteristics vary with planting dates and plant spacing (Freitas *et al*., 2016) [3]. Taking into consideration the growth and development conditions for the plants *viz a vis* nutrients, moisture and light; it becomes necessary to derive out the proper spacing depicting plant population/ha (Karim *et al*., 2015 and Yeboah *et al*., 2014) [6, 12].

In light of the above facts, as chia is new to this State particularly so in western Rajasthan, present study has been initiated on various aspects like inter and intra-row spacing and date of sowing leading to different plant populations at different sowing time in the present investigation to find out the optimum date of sowing and plant spacing for enhancing its productivity.

Materials and Methods

The experimental site for the execution of experiment was locatde at Agricultural Research Station of Agriculture University -Jodhpur. The research site is located at 26º 15' N to 26 ^{0} 45' North latitude and 73º 00' E to latitude 73º 29' East longitude at an altitude of 231 meter above mean sea level. The average annual rainfall is about 367 mm (CV 52%) and bulk of it (85 to 90%) is received from June to September (*kharif* season) by the southwest monsoon.

Experimental Design with Treatment Details

The experiment consisted of two factors which included four sowing dates (Factor A) eg., 25th Oct. (D_1), 05th Nov. (D_2), 15th Nov. (D_3) and 25th Nov. (D_4) and (Factor B) (4) different crop spacings 30 cm x 30 cm (P_1), 45 cm x 30 cm (P_2), 60 cm x 45 cm (P_3) 90 cm x 45 cm (P_4) replicated 3 times. The variety taken for the experiment was Black type seed. The recommended basal dose of 20 kg Nitrogen and 40 kg P_2O_5/ha were applied maintaining the uniformity before sowing via urea and DAP, respectively in an individual plot at a depth of 7-8 cm below seed. Since there were varying crop geometry in different date of sowing, the seed rate was different as per treatment. Sowing was done at a depth of 4-5 cm by 'kera' method. An optimum required population per treatment was maintained through thinning, 15 days after sowing. For maintain the proper growth and development of chia crop many intercultural operations were executed as and when necessary. Two weeding were performed during the whole experimentation program one at 30 DAS and 2nd at 60 DAS in all the treatments. Tatal 4 no of irrigations were applied at branching, pre-flowering and seed formation and seed hardening stages during the overall growing season. To assess biological, seed and straw yields, the plants from borders were removed manually first followed by harvesting plants from each net plot at full maturity on different dates and stacked plot wise for sun drying separately, tied in bundles and tagged. These tagged bundles were left for sun drying in the respective plot.

Observations and Statistical Analyses

Biological yield: At maturity, weight of total biomass (whole plant) was taken from each net plot after complete drying for estimating biological yield per plot and then converted in to kg ha $^{-1}$

Seed yield: After winnowing, cleaned seeds were weighed to record seed yield per plant at moisture content of 12% and then converted in to kg ha^{-1}.

Husk yield was calculated by subtracting plot wise weight of seed yield from the plot wise weight of inflorescence portion before threshing and then converted in to per hectare (kg). The data obtained was analysed under Factorial RBD and result was interpreted for interactions (Panse and Sukhatme 1978) [7].

Results and Discussion

Interaction effect between date of sowing and plant geometry was found significant with respect to biological yield per hectare, which is presented in Tables 1. Interaction between first date of sowing i.e. 25th October with plant geometry of 30 cm x 30 cm (D_1P_1) recorded significantly higher biological yield (21169.98 kg/ha) than rest of the interactions. The minimum biological yield (4749.23 kg/ha) was recorded with 25th November date of sowing with 90 cm x 45 cm plant geometry. Interaction between first date of sowing i.e. 25th October with closer plant geometry of 30 cm x 30 cm (D_1P_1) proved significantly effective in enhancing the biological yield per hectare. These results are in according with those obtained by Ahmad & Hadipanah (2014) [1] and Sharma & Kanjilal (1999) [9].

Table 1: Interactive effect of date of sowing and plant geometry on biological yield per hectare (kg) on chia

Treatments	D_1	D_2	D_3	D_4
P_1	21169.98	20371.39	20017.76	19346.28
P_2	16568.38	15156.28	14976.53	13561.22
P_3	9688.63	8813.45	8142.46	7236.54
P_4	6594.97	5523.46	5178.53	4749.23
S.Em ±	174.32			
CD (P = 0.05)	503.46			

From data in Table 2, interaction effect (D x P) was evident in respect to seed yield per hectare. Interaction D_1P_2 between first date of sowing i.e. 25th October and plant geometry of 45 cm x 30 cm (685.44 kg) recorded significantly higher seed yield per hectare than rest of the interactions except D_1P_1 (658.15 kg). The minimum seed yield per hectare was recorded with D_4P_4 (154.03 kg ha^{-1}). (Fig.1) Interaction between first date of sowing on 25th October with closer plant geometry of 45 cm x 30 cm and 30 cm x 30 cm (D_1P_2 and D_1P_1) resulted in significantly higher seed yield per hectare. These results are in conformity with findings of Sadeghi *et al.* (2009) [8].

Table 2: Interactive effect of date of sowing and plant geometry on seed yield per hectare on chia

Treatments	D_1	D_2	D_3	D_4
P_1	658.15	495.13	439.77	337.57
P_2	685.44	564.06	546.27	323.05
P_3	423.76	382.76	327.42	246.52
P_4	282.01	228.20	214.01	154.03
S.Em ±	22.39			
CD (P = 0.05)	64.66			

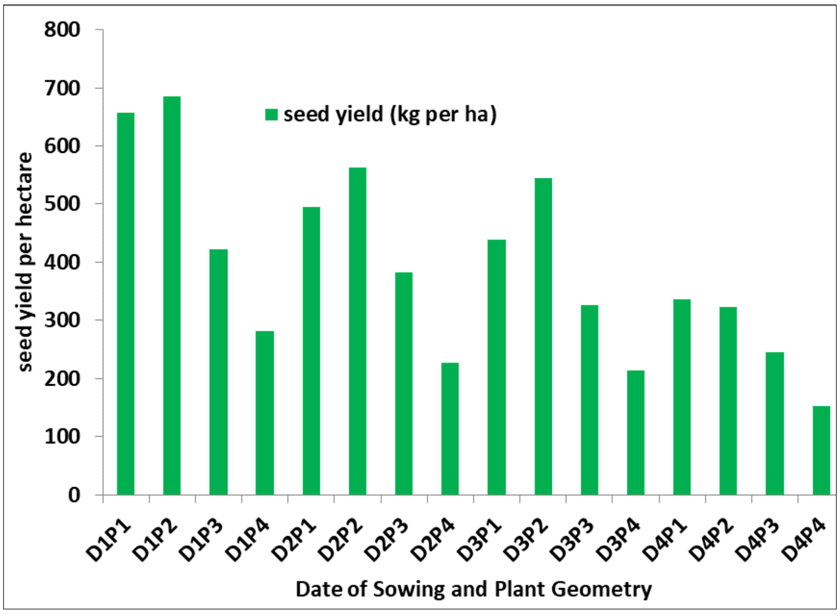

Fig 1: Interactive effect of date of sowing and plant geometry on seed yield per hectare on chia

Interaction effect (D x P) was found significant in respect to husk yield per hectare which is presented in Table 3. Interaction between 25th October date of sowing with plant geometry of 45 cm x 30 cm (272.79 kg ha^{-1}) proved significantly effective in enhancing the husk yield per hectare than rest of interactions except D_1P_1 (262.10 kg ha^{-1}). The minimum husk yield per hectare was observed when the crop was sown with 25th November date of sowing and 90 cm x 45 cm plant geometry (61.63 kg ha^{-1}). Interaction between first date of sowing on 25th October with closer plant geometry of 45 cm x 30 cm and 30 cm x 30 cm (D_1P_2 and D_1P_1) resulted in significantly higher husk yield per hectare. These results are in conformity with findings of Sadeghi *et al.* (2009) [8].

Table 3: Interactive effect of date of sowing and plant geometry on husk yield per hectare on chia

Treatments	D_1	D_2	D_3	D_4
P_1	262.10	200.96	162.96	131.82
P_2	272.79	224.71	219.24	131.62
P_3	169.98	153.15	134.61	97.80
P_4	110.60	89.47	85.81	61.63
S.Em ±	8.42			
CD (P = 0.05)	24.31			

Conclusion

It can be concluded that the interactive effect of D_1P_1 proved to be best in term of increasing Biological yield. and Interactive effect of D_1P_2 recorded best in term of increasing seed and husk yield that is on par with D_1P_1. Therefor based on above finding we can conduct more studies so that a strong recommendation can be derived out for the farmers of tropical region.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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