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Article

Effect of planting time on the growth and yield of chia (*Salvia hispanica* L.)

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Abstract: Chia (*Salvia hispanica* L.) contains the highest level of omega- 3 fatty acid available in any cultivated plant source. The objective of this research was to find out the suitable planting time for chia in Bangladesh and to study the effect of planting time on its growth and yield. An experiment was carried out at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University (BAU), Mymensingh, during the period from November 2013 to July 2014 to study the growth, morpho-physiological yield contributing characters and yield of chia. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The collected data were analyzed statistically and the means were adjudged by DMRT using the statistical computer package program, MSTAT-C. The tallest plant (136 cm), highest number of inflorescence plant^{-1} (13.67), highest amount of total dry matter (305 g) and highest root length (7.767 cm) were recorded from November planting at harvest. However, leaf area plant^{-1} (207.2 cm^2) and LAI (1.891) had also significantly higher from November planting at 90 days after sowing (DAS) compared to other planting times. November planting further recorded the higher CGR (33.43 g m^{-2} day^{-1}) at the stage between 76–90 DAS and thereafter they decreased. Higher seed yield (1033 Kg ha^{-1}), husk yield (888 Kg ha^{-1}), seed yield plant^{-1} (4.773 g), husk yield plant^{-1} (2.840 g) were also recorded from November planting. In December planting the seed yield, husk yield, seed yield plant^{-1}, husk yield plant^{-1} were 681 Kg ha^{-1}, 340 Kg ha^{-1}, 2.350g and 0.9467g, respectively. Lower seed yield (159 Kg ha^{-1}), husk yield (166 Kg ha^{-1}), seed yield plant^{-1} (0.6150 g) and husk yield plant^{-1} (0.5383 g) were recorded from January planting. Except total dry matter, other morpho-physiological characters, yield and yield contributing factors were less effective in January than other planting time. February and March planting did not produce any fertile spike resulting yield less vegetative growth. These results revealed that, November planting was found outstanding superiority for plant growth, yield and morpho-physiological characters of chia in Bangladesh.

Keywords: chia; *Salvia hispanica*; chia seed; omega- 3 fatty acid; alpha linolenic acid; linoleic acid

1. Introduction

Chia *(Salvia hispanica* L.) is an annual plant belonging to the *Lamiaceae* family native to Mexico and Guatemala (Ixtaina *et al*., 2008). Chia can grow up to 1 m tall and has opposite arranged leaves. *Salvia hispanica* produces white or purple flowers. It is reported that the chia seeds commercialized today were selected by Nahua botanists, but came into the twenty-first century as a mixed population. In pre-Columbian times, its seeds were one of the basic foods of Central American civilizations (Ayerza and Coates, 2005). It is cultivated in Argentina, Australia, Bolivia, Colombia, Guatemala, Mexico and Peru. Today, its cultivation is not only limited to America but is also extended to other areas such as Australia and Southeast Asia (Jamboonsri *et al*., 2012).

As public health awareness is increasing day by day throughout the world, demand for functional food with multiple health benefits is also increasing. The use of medicinal food from folk medicine to prevent diseases such as diabetes, obesity, and cardiovascular problems is now gaining momentum in the globe.

Chia seed is composed of protein (15% –25%), fats (30%–33%), carbohydrates (26%–41%), high dietary fiber (18%–30%), ash (4%–5%), minerals, vitamins, dry matter (90%–93%) and also contains a high amount of antioxidants (Ixtaina *et al*., 2008). Recently, chia seed has become important for human health and nutrition because its high content of ω-3 fatty acid that promotes beneficial health effects (Vuksan *et al*., 2010). The ALA (alpha linolenic fatty acid) in Chia seed is the only known essential omega-3 fatty acid that the body can't produce on its own. Omega-3 is found in foods such as chia seed, flax seed, flax oil, olive oil, walnuts, sea fish, kale, spinach, cauliflower, broccoli etc. If you're looking to boost your nutritional intake, look no further than the humble chia seed. Per gram chia seeds contain: 8× more omega-3 than salmon, 6× more calcium than milk, 3× more iron than spinach, 15× more magnesium than broccoli, 2× more fiber than bran flakes, 6× more protein than kidney beans, 4× more phosphorous than whole milk. Now a day chia is treated as a newly discovered superfood.

In Bangladesh, chia is a new crop, but the economic value of chia in international market and even in Bangladesh market is very high. So successful cultivation of chia in Bangladesh will improve economic and medicinal value. Selection of planting time is very effective to increase yield in crop plants, and being a new crop in Bangladesh chia needs adjustment in planting time for higher growth and yield in this new environment. Keeping this point in mind the present study was conducted at Bangladesh Agricultural University (BAU), Mymensingh (AEZ-9) to find out the feasibility of chia seed production in Bangladesh by optimizing time of planting.

2. Materials and Methods

The seeds of Chia were used as the planting materials for this experiment. The experimental field was medium high land belonging to the Sonatala soil series of grey flood plain soil type under the Agro-ecological Zone-9 (AEZ-9) named old Brahmaputra Flood Plain (FAO, 1988). The experiment was laid out as single factor experiment in Randomized Completely Block Design (RCBD) with 5 treatments and 3 replicates. The experiment consisted of 12 unit plots; each plot was 5 m × 4 m in size. Plot to plot distance was 0.5 m. The experimental land was first opened on 2nd November 2013 with a power tiller. The land was further ploughed and cross-ploughed several times followed by laddering until a good tilth was achieved. Fertilizers used in the experimental land were urea (120 Kg ha^{-1}), triple superphosphate (80 Kg ha^{-1}), muriate of potash (60 Kg ha^{-1}), gypsum (30 Kg ha^{-1}) and well decomposed cowdung (10 t ha^{-1}). Before final harrowing a basal dose of half of the amount of urea; all-triple superphosphate, muriate of potash gypsum and cowdung were applied. The remaining half of urea was top-dressed after 45 days after sowing (DAS) when the plants reached at juvenile stage. Planting times were the treatment of this research. Five planting times were used as follows: November, December, January, February and March. Agronomic practices like irrigation, weeding, thinning etc. were done accordingly. The plants were uprooted carefully for data collection. The crop of each experimental plot was harvested separately at full physiological maturity on different dates. The harvested crop of each plot was bundled separately and tagged properly. The bundles were dried in sunshine and brought to a clean floor. Seeds and other plant parts were collected by simple hand threshing and data were recorded properly. The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT‑C. (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Responses of planting time on morpho-physiological and growth characters of chia

Morpho-physiological and growth characters of chia were significantly influenced by planting time (Table 1). The tallest plant (135.9 cm) was recorded in November planting and the shortest plants (73.54 cm) were found in March planting which is statistically identical with January planting (74.38 cm).The longest roots (7.767 cm) were recorded in November planting. Total dry matter (245.7 g) at harvest obtained from November planting was found highest among all planting time and March planting showed the lowest (54.03 g) dry matter production. The Maximum leaf area plant^{-1} at juvenile stage (207.2 cm^2) was obtained from November planting. The minimum leaf area plant^{-1} (69.74 cm^2) was recorded in February planting. Plant height, root length, leaf area and total dry matter are the important growth contributing characters for any crop which would be related

on several factors like genetic makeup, planting time, nutrient availability, environmental or climatic condition, soil characteristics, regional adaptability, cultural practices etc. Moosavi *et. al.* (2012) reported that delay in sowing decreased significantly the plant height, leaf area index, total fresh and dry yield in Maize. Significant differences in plant height of two kenaf genotypes were found between the early and late plantings, throughout the growing period (Danalatos and Archontoulis, 2004)). This variation in plant height, root length, leaf area and total dry matter of chia were significant which may be due to planting time. This result indicated that plant height of chia may be influenced by temperature and other environmental conditions. Further investigation is required to clarify this issue. Leaf area index (LAI) at juvenile stage is an important indicator of vegetative growth which was found higher in November planting as compared to other planting times. Crop growth rate (CGR) was also found higher at every growth stages in November planting. These variations on LAI and CGR may be due to planting time.

3.2. Responses of planting time on Number of inflorescence plant^{-1}

The planting time significantly influenced the number of inflorescence plant^{-1} (Figure 1). The highest (13.67) number of inflorescence plant^{-1} was found in case of November planting and the lowest (4.67) one was found in case of January planting whereas the intermediate type (8.33) was found in December (Figure 1). This may be due to higher branching and the plant height as well. On the contrary, lower number of inflorescence was found in case of January planting may be due to less number of branch, soil and environmental conditions. In case of February planting, plant fail to produce any ripen inflorescence because before ripening of inflorescence re-growth was started and in case of March planting plant fail to set inflorescence because of starting of re-growth (Figure 3). This result indicated that chia may be a photo sensitive plant or short day plant. Further investigation is required to clarify this issue.

Table 1. Effect of planting time on some growth contributing characters of chia.

Planting time	Plant height at harvest (cm)	Root length at harvest (cm)	LA plant^{-1} (cm^2) at juvenile stage (90DAS)	TDM plant^{-1} at harvest (g)	LAI plant^{-1} at juvenile stage (90DAS)	CGR at juvenile stage (76-90) (g/m^2/d)
November	135.9 a	7.767 a	207.2 a	305.3 a	1.891 a	33.43 a
December	94.52 b	5.550 b	191.7 b	248.3 b	1.791 b	31.06 a
January	74.38 d	4.333 c	83.05 c	91.72 c	1.643 c	26.38 b
February	81.67 c	4.243 c	69.74 d	76.84 d	1.643 c	21.01 c
March	73.54 d	4.420 c	87.47 c	54.03 e	1.701 c	5.203 d
$LSD_{0.01}$	5.966	0.3124	8.821	9.995	0.08664	3.896
Sig. level	**	**	**	**	**	**

In a column, figures with similar letter do not differ significantly whereas figures with dissimilar letters differ significantly. ** indicates significant at P≤ 1.0% level and * indicates significant at P≤ 5.0% level.

Table 2. Effect of planting time on some yield contributing characters.

Planting time	Days to 100% flowering	Days to harvesting	Main inflorescence length (cm)	Average inflorescence length (cm)	Number of seeds floret^{-1}	Per cent sterile floret	Seed yield plant^{-1} (g)	Husk yield plant^{-1} (g)
November	80.70 b	109.2 b	20.80 a	9.49 a	3.547 a	7.217 b	4.773 a	2.840 a
December	84.07 ab	114.8 a	20.78 a	9.077 a	3.090 b	9.017 a	2.350 b	0.9467 b
January	86.23 a	118.6 a	19.67 a	7.760 b	2.167 c	10.54 a	0.6150 c	0.5383 c
February	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-
$LSD_{0.01}$	3.774	3.975	2.150	0.7704	0.1189	1.527	0.5824	0.2658
Sig. level	**	**	NS	**	**	**	**	**

In a column, figures with similar letter do not differ significantly whereas figures with dissimilar letters differ significantly, NS = non significant, ** indicates significant at P≤ 1.0% level, - indicates no yield was obtained.

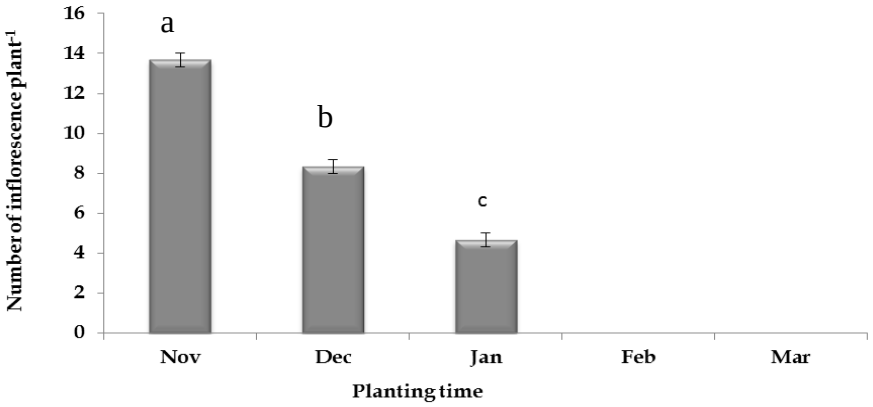


Figure 1. Effect of planting time of chia on number of inflorescence plant^{-1} (NIPP) at harvest. Vertical bars represent standard error of means (n=3).

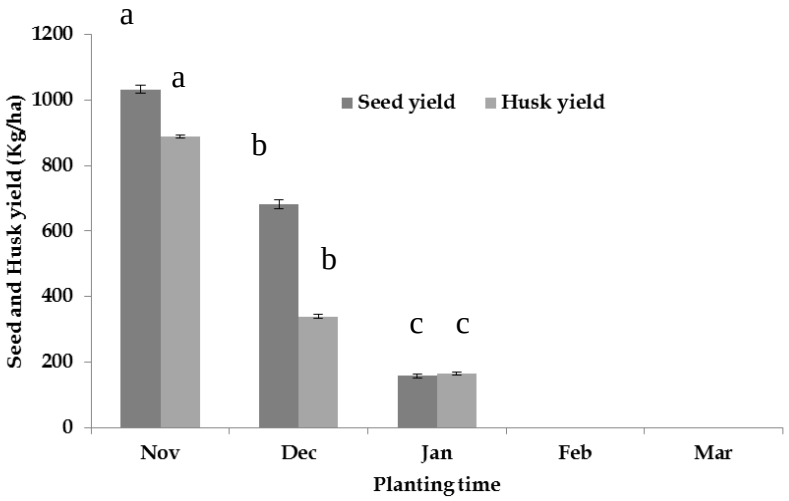


Figure 2. Seed and husk yield of chia plant (Kg ha^{-1}) at different planting time. Vertical bars represent standard error of means (n=3).

3.3. Responses of planting time on yield contributing characters of chia

Yield contributing characters like flowering, harvesting time, inflorescence length, number of seeds floret^{-1}, per cent sterile florets, seed yield plant^{-1}, husk yield plant^{-1} etc also significantly influenced by planting time (Table 2). Comparatively less time was required to full flowering in November planting. Average inflorescence length was also higher in November planting although main inflorescence length was statistically similar. Number of seed floret $^{-1}$(3.547), seed yield plant^{-1} (4.773 g) and husk yield plant^{-1}(2.840 g) were also found higher in November planting as compared to December (3.090 , 2.350 and 0.9467 g respectively) and January 2.167, 0.6150 g and 0.5383g respectively) planting. This variation may be due to the effect of variation of planting time. Percentage of sterile floret was higher in January planting (10.54) than December (9.017) and November planting (7.217). Due to late planting the sterility may be higher. Because of starting of re-growth yield contributing parameters could not be achieved from February and March planting, (Figure 3). Possible cause of starting re-growth may be due to higher temperature and day length effect on chia.

3.4. Responses of planting time on seed yield and husk yield

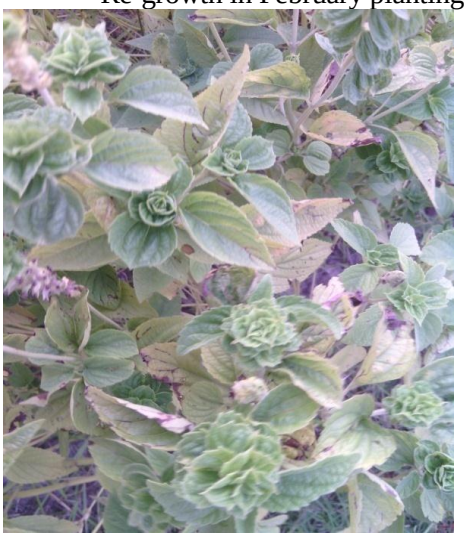
Seed yield and husk yield (kg ha^{-1}) differ significantly (P≤ 1.0%) among the planting times (Figure 2). Higher seed yield (1033 kg ha^{-1}) and husk yield (888 kg ha^{-1}) was found from November planting. Lower seed yield (159 kg ha^{-1}) and husk yield (166 kg ha^{-1}) was found from January planting. Intermediate type seed yield and husk yield (681 and 340 kg ha^{-1}, respectively) were found from December planting (Figure 2). This variation on seed and husk yield may be due to planting time, soil, environmental conditions etc. Yield cannot be achieved due to starting of re-growth in case of February and March planting. Similar findings were also obtained by Ayerza and

Coates (2005) who reported the seed yield as 500–600 kg ha^{-1} of seeds; however, experimental plots located in Salta, Argentina, provide a yield of around 2500 Kg ha^{-1}, with the assistance of irrigation and nitrogen fertilization. Ayerza and Coates (2007) also reported that the yield of chia 2253 kg ha^{-1} and the growth period required 135 days in yungas ecosystem of tropical Argentina.

Normal growth of chia shoot

Re-growth in February planting

Re-growth at the apex of the inflorescence



No reproductive growth in March planting

Figure 3. Some pictorial view of the experiment.

4. Conclusions

Based on the research result it may be concluded that Bangladesh has a good potential for chia seed production and it should be planted on November for higher seed yield.

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