

Original Research Article

Influence of planting time on yield and quality of Spinach (*Spinacia oleracea*) varieties

Abstract

The present investigation was conducted during rabi season of 2020 at Experimental Farm of Vegetable Sciences, Faculty of Agricultural Sciences, DAV University, Jalandhar to study the effect of different dates of sowing viz., 9 October, 24 October and 8 November and three cultivars, Supriya, All Green, Punjab Green on growth, yield and quality of spinach. The experiment was conducted in a Factorial Randomized Block Design with three replications. Observations were recorded on days to emergence, days to complete germination, plant height (cm), number of leaves per plant, leaf area (cm²), fresh yield per plot, total fresh yield per hectare, chlorophyll a, chlorophyll b, total chlorophyll, days to 50% bolting, number of branches, days to harvesting, seed yield per plot and yield per hectare. Analysis of variance (ANOVA) revealed significant differences among date of sowings, cultivars and interaction effect of dates of sowing and cultivars for all characters under study. It was observed that plants sown on 9 October resulted in superior performance for most of the traits studied. Among cultivars, desirable results were observed in All Green. Considering the interaction of date of sowing and cultivars it was concluded that All Green sown on 9 October can result in superior performance with respect to growth, yield and quality parameters of spinach.

Introduction

Spinach (*Spinacia oleracea*) belonging to the family *Chenopodiaceae*, is a cool-season crop. It is the most established leafy vegetable as it is rich in vitamins and minerals and falls in a major category of vegetable groups that have been designated as 'nature anti-aging wonders' and medicinal value (Gupta and Prakash, 2009). It is poor source of fat therefore, suitable

food for obese and diabetic people. It is also a good source of chlorophyll, which is known to aid in digestion (Roughani et al, 2011; Gaikwad et al, 2010; Verma, 2018). Spinach is a valuable crop for food and medicinal purposes with production of over 26 million tons on about 921000 ha in the world. About 25 million tons produced in Asia and China with about 24 million tons was pioneer and Iran was 6th in the 2016 on spinach production world ranking by commodity about 117000 tons (FAO,2018).

Genetic, environmental and agronomic factors and the interaction between them play a vital role in determining the yield and its contributing traits (Sidlauskas and Bernotas, 2003). Therefore, yield can be enhanced by way of using high yielding varieties and adoption of proper management practices such as date of sowing, seed rate, irrigation, fertilizer application and other cultural operations. Among all these factors, sowing time is the most important factors which affect the production of this crop. It is a cool season, long-day plant for good vegetative growth. Long days coupled with temperatures above 25°C cause the plant to bolt and flower, which is detrimental to spinach production (Waseem and Nadeem 2001). For adapting the crop to cope with the temperature extremes, alteration in the time of sowing is among the few strategies available. Following the timely planting provides favourable climatic conditions resulting in enhanced growth during establishment and early vegetative growth (Bake et al., 2017). Precise knowledge of optimum sowing time and selection of important varieties plays an important role in increasing crop yields as it provides suitable environmental conditions at all the growth stages of the crop. Sowing in the late spring resulting in exposure to higher temperatures during the early stages of its development causing lower yields and if such a crop is also long day (LD) requiring for its development, such as spinach (*Spinacia oleracea* L.) the yield will drop even more with later sowings (Parlevliet 1967a, b).

Genetic potentiality of a variety is fully expressed when it is synchronised with the optimum environmental conditions such as temperature, light, humidity, rainfall etc. (Salmasi et al., 2006). The different genotypes, growth responses varies to different environment and eventually decides the selection of a genotypes for a particular or different date of sowing for stabilizing higher yields. In spite of the importance of this vegetable, little attention has been paid to evolve suitable package of practice for remunerative cultivation since temperature plays a major role in germination, vegetative growth, flowering and fruiting, so the appropriate sowing time is to be ascertained to get highest leaf and seed yield. Therefore, in order to increase the quality and quantity of spinach production, the present study aimed to determine suitable sowing dates for popular varieties of Punjab in Jalandhar region was executed.

MATERIALS AND METHODS

The present investigation was carried out at the Experimental Farm of Faculty of Agricultural Sciences, DAV University, Jalandhar during summer season of 2020-2021. The experiment was laid out in Factorial Randomized Block Design (FRBD) with the three replications. All the agronomic practices were followed as per the package of practices. The experiment material consisted of three cultivars viz., C₁ (Supriya), C₂ (All Green) and C₃ (Punjab Green) and three dates of sowing at 15 days interval viz., D₁ (9 October), D₂ (24 October) and D₃ (8 November). All the observations on yield and quality attributes viz., days to germination, days to complete germination, plant height (cm), number of leaves per plant, leaf area (cm²), fresh yield per plot, total fresh yield per hectare (t/ha), days to 50% bolting, number of branches per plant, days to harvesting, total seed yield per hectare (t/ha), chlorophyll a (mg/ 100g fresh weight), chlorophyll b (mg/ 100g fresh weight), and total chlorophyll (mg/ 100g fresh weight) were recorded as per standard methods and were analyzed statistically. The statistical analysis of data recorded during the course of investigation for all the

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characters was done by analysis of variance method for factorial randomized block design described by Panse and Sukhatme (1985).

Comment [P2]: need a table of climatic conditions for the Experimental area, especially temperatures

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance (ANOVA) revealed significant differences among dates of sowing, cultivars and their interactions for all the characters under study (Table 1).

Growth attributes

Days to emergence

The perusal of data (Table 2) revealed that minimum numbers of days to emergence (4.22 days) were observed when sowing was done on D₁ (9 October) which were significantly minimum than all other dates of sowing. Maximum number of days to emergence (19.44 days) were observed in D₃ (8 November) which was significantly highest than the other dates of sowing. Among cultivars, least number of days to emergence (9.44 days) were observed in C₂ (All Green) which was statistically at par with C₁ (Supriya) which took 10 days to emerge. Maximum number of days to emergence (11.55) were observed in C₃ (Punjab Green) which was significantly highest among all the cultivars.

Table 2.1 revealed that among interaction effects of dates of sowing and cultivars, minimum number of days to emergence (3.66 days) were observed in D₁ × C₂ (9 October × All Green) which was statistically at par with number of days to emergence observed in D₁ × C₃ (9 October × Punjab Green), D₁ × C₁ (9 October × Supriya) and D₂ × C₁ (24 October × Supriya) which took 4.33, 4.66 and 5.33 days to emergence, respectively. Maximum number of days to emergence (20.33 days)

were observed in $D_3 \times C_3$ (8 November \times Punjab Green) which was statistically at par with $D_3 \times C_1$ (8 November \times Supriya) and $D_3 \times C_2$ (8 November \times All Green) which took 20.00 and 18.00 days to emergence, respectively.

The environment created by temperature, humidity, rainfall and other meteorological factors has predominant influence on growth and yield of spinach. Germination initiation is the indication of availability of most favorable environmental factors. In spinach, days to emergence were significantly influenced by sowing dates and cultivars. Minimum days to emergence was observed when sowing was done on 9 October. This might be due to the availability of optimum temperature for seed emergence during early sowing dates as compared to later sowing dates. These findings are in line with the findings of earlier researches namely, Guha *et al.* (2014); Karetha *et al.* (2014); Sharangi and Roychowdhury (2014); Moniruzzaman *et al.* (2015) and Lal *et al.* (2017) who also reported significant differences among dates of sowing for germination in coriander.

Cultivars also influenced germination significantly which was in accordance with the findings of Latye *et al.*, (2016) in fenugreek; Mahajan *et al.*, (2017) and Lal *et al.* (2017) in coriander.

Interaction effects of dates of sowing and cultivars revealed that 'All Green' cultivar when sown on 9 October showed earlier seed emergence which indicated the high temperature during early sowing was best for seed emergence of 'All Green'. The results are in line with the findings of Guha *et al.*, (2014); Karetha *et al.*, (2014); Moniruzzaman *et al.*, (2015); Lal *et al.*, (2017) who also suggested the role of dates of sowing in the germination of coriander.

Days to complete germination

The perusal of data (Table 2) showed that D₁ (9 October) took minimum numbers of days to complete germination (11.88 days) which was significantly lowest than all other dates of sowing. Maximum number of days to complete germination were observed (29.66 days) in D₃ (8 November). Among cultivars, least number of days to complete germination (20.00 days) were observed in C₁ (Supriya) which was statistically at par with C₂ (All Green) which took 22 days to complete germination. Maximum number of days to complete germination (23.33 days) was observed in C₃ (Punjab Green) which was significantly highest among all the cultivars.

Interaction effects of sowing dates and cultivars were significant for days to complete germination. The perusal of data (Table 2.1) depicted that minimum number of days to complete germination (11.00 days) were observed in D₁ × C₁ (9 October × Supriya) which was statistically at par with number of days to complete germination observed in D₁ × C₃ (9 October × Punjab Green) and D₁ × C₂ (9 October × All Green) which took 11.33 and 13.33 days to complete germination, respectively. Maximum number of days to complete germination (31.66 days) were observed in D₃ × C₃ (8 November × Punjab Green) which was statistically at par with D₃ × C₂ (8 November × All Green) which took 29.00 days to complete germination.

The results obtained on days to complete germination were similar to those obtained for days to emergence which indicated that sowing done on 9 October resulted in minimum days to complete germination. This might be due to the availability of optimum temperature for spinach seed germination during early sowing dates as compared to lateral sowing dates. Findings are in accordance with the earlier researchers namely Sensoy *et al.*, (2011) who observed that high temperature leads to

early germination in spinach; Sharangi and Roychowdhury (2014) and Lal *et al.*, (2017) in coriander. Cultivars showed significant differences in complete germination which is in line with the findings of Lal *et al.*, (2017) and Duwal *et al.*, (2019) in coriander and Bhutia *et al.*, (2017) in fenugreek.

Interaction effects also advocated the greater influence of dates of sowing in complete germination, which is in accordance with the findings of Sensoy *et al.*, (2011) in spinach.

Plant height (cm)

The observations on plant height of spinach were significantly influenced by sowing dates and cultivars. The data (Table 2) depicted that tallest plants (32.29 cm) were obtained when sowing was done on D₁ (9 October) which was significantly highest than height of plants observed in all other dates of sowing. The shortest plants (20.66 cm) were obtained when seeds were sown on D₃ (8 November) which was significantly minimum than the plant height observed in other dates of sowing. Among cultivars, C₂ (All Green) produced the tallest plants (30.26 cm) which was significantly highest than the plant height observed in other cultivars. The plants with least height (21.78 cm) were observed in C₁ (Supriya), which was significantly shorter than obtained in other cultivars.

The interaction effects of sowing dates and cultivars were found to be significant for plant height. Table 2.1 revealed that D₁ × C₂ (9 October × All Green) produced the plants with maximum height (34.82 cm) which was statistically at par with D₁ × C₃ (9 October × Punjab Green) producing 34.03 cm tall plants. The least plant height (18.02 cm) was observed in D₂ × C₃ (24 October × Punjab Green) which was statistically at par with D₃ × C₁ (8 November × Supriya) and D₂ × C₁ (24 October

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× Supriya) which resulted 18.29 cm and 19.04 cm tall plants, respectively. Sowing on 9 October recorded significantly taller plants as compared to 24 October and 8 November sowings. These results may be due to the favorable climatic condition existing during early October as compared to November for the growth and development of spinach. Similar findings were observed by earlier researchers viz., Ibrahim *et al.*, (2010) and Abed and shebl (2016) in spinach; Afroz *et al.*, (2011) and Alam *et al.*, (2015) in mustard seed; Anitha *et al.*, (2016) and Bhavar *et al.*, (2019) in fenugreek and Dhillon *et al.*, (2019) in fennel.

The cultivar 'All Green' produced taller plants as compared to Supriya and Punjab Green which might be attributed to its varietal characteristics. The results obtained from the present investigation on plant height exhibiting significant differences for plant height are in accordance with the findings of earlier researchers viz., Afroz *et al.*, (2011) in mustard seed; Latye *et al.*, (2016); Anitha *et al.*, (2016) and Bhutia *et al.*, (2017) in fenugreek and Bajad *et al.*, (2017) in coriander.

As evident from the interaction effects of dates of sowing and cultivars, early sowing in October showed greater influence in determining the plant height which could be due to the fact that October sowing promoted vegetative growth as compared to delayed planting. Similar findings were observed by earlier researchers viz., Afroz *et al.*, (2011) in mustard seed; Anitha *et al.*, (2016) in fenugreek and Abed and Shebl (2016) who reported greater plant height in October sowing as compared to November sowing in spinach.

Number of leaves per plant

The effect of sowing dates and cultivars on spinach were found significant for number of leaves per plant. The examination of data (Table 2) showed that the highest

number of leaves per plant (9.86) were observed when sowing was done on D₁ (9 October) which was significantly higher than all other dates of sowing. The least number of leaves per plant (8.63) were observed in D₃ (8 November) which was statistically at par with number of leaves produced by the plants when sowing was done on D₂ (24 October) which produced 9.14 leaves. Among the cultivars, maximum number of leaves per plant (10.20) were observed in C₃ (Punjab Green) which was statistically at par with C₂ (All Green) producing (9.34) leaves per plant. Minimum number of leaves per plant (8.15) were observed in C₁ (Supriya) which was significantly lower among all the cultivars.

Interaction effects between sowing dates and cultivars for number of leaves per plant was found significant Table 2.1 depicted that D₁ × C₃ (9 October × Punjab Green) produced maximum number of leaves per plants (11.70) which was statistically at par with number of leaves per plant (10.64) observed in D₁ × C₂ (9 October × All Green). Minimum number of leaves per plant (7.26) were observed in D₁ × C₁ (9 October × Supriya) which was statistically at par with number of leaves observed in D₃ × C₂ (8 November × All Green), D₂ × C₁ (24 October × Supriya) and D₃ × C₁ (8 November × Supriya) which produced 8.05, 8.50 and 8.68 leaves per plant, respectively.

Significant influence of sowing dates on number of leaves per plant clearly indicates the role of temperature, humidity and other meteorological factors in growth and production of spinach plants. Maximum number of leaves per plant were observed in 9 October sowing this could be attributed to higher photosynthesis during this period. The findings are in accordance with the findings of Singh *et al.*, (2013) and Abed and shebl (2016) in spinach; Alam *et al.*, (2015) in mustard seed and Anitha *et al.*, (2016) in fenugreek.

The number of leaves per plant were influenced significantly due to different cultivars. The variation in number of leaves between different cultivars is attributed to inherent nature of genotypes. The results are in line with the findings of Ibrahim *et al.*, (2010) in spinach and Mahajan *et al.*, (2017) in coriander.

The result on interaction effects of dates of sowing and cultivars indicated that there was greater influence of sowing dates on number of leaves per plant. Maximum number of leaves obtained in above mention interactions when sowing was done on 9 October. This could be due to prevalence of optimum temperature during the vegetative growth period, greater photosynthesis and mobilization of assimilates. High number of leaves per plant in ambient temperature was also reported by Mahajan *et al.*, (2017) in coriander and Anitha *et al.*, (2018) in fenugreek.

Leaf area (cm²)

A perusal of the data presented in (Table 2) depicted significant differences for leaf area among of different dates of sowing and cultivars. The plants sown at D₁ (9 October) produced biggest leaves (5.59 cm²) which was statistically at par with D₂ (All Green) producing leaves with 5.33 cm² leaf area. The least leaf area (5.04 cm²) was observed in plants sown at D₃ (8 November) which was statistically at par with D₂ (24 October) producing leaves with 5.33 cm² leaf area. Among cultivars, biggest leaves (5.53 cm²) was observed in C₂ (All Green) which was statistically at par with C₃ (Punjab Green) producing leaves with 5.30 cm² leaf area. The least leaf area (5.15 cm²) was observed in C₁ (Supriya) which was statistically at par with C₃ (Punjab Green) producing leaves with area of 5.30 cm² leaf area.

Significant effect of interactions between sowing dates and cultivars for leaf area were observed. Table 2.1 revealed that biggest leaves (5.95 cm²) was observed in D₁

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× C₃ (9 October × Punjab Green) which was statistically at par with leaf area observed in D₁ × C₂ (9 October × All Green), D₂ × C₂ (24 October × All Green) and D₂ × C₁ (24 October × Supriya) producing plants with leaf area of 5.83 cm², 5.64 cm² and 5.58 cm², respectively. The minimum leaf area (4.76 cm²) was produced by plants under interaction D₂ × C₃ (24 October × Punjab Green) which was statistically at par with D₃ × C₁ (8 November × Supriya), D₁ × C₁ (24 October × Supriya), D₃ × C₂ (8 November × All Green) and D₃ × C₃ (8 November × Punjab Green) which produced 4.90 cm², 4.97 cm², 5.10 cm² and 5.18 cm² leaf area, respectively.

Delayed sowing resulted in decrease in leaf area. It was observed that plants with broadest leaves were produced when sowing was done 9 October. This can be attributed to the extended growing period when planted earlier, resulting in increased leaf area due to maximum photosynthesis with longer growth period than later sowing in which there is cessation of growth due to decreased temperature. This corroborates with the findings of earlier researches *viz.*, Sharma *et al.*, (2009) in lettuce; Anitha *et al.*, (2016) in fenugreek and Abed and Shebl (2016) in spinach.

Cultivars also affected the leaf area significantly. 'All Green' produced significantly maximum leaf area as compared to other cultivars. Similar results were obtained by earlier researchers *viz.*, Anitha *et al.*, (2016) in fenugreek; Singh *et al.*, (2017) in mustard, who observed significant differences among cultivars for leaf area.

The interaction effect between dates of sowing and cultivars for leaf area of spinach were found to be significant. Maximum leaf area was observed when sowing was done on 9 October in cultivar 'Punjab Green'. These results are in line with earlier

researchers viz., Anitha *et al.*, (2016) in fenugreek; Mahajan *et al.*, (2017) in coriander.

Yield attributes

Fresh yield per plot (kg)

An inquisition of the data (Table 3) revealed that the effect of sowing dates and cultivars on fresh yield of spinach was significant. Maximum fresh yield per plot (3.58 kg) was observed when sowing was done on D₁ (9 October) yield per plot which was significantly highest among all other dates of sowing. Minimum fresh yield per plot (1.95 kg) was observed when sowing was done on D₃ (8 November) which was lowest than other sowing dates. Among cultivars, maximum fresh yield per plot (2.97 kg) was produced by C₂ (All Green) which was statistically at par with fresh yield per plot observed in C₃ (2.58). Minimum fresh yield per plot (2.40 kg) was observed in C₁ (Supriya) which was statistically at par with fresh yield observed in C₃ (Punjab Green) which was 2.58 kg fresh yield per plot.

Significant interaction effects of sowing dates and cultivars on fresh yield per plot were observed. The perusal of data (Table 3.1) revealed that maximum fresh yield per plot (4.49 kg) was observed in D₁ × C₂ (9 October × All Green), which was significantly higher among all the interaction effects. Minimum fresh yield per plot (1.74 kg) was observed in D₃ × C₂ (8 November × All Green) which was statistically at par with D₃ × C₃ (8 November × Punjab Green), D₃ × C₁ (8 November × Supriya), D₃ × C₁ (8 November × Supriya), D₂ × C₁ (24 October × Supriya) and D₂ × C₃ (24 October × Punjab Green) which produced 1.91 kg, 2.21 kg, 2.22 kg, 2.22 kg and 2.35 kg fresh yield per plot, respectively.

Favourable conditions like temperature, humidity when sowing was done on 9 October could have led to better germination, maximum photosynthesis surface (as indicated by number of leaves per plant) leading to accumulation of maximum fresh weight as compared to those sown on late rabi. Similar results of significant differences in fresh weight due to different dates of sowing were also reported by Ibrahim *et al.*, (2010); Sensoy *et al.*, (2011); Abed and shebl (2016); Narayan *et al.*, (2018) and heyduck *et al.*, (2019) in spinach and kaleri *et al.*, (2016) in lettuce.

Performance of any crop in respect of growth, yield and quality is highly influenced by various factors out of which genetic constitutions of cultivars is of the most important factors. Fresh yield varied significantly among the cultivars and it was maximum in 'All Green' which showed maximum germination, plant height, number of leaves per plant etc. significant effect of cultivars on leaf yield per plot were observed by Mahajan *et al.*, (2017) and Anitha *et al.*, (2016) in fenugreek.

Significantly maximum fresh yield when sowing was done on 9 October in cultivar 'All Green' as depicted by interaction effect of dates of sowing and cultivars also pointed out the greater role of dates of sowing in determining the yield potential of a cultivar. The findings are similar to the early reports of Anitha *et al.*, (2016) in fenugreek.

Total fresh yield per hectare (t/ha)

Examination of data (Table 3) revealed that the effect of sowing time and cultivars on total fresh yield of spinach were significant. It revealed that maximum total fresh yield (14.94 t/ha) was observed when sowing was done on D₁ (9 October) which was significantly highest among other dates of sowing. Minimum total fresh yield (8.16 t/ha) was observed when sowing was done on D₃ (8 November) which was

significantly lowest than other sowing dates. Among Cultivars, maximum total fresh yield (12.41 t/ha) was reported in C₂ (All Green) which was statistically at par with C₃ (Punjab Green) which produced (10.76 t/ha) total fresh yield. Minimum total fresh yield (10.02 t/ha) was observed in C₁ (Supriya) which was statistically at par with C₃ (Punjab Green) which produced (10.76 t/ha) total fresh yield.

Interaction of sowing dates and cultivars were significant for total fresh yield per hectare. Table 3.1 revealed that D₁ × C₂ (9 October × All Green) resulted in maximum total fresh yield (18.72 t/ha) which was significantly highest among all other interaction effects. Minimum total fresh yield (7.28 t/ha) was observed in D₃ × C₂ (8 November × All Green) which was statistically at par with D₃ × C₃ (8 November × Punjab Green), D₃ × C₁ (8 November × Supriya), D₂ × C₁ (24 October × Supriya) and D₂ × C₃ (24 October × Punjab Green) which produced 7.97, 9.23, 9.24 and 9.79 fresh yield per hectare, respectively.

The maximum total fresh yield per plot as well as per hectare varied significantly among sowing time recorded in 9 October sowing. These findings are in close conformity with the result of Ibrahim *et al.*, (2010), Sensoy, *et al.* (2011), Abed and shebl (2016) and Heyduck *et al.*, (2019) in spinach.

Total fresh yield per hectare varied significantly among the cultivars. It was maximum in 'All Green' which might be due to its genetic makeup. Similar results of significant differences in total fresh yield due to different cultivars were also reported by Anitha *et al.*, (2016) in fenugreek and Mahajan *et al.*, (2017) in coriander.

Significantly high total fresh yield when sowing was done on 9 October as depicted from interaction effect of date of sowing and cultivars also pointed out the greater

role of date of sowing in determining the yield potential of a cultivars. The findings are similar to the early reports of Anitha *et al.* (2016) in fenugreek.

Days to 50% bolting

The examination of data indicated that the effect of sowing dates and cultivars on spinach was significant for days to 50% bolting. Table 3 depicted that least numbers of days for 50% bolting (111.66 days) were observed when sowing was done on D₃ (8 November) which was significantly lowest than all other dates of sowing. Maximum days (130.55 days) for 50% bolting were observed in D₁ (9 October) which was significantly highest than all other sowing dates. Among cultivars, C₃ (Punjab Green) resulted in least number of days for 50% bolting (121.55 days), which was significantly lowest than other cultivars. Maximum number of days for 50% bolting (124.33 days) were observed in C₂ (All Green) which was significantly higher than other cultivars.

Significant effect of interactions between sowing dates and cultivars for days in 50% bolting was reported. Table 3.1 depicted that minimum number of days for 50% bolting (111 days) was observed in D₃ × C₁ (8 November × Supriya) and D₃ × C₃ (8 November × Punjab Green) which were minimum than other interaction effects. Maximum days to 50% bolting (132 days) was observed in D₁ × C₂ (9 October × All Green) was statistically at par with number of days in bolting initiation observed in D₁ × C₁ (9 October × Supriya) which took 131.66 days for 50% bolting.

Sowing dates greatly affected the flower bud development. Earliest flowering was observed in the plants sown on 8 November. This suggests that delay in sowing caused early flowering in spinach. The possible reason for delayed flowering in early sowing might be due to the fact that environmental conditions for plant growth were more

favourable at early sowing. In delayed sowing plants tend to reach reproduction and seed production stage earlier due to little aberrant environment conditions when crop was sown on 8 November. Delayed planting resulting in early bolting had also been reported by Moniruzzaman *et al.*, (2015) in coriander and Singh *et al.*, (2017) in mustard.

Earliest flowering were observed in cultivar 'Punjab Green' which was significantly superior to Supriya and All Green. The probable reason may be attributed to the genetic characters of All Green which has higher capacity to utilize the photosynthetic. The similar findings have been reported by Singh *et al.*, (2017) in mustard; Bhutia *et al.*, (2017) and Anitha *et al.*, (2016) in fenugreek and Duwal *et al.*, (2019) in coriander.

Interaction effects revealed that 'Supriya' when sown on 8 November resulted in minimum days to flowering. This depicts the greater response of this variety on late sowing. In general, late sowing resulted in early bolting which suggests the greater influence of date of sowing on the bolting. The results are in line with the findings of Moniruzzaman *et al.*, (2015) in coriander and Singh *et al.*, (2017) in mustard.

Number of branches per plant

The perusal of data (Table 3) revealed that highest number of branches per plant (6.14) were observed when sowing was done on D₁ (9 October) which was significantly highest than all other dates of sowing. Minimum number of branches per plant (4.55) were observed in plants sown on D₃ (8 November) which was statistically at par with number of branches per plant observed in plants sown on D₂ (24 October) producing 4.87 branches per plant. Among the cultivars, maximum number of branches per plant (6.08) were observed in C₂ (All Green) which was statistically at

par with C₃ (Punjab Green) which produced 5.81 branches per plant. Minimum number of branches per plant (3.67) was observed in C₁ (Supriya) which was significantly lower among all the cultivars.

Interaction effects of sowing dates and cultivars for number of branches per plant were significant. Table 3.1 showed that D₁ × C₂ (9 October × All Green) produced the maximum number of branches per plants (8.54) which was significantly higher than other interaction effects. Minimum number of branches per plant (3.07) were observed in D₃ × C₂ (8 November × All Green) which was statistically at par with D₃ × C₁ (8 November × Supriya), D₂ × C₁ (24 October × Supriya), D₁ × C₁ (9 October × Supriya) and D₂ × C₃ (24 October × Punjab Green) which produced 3.62, 3.69, 3.70 and 4.27 branches per plant, respectively.

Maximum number of branches per plant were obtained in early sowing. This might be due to the fact that better vegetative growth was achieved due to early sowing and congenial climatic conditions availed by the crop during the growth period. Similar findings were also reported by Afroz *et al.*, (2011) in mustard seed; Sowmya *et al.*, (2016) and Anitha *et al.*, (2016) in fenugreek.

The genotypes under study varied significantly for their number of branches per plant. This might be due to their genetic makeup. These results are in conformity with the findings of Afroz *et al.*, (2011) in mustard; Latye *et al.*, (2016) and Bhutia *et al.*, (2017) in fenugreek and Mahajan *et al.*, (2017) in coriander.

The interaction effects of dates of sowing and cultivars on number of branches per plant in spinach were found significant. Maximum number of branches per plant were observed when sowing was done on 9 October in 'All Green' which again emphasized on greater influence of date of sowing on number of branches per plant.

The results are in conformity with the reports of earlier researchers *viz.*, Afroz *et al.*, (2011) in mustard seed; Dinda *et al.*, (2015) in rapeseed; Anitha *et al.*, (2016) in fenugreek and Mahajan *et al.*, (2017) in coriander.

Days to harvesting

The data revealed the significant effects of sowing dates and cultivars on spinach for days to harvest. Table 3 showed that the least numbers of days to harvest (117 days) were observed when sowing was done on D₃ (8 November) which was significantly lowest than all other dates of sowing. Maximum days to harvest (166.66 days) were observed when sowing was done on D₃ (8th November) which was significantly maximum than other dates of sowing. Among cultivars, least number of days to harvest (142.66 days) were observed in C₃ (Punjab Green) which was statistically at par with C₂ (All Green) which took 142.76 days to harvesting. Maximum number of days to harvesting (146.33 days) was observed in C₁ (Supriya) which was statistically at par with C₃ (Punjab Green) which was statistically higher than other cultivars.

Significant effect of interaction between sowing dates and cultivars for days to harvesting were observed. The perusal of data (Table 3.1) revealed minimum number of days to harvesting (114 days) in D₃ × C₁ (8 November × Supriya) which was statistically at par with number of days to harvest observed in D₃ × C₂ (8 November × All Green) which took 116 days to harvest. Maximum number of days to harvest (176 days) were observed in D₁ × C₁ (9 October × Supriya) which was significantly higher than all other interaction effects.

Harvest duration is indication of time at which plant has completed its development including seeds which when planted can survive on their own. It was observed to be significantly influenced by dates of sowing. Late sowing was found to have minimum

days to harvest. The results corroborates the finding of early researchers *viz.*, Guha *et al.*, (2014) in coriander and Bhutia, *et al.*, (2017) in fenugreek who observed that plants late sown took least time to mature.

Cultivars varied significantly for days to harvesting 'All Green' showed minimum days to harvest. The significant differences for harvest duration among cultivars might be due to differences in their genetic makeup. The results are in close conformity with results of Guha *et al.*, (2014) and Mahajan *et al.*, (2017) in coriander; Bhutia *et al.*, (2017) in fenugreek.

The interaction effects of dates of sowing and cultivar revealed that minimum days to harvest were observed when sowing was done on 8 November in 'Supriya' and 'All Green' which confirm the effect of date of sowing on harvest duration. The results are in line with findings of Guha *et al.*, (2014) in coriander and Bhutia *et al.*, (2017) in fenugreek who observed greater influence of date of sowing on harvest duration.

Seed yield per plot (g)

An inquisition of the data (Table 3) revealed that the effect of sowing dates and cultivars on seed yield per plot was significant. It revealed that maximum seed yield per plot (424.44 g) was observed when sowing was done on D₁ (9 October) which was significantly higher among all other dates of sowing. Minimum seed yield per plot was observed in D₃ (8 November) which produced (149.44 g) seed yield per plot which was significantly lowest than other sowing dates. Among Cultivars, C₁ (Supriya) resulted in maximum seed yield per plot (305.55 g) which was significantly highest among all the cultivars. Minimum seed yield per plot (268.33 g) was observed in C₃ (Punjab Green) which was statistically at par with C₂ (All Green) which produced 274.44 g seed yield per plot.

Interaction effects of sowing dates and cultivars were significant. Table 3.2 revealed that maximum seed yield per plot (483.33 g) was observed in $D_1 \times C_1$ (9 October \times Supriya) which was significantly highest among other interaction effects. Minimum seed yield per plot was observed in $D_3 \times C_1$ (8 November \times Supriya) and $D_3 \times C_2$ (8 November \times All Green) which produced (141.66 g) seed yield per plot and was significantly lowest than other interaction effects. Delayed sowing resulted in reduction in seed yield per plot as revealed from the results. The lower seed yield might be due to shorter growth period of the plants in late sowing which hinder them to make full use of available resources. Similar results were obtained by earlier researchers *viz.*, Ayub *et al.*, (2008) in fennel, Bhutia *et al.*, (2017) in fenugreek and Narayan *et al.*, (2018) in spinach.

Cultivar 'Supriya' showed higher number seed yield per plot. significant variation for seed yield per plot among varieties due to their genetic differences was also observed by earlier researchers Bhutia *et al.*, (2017) in fenugreek.

Interaction effects of 9 October in cultivar 'Supriya' resulted in significantly higher seed yield per plot. This could be due to the genetic and environmental interactions i.e. a particular variety surpassed the performance for a particular character due to availability of most effective climatic condition for its genetic makeup to perform at it's best. Similar reports were also observed by earlier researchers *viz.*, Razzaque *et al.*, (2007) and Anitha *et al.*, (2016) in fenugreek; Afroz *et al.*, (2011) and Dinda *et al.*, (2015) in mustard.

Total seed yield per hectare (t/ha)

An examination of the data (Table 3) revealed that the effect of sowing dates and cultivars on total Seed yield were significant. Table 3 showed maximum total seed

yield (1.77 t/ha) when sowing was done on D₁ (9 October) which was significantly highest among all other dates of sowing. Minimum total seed yield per hectare (0.62 t/ha) was observed in D₃ (8 November) which significantly lowest than the other dates of sowing. Among Cultivars, C₁ (Supriya) recorded maximum total seed yield (1.27 t/ha) which was statistically highest among all the cultivars. Minimum total seed yield (1.12 t/ha) was observed in C₃ (Punjab Green) which was statistically at par with C₂ (All Green) which produced 1.14 t/ha total seed yield.

Interaction effects of sowing dates and cultivars were significant for total seed yield per hectare. Table 3.2 showed that maximum total seed yield (2.02 t/ha) was observed in D₁ × C₁ (9 October × Supriya) which was significantly highest than other interaction effects. Minimum total seed yield (0.59 t/ha) was observed in D₁ × C₁ (8 November × Supriya) and D₃ × C₂ (8 November × All Green) which were significantly lowest than other interaction effects. Different sowing dates under investigation showed a wide range of variability on seed yield per hectare. The maximum seed yield per hectare was recorded in 9 October sowing. This might be attributed to the favourable climatic conditions that prevailed throughout the crop growth when sown on 9 October. These findings are in close conformity with the result of Ayub *et al.*, (2008) and Moosavi *et al.*, (2015) in fennel; Aziz *et al.*, (2011) and Singh *et al.*, (2017) in mustard; Bhutia *et al.*, (2017) in fenugreek; Ghobadi and Ghobadi (2010) and Lal *et al.*, (2017) in coriander.

Total seed yield per hectare varied significantly among the cultivars. It was maximum in 'Supriya' which might be due to varietal differences. The variation in seed yield per hectare in different genotypes might be due to variation in maturity days of the genotypes and genetic makeup. Similar results of significant differences in total seed yield due to different dates of sowing were also reported by Afroz *et al.*, (2011) and

Moniruzzaman *et al.*, (2015) in mustard seed; Bhutia *et al.*, (2017) and Singh *et al.*, (2017) in fenugreek.

Quality attributes

Chlorophyll content

Chlorophyll a (mg/ 100g fresh weight)

A perusal of the data (Table 3) revealed that the effect of dates of sowing and cultivars were significant for chlorophyll-a. The highest amount of chlorophyll- a content (24.50 mg) was observed in D₁ (9 October) which was significantly highest among all other dates of sowing. D₃ (8th November) resulted in minimum chlorophyll- a content (20.70 mg) which was statistically at par with chlorophyll- a content observed in plants sown on D₂ (24 October) which was (21.71 mg). Among cultivars, C₁ (Supriya) produced highest amount of chlorophyll- a content (23.24 mg) which was significantly highest among all other cultivars. Minimum amount of chlorophyll- a content (21.20 mg) was observed in C₃ (Punjab Green) which was statistically at par with C₂ (All Green) (22.48 mg).

Significant effect of interactions between sowing dates and cultivars for chlorophyll- a content in spinach were observed. Table 3.2 revealed that highest amount of chlorophyll-a (26.32 mg) was observed in D₁ × C₂ (9 October × All Green) which was statistically at par with chlorophyll- a content observed in D₁ × C₁ (9 October × Supriya), D₂ × C₃ (24 October × Punjab Green), D₁ × C₃ (9 October × Punjab Green), D₃ × C₃ (8 November × Punjab Green) which resulted 24.12 mg, 23.81 mg, 23.07 mg and 22.83 mg chlorophyll- a contents, respectively. Minimum amount of chlorophyll-a (18.66 mg) was observed in D₃ × C₁ (8 November × Supriya) which was statistically

at par with $D_2 \times C_2$ (24 October \times All Green), $D_3 \times C_2$ (8 November \times All Green) and $D_2 \times C_1$ (24 October \times Supriya) which resulted 20.51 mg, 20.62 mg and 20.81 mg chlorophyll- a contents, respectively. Maximum chlorophyll a content observed in 9 October sowing. Chlorophyll is the centre of energy producing system in plants and any significant changes in chlorophyll concentration could seriously affect plant life cycle. The reduction in chlorophyll content with delay in sowing could be due to reduction in transpiration pull in late cooler months. These findings were in close conformity with the result of Anitha *et al.*, (2016) in fenugreek.

Cultivar 'Supriya' which showed maximum chlorophyll a content. Significant variation in chlorophyll a content among cultivars could be due to their genetic differences. These findings were in close confirmative with the result of Anitha *et al.*, (2016) in fenugreek.

Interaction effects of dates of sowing and cultivars also revealed greater influence of dates of sowing and different cultivars on chlorophyll a content. It was reported to show a decreasing trend with delayed sowing. The results were in line with the findings of Anitha *et al.*, (2016) in fenugreek.

Chlorophyll b (mg/ 100g fresh weight)

Data presented in table 3 revealed that the effect of dates of sowing and cultivars were significant for chlorophyll-b. The highest amount of chlorophyll- b (35.29 mg) was observed in D_1 (9 October) which was significantly highest than other dates of sowing. Minimum chlorophyll- b content (27.24 mg) was observed in D_3 (8 November) which was significantly lowest among than other sowing dates. Among cultivars, highest amount of chlorophyll b (32.72 mg) was observed in C_1 (Supriya) which was statistically at par with C_2 (All Green) which produced 32.27 mg

chlorophyll- b content while minimum chlorophyll- b (28.86 mg) was observed in C₃ (Punjab Green) which was significantly lower than other cultivars.

Significant interaction effects of sowing dates and cultivars for chlorophyll- b content in spinach were observed. Table 3.2 revealed that highest amount of chlorophyll-b (38.99 mg) was observed in D₁ × C₂ (9 October × All Green) which was statistically at par with chlorophyll- b content (34.88 mg) observed in D₁ × C₁ (9 October × Supriya). Minimum amount of chlorophyll-b (24.04 mg) was observed in combination of D₃ × C₃ (8 November × Punjab Green) which was significantly lowest among all other interaction effects.

Maximum chlorophyll-b content observed in 9 October sown crop. The reduction in chlorophyll content with delay in sowing could be due to reduction in transpiration pull in late cooler months. These findings are in confirmation with the earlier researchers Anitha *et al.*, (2016) in fenugreek.

Cultivar 'Supriya' which showed maximum chlorophyll b content. Significant variation in chlorophyll b content among cultivars could be due to their genetic makeup. These findings are in line with the earlier researchers Anitha *et al.*, (2016) in fenugreek.

Interaction effects of dates of sowing and cultivars also revealed greater influence of dates of sowing and different cultivars. It was reported to show a decreasing trend with delayed sowing. The results are in line with the findings of Anitha *et al.*, (2016) in fenugreek.

Total chlorophyll (mg/ 100g fresh weight)

A perusal of the data (Table 3) revealed that the effect of dates of sowing and cultivars were significant for total chlorophyll content. The highest amount of total

chlorophyll content (80.82 mg) was observed in D₁ (9 October) which was significantly maximum than other dates of sowing. Minimum chlorophyll content (60.26 mg) was observed in D₃ (8 November) which was significantly at par with chlorophyll content observed in D₂ (24 October) which resulted in 60.52 mg total chlorophyll content. Among cultivars, C₁ (Supriya) produced maximum (71.61 mg) total chlorophyll content which was significantly highest than other cultivars. C₂ (All Green) produced minimum resulted in (64.59 mg) total chlorophyll content which was statistically at par with C₃ (Punjab Green) resulting in (65.40 mg) total chlorophyll content.

Significant effect of interactions of sowing dates and cultivars for total chlorophyll content in spinach were observed. The perusal of data (Table 3.2) revealed that the highest total chlorophyll content (88.50 mg) in D₁ × C₂ (9 October × All Green) which was significantly highest than other interaction effects. Minimum amount of total chlorophyll content (51.37 mg) was observed in D₃ × C₂ (8 November × All Green) which was statistically at par with D₂ × C₃ (24 October × Punjab Green) which resulted in (55.04 mg) total chlorophyll.

Maximum total chlorophyll content was observed in 9 October sown crop. These findings are in conformity with the earlier researchers *viz.*, Sarkar *et al.*, (2014) and Abed and shebl (2016) in spinach; Sowmya *et al.*, (2018) and Anitha *et al.*, (2016) in fenugreek who also observed significant effect of dates of sowing on chlorophyll content.

Cultivar 'Supriya' showed maximum total chlorophyll content. These findings were in close conformity with the earlier researchers Latye *et al.*, (2016) and Anitha *et al.*, (2016) in fenugreek who also observed significant differences for chlorophyll content among different cultivars.

Interaction effects of date of sowing and cultivars also revealed greater influence of dates of sowing and different cultivars. A decreasing trend with delayed sowing was observed. The results were in line with the findings of Ibrahim *et al.*, (2010) in spinach; Significant effect of sowing dates on total chlorophyll content was also observed by Sarkar *et al.*, (2014) and Shirani *et al.*, (2014) in rapeseed; Anitha *et al.*, (2016) and Sowmya *et al.*, (2017) in fenugreek.

CONCLUSION

In the present investigation we concluded that the dates of sowing and cultivars significantly affected the growth, yield and quality attributes of spinach. Plants sown on 9 October resulted in superior performance for most of the traits of spinach. Among cultivars, All Green performed best for most of the traits. The interaction of sowing dates and cultivars performed better in All Green when sown on 9 October in Jalandhar region.

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Table 1: Analysis of variance for growth and yield parameters of spinach

Observations	MSS Factor A	MSS Factor B	MSS Factor A x B	Error
Days to emergence	582.11*	10.87*	6.05*	1.98
Days to complete Germination	738.11*	25.33*	9.44*	3.08
Plant height (cm)	331.88*	169.93*	52.74*	0.97
Number of leaves per plant	3.21*	9.60*	4.36*	0.75
Leaf area (cm ²)	0.61*	0.32*	0.66*	0.08
Fresh yield per plot (kg)	6.33*	0.77*	0.90*	0.20
Total fresh yield per hectare (t/ha)	110.00*	13.46*	15.62*	3.60
Chlorophyll – a (mg/100g fresh weight)	34.97*	9.67*	10.83*	2.42
Chlorophyll –b (mg/100g fresh weight)	145.80*	40.03*	20.30*	6.55
Total chlorophyll (mg/100g fresh weight)	1142.76*	103.108*	198.87*	7.98
Days to 50% bolting	895.37*	17.37*	2.87*	0.62
Number of branches per plant	1.39*	0.81*	2.07*	0.21
Days to harvesting	5,821.00 *	37.00*	152.00*	8.50
Seed yield per plot (g)	170625.00*	3586.11*	3127.77*	78.81
Total seed yield (t/ha)	2.96*	0.06*	0.05*	0.00

Significant at 5% level*Factor A = Date of sowing****Factor B = Cultivars**

Table 2: Effect of date of sowing and cultivars on growth parameters of spinach

Treatment	Days to emergence	Days to complete germination	Plant height (cm)	Number of leaves per plant	Leaf area (cm ²)
Date of sowing					
D₁	4.22	11.88	32.29	9.86	5.59
D₂	7.33	23.77	23.46	9.14	5.33
D₃	19.44	29.66	20.66	8.63	5.06
CD (5%)	1.42	1.77	0.99	0.87	0.28
SE (d)	0.66	0.82	0.46	0.41	0.13
Cultivars					
C₁	10.00	20.00	21.78	8.15	5.15
C₂	9.44	22.00	30.26	9.34	5.53
C₃	11.55	23.33	24.36	10.20	5.30
CD (5%)	1.42	1.77	0.99	0.87	0.28
SE (d)	0.66	0.82	0.46	0.41	0.13

Table 2.1: Interaction effect of date of sowing and cultivars on growth parameters of spinach

Date of sowing/ cultivars	Days to emergence			Days to complete germination			Plant height (cm)			Number of leaves per plant			Leaf area (cm ²)		
	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃
D ₁	4.66	3.66	4.33	11.00	13.33	11.33	28.01	34.82	34.03	7.26	10.64	11.70	4.97	5.83	5.95
D ₂	5.33	6.66	10.00	20.66	23.66	27.00	19.04	31.31	18.02	8.50	9.33	9.60	5.58	5.64	4.76
D ₃	20.00	18.00	20.33	28.33	29.00	31.00	18.29	22.26	20.04	8.68	8.05	9.31	4.90	5.10	5.18
CD(5%)	2.46			3.06			1.72			1.52			0.50		
SE (d)	1.15			1.43			0.80			0.71			0.23		

Table 3: Effect of sowing date on yield and quality attributes in different cultivars of spinach

Treatments	Fresh yield per plot (kg)	Total fresh yield per hectare (t/ha)	Days to 50% bolting	Number of branches per plant	Days to harvesting	Seed yield per plot (g)	Total Seed yield per hectare (t/ha)	Chlorophyll a (mg/100g fresh weight)	Chlorophyll b (mg/100g fresh weight)	Total chlorophyll (mg/100g fresh weight)
Date of sowing										
D ₁	3.58	14.94	130.55	6.14	166.76	424.44	1.77	24.50	35.29	80.82
D ₂	2.42	10.08	126.66	4.87	151.33	274.44	1.14	21.71	31.32	60.52
D ₃	1.95	8.16	111.66	4.55	117	149.44	0.62	20.70	27.24	60.26
CD (5%)	0.45	1.91	0.79	0.96	2.93	8.49	0.03	1.57	2.58	3.39
SE (d)	0.21	0.89	0.37	0.44	1.37	4.18	0.01	0.73	1.20	1.58
Cultivars										
C ₁	2.40	10.02	123.00	3.67	146.33	305.55	1.27	23.24	32.72	71.61
C ₂	2.97	12.41	124.33	6.08	142.33	274.44	1.14	22.48	32.27	64.59
C ₃	2.58	10.76	121.55	5.81	142.00	268.33	1.12	21.20	28.86	65.40
CD (5%)	0.45	1.91	0.79	0.96	2.93	8.94	0.03	1.57	2.58	3.39
SE (d)	0.21	0.89	0.37	0.44	1.37	4.18	0.01	0.73	1.20	1.58

Table 3.1: Interaction effect of sowing date on yield and quality attributes in different cultivars of spinach

Date of sowing/ cultivars	Fresh yield per plot (kg)			Total fresh yield per hectare (t/ha)			Days to 50% bolting			Number of branches per plant			Days to harvesting		
	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃
D ₁	2.78	4.49	3.48	11.58	18.72	14.53	131.66	132.00	128.00	3.70	8.54	6.19	176.00	157.00	167.00
D ₂	2.21	2.69	2.35	9.24	11.22	9.79	126.33	128.00	125.66	3.69	6.65	4.27	149.00	155.00	150.00
D ₃	2.22	1.74	1.91	9.23	7.28	7.29	111.00	113.00	111.00	3.62	3.07	6.97	114.00	116.00	121.00
CD(5%)	0.79			3.31			1.37			1.66			5.09		
SE (d)	0.37			1.55			0.64			0.77			2.38		

Table 3.2: Interaction effect of sowing date on yield and quality attributes in different cultivars of spinach

Date of sowing/ cultivars	Seed yield per plot (g)			Total Seed yield per hectare (t/ha)			Chlorophyll a (mg/100g fresh weight)			Chlorophyll b (mg/100g fresh weight)			Total chlorophyll (mg/100g fresh weight)		
	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃	C ₁	C ₂	C ₃
D ₁	483.33	400.00	390.00	2.02	1.67	1.63	24.12	26.32	23.07	34.88	38.99	32.01	81.14	88.50	72.83
D ₂	291.66	281.66	250.00	1.22	1.17	1.04	20.81	20.51	23.81	34.24	29.18	30.54	65.27	61.26	55.04
D ₃	141.66	141.66	165.00	0.59	0.59	0.69	18.66	20.62	22.83	29.05	28.64	24.04	61.07	51.37	68.33
CD(5%)	15.49			0.06			2.72			4.46			5.88		
SE (d)	7.24			0.03			1.27			2.09			2.75		