International Journal of Plant & Soil Science

34(23): 1174-1190, 2022; Article no.IJPSS.93170
ISSN: 2320-7035

Influence of Planting Time on Yield and Quality of Spinach (*Spinacia oleracea*) Varieties

Sandeep Kaur [a], Puja Rattan [a*], A. H. Reddy [a] and Anju Pathania [a]

[a] Faculty of Agricultural Sciences, DAV University, Jalandhar, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i232531

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/93170

Original Research Article

Received 04 September 2022
Accepted 08 November 2022
Published 15 November 2022

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 (cm^2), 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.

Keywords: Spinach; cool-season crop; agronomic factors; minerals.

**Corresponding author: E-mail: puja10167@davuniversity.org;*

1. 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" [1]. "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" [2-4]. "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" [5].

"Genetic, environmental and agronomic factors and the interaction between them play a vital role in determining the yield and its contributing traits" [6]. Therefore, yield can be enhances 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 25ºC cause the plant to bolt and flower, which is detrimental to spinach production [7]. 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 [8]. 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 [9,10].

Genetic potentiality of a variety is fully expressed when it is synchronised with the optimum environmental conditions such as temperature, light, humidity, rainfall etc. [11]. 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.

2. MATERIALS AND METHODS

The present investigation was carried out at the Experimental Farm of Faculty of Agricultural Sciences, DAV University, Jalandhar during winter 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.,* C_1 (Supriya), C_2 (All Green) and C_3 (Punjab Green) and three dates of sowing at 15 days interval *viz.,* D_1 (9 October), D_2 (24 October) and D_3 (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 (cm^2), 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 characters was done by analysis of variance method for factorial randomized block design described by Panse and Sukhatme [12].

3. RESULTS AND DISCUSSION

3.1 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).

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*

3.2 Growth Attributes

3.2.1 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 D_1 (9 October) which were significantly minimum than all other dates of sowing. Maximum number of days to emergence (19.44 days) were observed in D_3 (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 C_2 (All Green) which was statistically at par with C_1 (Supriya) which took 10 days to emerge. Maximum number of days to emergence (11.55) were observed in C_3 (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 $D_1 \times C_2$ (9 October × All Green) which was statistically at par with number of days to emergence observed in $D_1 \times C_3$ (9 October × Punjab Green), $D_1 \times C_1$ (9 October × Supriya) and $D_2 \times C_1$ (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 × Punjab Green) which was statistically at par with $D_3 \times C_1$ (8 November × Supriya) and $D_3 \times C_2$ (8 November × 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. [13]; Karetha et al. [14]; Sharangi and Roychowdhury [15]; Moniruzzaman et al. [16] and Lal et al. [17] 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. [18] in fenugreek; Mahajan et al. [19] and Lal et al. [17] 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. [13]; Karetha et al. [14]; Moniruzzaman et al. [16]; Lal et al. [17] who also suggested the role of dates of sowing in the germination of coriander.

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					
D_1	4.22	11.88	32.29	9.86	5.59
D_2	7.33	23.77	23.46	9.14	5.33
D_3	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					
C_1	10.00	20.00	21.78	8.15	5.15
C_2	9.44	22.00	30.26	9.34	5.53
C_3	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	

3.2.2 Days to complete germination

The perusal of data (Table 2) showed that D_1 (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 D_3 (8 November). Among cultivars, least number of days to complete germination (20.00 days) were observed in C_1 (Supriya) which was statistically at par with C_2 (All Green) which took 22 days to complete germination. Maximum number of days to complete germination (23.33 days) was observed in C_3 (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 $D_1 \times C_1$ (9 October × Supriya) which was statistically at par with number of days to complete germination observed in $D_1 \times C_3$ (9 October × Punjab Green) and $D_1 \times C_2$ (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 $D_3 \times C_3$ (8 November × Punjab Green) which was statistically at par with $D_3 \times C_2$ (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. [20] who observed that high temperature leads to early germination in spinach; Sharangi and Roychowdhury [15] and Lal et al. [17] in coriander. Cultivars showed significant differences in complete germination which is in line with the findings of Lal et al. [17] and Duwal et al. [21] in coriander and Bhutia et al. [22] 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. [20] in spinach.

3.2.3 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 D_1 (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 D_3 (8 November) which was significantly minimum than the plant height observed in other dates of sowing. Among cultivars, C_2 (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 C_1 (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 $D_1 \times C_2$ (9 October × All Green) produced the plants with maximum height (34.82 cm) which was statistically at par with $D_1 \times C_3$ (9 October × Punjab Green) producing 34.03 cm tall plants. The least plant height (18.02 cm) was observed in $D_2 \times C_3$ (24 October × Punjab Green) which was statistically at par with $D_3 \times C_1$ (8 November × Supriya) and $D_2 \times C_1$ (24 October × 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. [23] and Abed and shebl [24] in spinach; Afroz et al. [25] and Alam et al. [26] in mustard seed; Anitha et al. [27] and Bhavar et al. [28] in fenugreek and Dhillon et al. [29] 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. [25] in mustard seed; Latye et al. [18]; Anitha et al. [27] and Bhutia et al. [22] in fenugreek and Bajad et al. [30] 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. [25] in mustard seed; Anitha et al. [27] in fenugreek and Abed and Shebl [24] who reported greater plant height in October sowing as compared to November sowing in spinach.

3.2.4 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 D_1 (9 October) which was significantly higher than all other dates of sowing. The least number of leaves per plant (8.63) were observed in D_3 (8 November) which was statistically at par with number of leaves produced by the plants when sowing was done on D_2 (24 October) which produced 9.14 leaves. Among the cultivars, maximum number of leaves per plant (10.20) were observed in C_3 (Punjab Green) which was statistically at par with C_2 (All Green) producing (9.34) leaves per plant. Minimum number of leaves per plant (8.15) were observed in C_1 (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 $D_1 \times C_3$ (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 $D_1 \times C_2$ (9 October × All Green). Minimum number of leaves per plant (7.26) were observed in $D_1 \times C_1$ (9 October × Supriya) which was statistically at par with number of leaves observed in $D_3 \times C_2$ (8 November × All Green), $D_2 \times C_1$ (24 October × Supriya) and $D_3 \times C_1$ (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. [31] and Abed and shebl [24] in spinach; Alam et al. [26] in mustard seed and Anitha et al. [27] 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. [23] in spinach and Mahajan et al. [19] 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. [19] in coriander and Anitha et al. [27] in fenugreek.

3.2.5 Leaf area (cm^2)

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 D_1 (9 October) produced biggest leaves (5.59 cm^2) which was statistically at par with D_2 (All Green) producing leaves with 5.33 cm^2 leaf area. The least leaf area (5.04 cm^2) was observed in plants sown at D_3 (8 November) which was statistically at par with D_2 (24 October) producing leaves with 5.33 cm^2 leaf area. Among cultivars, biggest leaves (5.53 cm^2) was observed in C_2 (All Green) which was statistically at par with C_3 (Punjab Green) producing leaves with 5.30 cm^2 leaf area. The least leaf area (5.15 cm^2) was observed in C_1 (Supriya) which was statistically at par with C_3 (Punjab Green) producing leaves with area of 5.30 cm^2 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 cm^2) was observed in $D_1 \times C_3$ (9 October × Punjab Green) which was statistically at par with leaf area observed in $D_1 \times C_2$ (9 October × All Green), $D_2 \times C_2$ (24 October × All Green) and $D_2 \times C_1$ (24 October × Supriya) producing plants with leaf area of 5.83 cm^2, 5.64 cm^2 and 5.58

cm^2, respectively. The minimum leaf area (4.76 cm^2) was produced by plants under interaction $D_2 \times C_3$ (24 October × Punjab Green) which was statistically at par with $D_3 \times C_1$ (8 November × Supriya), $D_1 \times C_1$ (24 October × Supriya), $D_3 \times C_2$ (8 November × All Green) and $D_3 \times C_3$ (8 November × Punjab Green) which produced 4.90 cm^2, 4.97 cm^2, 5.10 cm^2 and 5.18 cm^2 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*.* [32] in lettuce; Anitha et al. [27] in fenugreek and Abed and Shebl [24] 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. [27] in fenugreek; Singh et al. [33] 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. [27] in fenugreek; Mahajan et al. [19] in coriander.

3.3 Yield Attributes

3.3.1 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 D_1 (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 D_3 (8 November) which was lowest than other sowing dates. Among cultivars, maximum fresh yield per plot (2.97 kg) was produced by C_2 (All Green) which was statistically at par with fresh yield per plot observed in C_3 (2.58). Minimum fresh yield per plot (2.40 kg) was observed in C_1 (Supriya) which was statistically at par with fresh yield observed in C_3 (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 $D_1 \times C_2$ (9 October × All Green), which was significantly higher among all the interaction effects. Minimum fresh yield per plot (1.74 kg) was observed in $D_3 \times C_2$ (8 November × All Green) which was statistically at par with $D_3 \times C_3$ (8 November × Punjab Green), $D_3 \times C_1$ (8 November × Supriya), $D_3 \times C_1$ (8 November × Supriya), $D_2 \times C_1$ (24 October × Supriya) and $D_2 \times C_3$ (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. [23]; Sensoy et al. [20]; Abed and shebl [24]; Narayan et al. [34] and Heyduck et al. [35] in spinach and Kaleri et al. [36] 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. [19] and Anitha et al. [27] 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. [27] in fenugreek.

3.3.2 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 D_1 (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 D_3 (8 November) which was significantly lowest than other sowing dates. Among Cultivars, maximum total fresh yield (12.41 t/ha) was reported in C_2 (All Green) which was statistically at par with C_3 (Punjab Green) which produced (10.76 t/ha) total fresh yield. Minimum total fresh yield (10.02 t/ha) was observed in C_1 (Supriya) which was statistically at par with C_3 (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 $D_1 \times C_2$ (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 $D_3 \times C_2$ (8 November × All Green) which was statistically at par with $D_3 \times C_3$ (8 November × Punjab Green), $D_3 \times C_1$ (8 November × Supriya), $D_2 \times C_1$ (24 October × Supriya) and $D_2 \times C_3$ (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. [23], Sensoy, et al. [20], Abed and shebl [24] and Heyduck et al. [35] 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. [27] in fenugreek and Mahajan et al. [19] 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. [27] in fenugreek.

3.3.3 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 D_3 (8 November) which was significantly lowest than all other dates of sowing. Maximum days (130.55 days) for 50% bolting were observed in D_1 (9 October) which was significantly highest than all other sowing dates. Among cultivars, C_3 (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 C_2 (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 $D_3 \times C_1$ (8 November × Supriya) and $D_3 \times C_3$ (8 November × Punjab Green) which were minimum than other interaction effects. Maximum days to 50% bolting (132 days) was observed in $D_1 \times C_2$ (9 October × All Green) was statistically at par with number of days in bolting initiation observed in $D_1 \times C_1$ (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. [16] in coriander and Singh et al. [33] 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. [33] in mustard; Bhutia et al. [22] and Anitha et al. [27] in fenugreek and Duwal et al. [21] 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. [16] in coriander and Singh et al. [33] in mustard.

3.3.4 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 D_1 (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 D_3 (8 November) which was statistically at par with number of branches per plant observed in plants sown on D_2 (24 October) producing 4.87 branches per plant. Among the cultivars, maximum number of branches per plant (6.08) were observed in C_2 (All Green) which was statistically at par with C_3 (Punjab Green) which produced 5.81 branches per plant. Minimum number of branches per plant (3.67) was observed in C_1 (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 $D_1 \times C_2$ (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 $D_3 \times C_2$ (8 November × All Green) which was statistically at par with $D_3 \times C_1$ (8 November × Supriya), $D_2 \times C_1$ (24 October × Supriya), $D_1 \times C_1$ (9 October × Supriya) and $D_2 \times C_3$ (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. [25] in mustard seed; Sowmya et al. [37] and Anitha et al. [27] 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. [25] in mustard; Latye et al. [18] and Bhutia et al. [22] in fenugreek and Mahajan et al. [19] 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. [25] in mustard seed; Dinda et al. [38] in rapeseed; Anitha et al. [27] in fenugreek and Mahajan et al. [19] in coriander.

3.3.5 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 D_3 (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 D_3 (8^{th} November) which was significantly maximum than other dates of sowing. Among cultivars, least number of days to harvest (142.66 days) were observed in C_3 (Punjab Green) which was statistically at par with C_2 (All Green) which took 142.76 days to harvesting. Maximum number of days to harvesting (146.33 days) was observed in C_1 (Supriya) which was statistically at par with C_3 (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 $D_3 \times C_1$ (8 November × Supriya) which was statistically at par with number of days to harvest observed in $D_3 \times C_2$ (8 November × All Green) which took 116 days to harvest. Maximum number of days to harvest (176 days) were observed in $D_1 \times C_1$ (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*.* [13] in coriander and Bhutia, et al*.* [22] 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 makup. The results are in close conformity with results of Guha et al. [13] and Mahajan et al. [19] in coriander; Bhutia et al. [22] 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. [22] in fenugreek who observed greater influence of date of sowing on harvest duration.

3.3.6 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 D_1 (9 October) which was significantly higher among all other dates of sowing. Minimum seed yield per plot was observed in D_3 (8 November) which produced (149.44 g) seed yield per plot which was significantly lowest than other sowing dates. Among Cultivars, C_1 (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 C_3 (Punjab Green) which was statistically at par with C_2 (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 × Supriya) which was significantly highest among other interaction effects. Minimum seed yield per plot was observed in $D_3 \times C_1$ (8 November × Supriya) and $D_3 \times C_2$ (8 November × 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. [39] in fennel, Bhutia et al. [22] in fenugreek and Narayan et al. [33] 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. [22] 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. [40] and Anitha et al. [27] in fenugreek; Afroz et al. [25] and Dinda et al. [38] in mustard.

3.3.7 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 D_1 (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 D_3 (8 November) which significantly lowest than the other dates of sowing. Among Cultivars, C_1 (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 C_3 (Punjab Green) which was statistically at par with C_2 (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 $D_1 \times C_1$ (9 October × Supriya) which was significantly highest than other interaction effects. Minimum total seed yield (0.59 t/ha) was observed in $D_1 \times C_1$ (8 November × Supriya) and $D_3 \times C_2$ (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. [39] and Moosavi et al. [41] in fennel; Aziz et al. [42] and Singh et al. [31] in mustard; Bhutia et al. [22] in fenugreek; Ghobadi and Ghobadi [43] and Lal et al. [17] 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. [25] and Moniruzzaman et al. [16] in mustard seed; Bhutia et al. [22] and Singh et al. [33] in fenugreek.

3.4 Quality Attributes

3.4.1 Chlorophyll content

3.4.1.1 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 D_1 (9 October) which was significantly highest among all other dates of sowing. D_3 (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 D_2 (24 October) which was (21.71 mg). Among cultivars, C_1 (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 C_3 (Punjab Green) which was statistically at par with C_2 (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 $D_1 \times C_2$ (9 October × All Green) which was statistically at par with chlorophyll- a content observed in $D_1 \times C_1$ (9 October × Supriya), $D_2 \times C_3$ (24 October × Punjab Green), $D_1 \times C_3$ (9 October × Punjab Green), $D_3 \times C_3$ (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 $D_3 \times C_1$ (8 November × Supriya) which was statistically at par with $D_2 \times C_2$ (24 October × All Green), $D_3 \times C_2$ (8 November × All Green) and $D_2 \times C_1$ (24 October × 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. [27] 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. [27] 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. [27] in fenugreek.

3.4.1.2 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 chorophyll 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 C_3 (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

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**	

amount of chlorophyll-b (38.99 mg) was observed in D_1 × C_2 (9 October × All Green) which was statistically at par with chlorophyll- b content (34.88 mg) observed in D_1 × C_1 (9 October × Supriya). Minimum amount of chlorophyll-b (24.04 mg) was observed in combination of D_3 × C_3 (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. [27] 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. [27] 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. [27] in fenugreek.

3.4.2 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 D_1 (9 October) which was significantly maximum than other dates of sowing. Minimum chlorophyll content (60.26 mg) was observed in D_3 (8 November) which was significantly at par with chlorophyll content observed in D_2 (24 October) which resulted in 60.52 mg total chlorophyll content. Among cultivars, C_1 (Supriya) produced maximum (71.61 mg) total chlorophyll content which was significantly highest than other cultivars. C_2 (All Green) produced minimum resulted in (64.59 mg) total chlorophyll content which was statistically at par with C_3 (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 D_1 × C_2 (9 October × All Green) which was significantly highest than other interaction effects. Minimum amount of total chlorophyll content (51.37 mg) was observed in D_3 × C_2 (8 November × All Green) which was statistically at par with D_2 × C_3 (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. [44] and Abed and shebl [24] in spinach; Sowmya et al. [37] and Anitha et al. [27] 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. [18] and Anitha et al. [27] 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. [23] in spinach; Significant effect of sowing dates on total chlorophyll content was also observed by Sarkar et al. [44] and Shirani et al. [45] in rapeseed; Anitha et al. [27] and Sowmya et al. [37] in fenugreek.

4. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sheetal Gupta, Jamuna Prakash. Studies on Indian green leafy vegetables for their

antioxidant activity. Plant Foods for Human Nutrition. 2009;64:39–45.
2. Roughani A, Miri SM, Kashi AK. Effect of colchicin, trifluralin and oryzalin on polyploid induction in spinach. MSc Thesis of Horticultural Science. Islamic Azad University, Karaj Branch; 2011.
3. Gaikwad PS. Shete RV, Otari KV. Spinacia oleracea Linn: A pharmacognostic and pharmacological overview. International Journal of Research in Ayurveda and Pharmacy. 2010; 1(1):78-84.
4. Verma S. A study on medicinal herb Spinacia oleraceae Linn: Amaranthaceae. Journal of Drug Delivery and Therapeutics. 2018;8(4):59-61.
5. FAO (Food and Agriculture Organization). FAO Production Year Book. India; 2018.
6. Sidlauskas C, Bernotas S. Some factors affecting seed yield of spring oilseed rape (*Brassica napus* L.). Agronomy Research. 2003;1(2):229-243.
7. Waseem, Kashif, Nadeem, Mohammad. Enhancement of spinach production by varying sowing dates, row spacing and frequency of cuttings. Journal of Biological Sciences; 2001. DOI:10.3923/jbs.2001.902.904.
8. Bake ID, Singh BK, Singh AK, Moharana DP, Maurya AK. Impact of planting distances and sowing dates on yield attributing traits of okra [*Abelmoschus esculentus* (L.) Moench] cv. Kashi Pragati. International Journal of Current Microbiology and Applied Sciences. 2017; 6(7):4112-4125.
9. Parlevliet JE. Influence of external factors on the growth and development of spinach cultivars (*Spinacia oleracea* L.). Mededel. Landbouwhogeschool Wageningen. 1967a;67-2:75.
10. Parlevliet JE. Temperature and daylength requirements in flower initiation of chervil. (*Anthriscus cerefollum* Hoffm.). Zeit sehr. für Pflanzenphys; 1967b.
11. Salmasi SZ, Golez KG, Moghbeli S. Effect of sowing date and limited irrigation on the seed yield and quality of dill (*Anethum graveolens* L.). Turk. J. Agric. For. 2006;30:281-286.
12. Panse VG, Sukhatme PV. Statistical methods for agriculture workers. Indian council of Agriculture, New Delhi; 1967.
13. Guha S, Sharangi AB, Debnath S. Phenology and green leaf yield of coriander at different sowing dates and harvesting times. J Food Agric Environ. 2014;12(3):251-254.
14. Karetha KM, Giriraj J, Ladumor AR. Effect of different date of sowing and growing conditions on coriander (*Coriandrum sativum* L.) cv. Gujarat Coriander-2.International Journal of Agricultural Sciences. 2014;10(2):524-528.
15. Sharangi AB, Roychowdhury A. Phenology and yield of coriander (*Coriandrum sativum* L.) at different sowing dates. Journal of Plant Sciences. 2014;9(2):32-42.
16. Moniruzzaman M, Rahman MM, Hossain MM, Karim AS, Khaliq QA. Effect of sowing dates and genotypes on the yield of coriander (*Coriandrum sativum* L.). Bangladesh Journal of Agricultural Research. 2015;40(1):109-119.
17. Lal G, Metha RS, Singh R, Choudhary MK, Maheria SP. Effects of sowing dates on plant growth and seed yield of ajmer green coriander-1 in winter season. International Journal of Seed Spices. 2017;7(2):14-18.
18. Latye PT, Bharad SG, Kale VS, Nandeshwar VN, Kholia A. Varietal performance of fenugreek under Akola conditions. International Journal of Minor Fruits, Medicinal and Aromatic Plants (IJMFM&AP). 2016;2:32 - 34.
19. Mahajan RD, Patgaonkar DR, Garande VK, Pawar RD, Dhumal SS, Sonawane PN. Response of coriander cultivars under different shade net intensities during summer. Asian Journal of Horticulture. 2017;12(2):211-217.
20. Sensoy S, Turkmen O, Gorgun Y. Determination of suitable sowing dates for spinach production in van ecological condition. YYU Journal of Agricultural Sciences. 2011;21(2):140-145
21. Duwal A, Nepal A, Luitel S, Acharya S, Pathak R, Poudel PR, Shrestha J. Evaluation of coriander (*Coriandrum sativum* L.) varieties for growth and yield parameters. Nepalese Journal of Agricultural Sciences. 2019;18:36-46.
22. Bhutia KC, Bhutia SO, Chatterjee R, Chattopadhyay N. Growth, phenology and yield of fenugreek (*Trigonella foenum–graecum* L.) as influenced by date of sowing. International Journal of Current Microbiology and Applied Sciences. 2017;6(10):1810-1817.
23. Ibrahim EA, El-Gendy SE, Ramadan AY. Effect of sowing date and some soil amendments on yield and quality of spinach (*Spinacia oleracea* L.): The Sixth

Inter. Conf. of Sustain. Agric. And Develop. Fac. Of Agric, Fayoum Univ. December 2010;27-29.

24. Abed MY, Shebl EF. Effect of sowing dates and number of cuttings on yield and quality of spinach (*Spinacia oleraceae* L.). Journal of Plant Production. 2016;7(12):1437-1442.
25. Afroz MM, Sarkar MAR, Bhuiya MSU. Effect of sowing date and seed rate on yield performance of two mustard varieties. Journal of the Bangladesh Agricultural University. 2011;9(452-2016-35731): 5-9.
26. Alam MJ, Ahmed KS, Mollah MRA, Tareq MZ, Mottalib MA. Effect of seed rate and sowing method on the yield of mustard. Bangladesh Journal of Environment Science. 2015;29:37-40.
27. Anitha B, Reddy MLN, Rao AVDD, Patro TSKKK, Suneetha DS. Effect of sowing date on yield and quality of fenugreek. Plant Archives. 2016;16(1):479-484.
28. Bhavar SV, Ghawade SM, Lajurkar VG, Gore RP. Influence of sowing times and fertilizer levels on vegetative growth in kasuri methi (*Trigonella corniculata* L.):under Akola (MS) conditions. IJCS. 2019;7(3):3427-3429.
29. Dhillon DT, Gandhi N. Effect of different sowing dates and doses of nitrogen on morphology, yield contributing characters and yield of fennel (*Foeniculum vulgare*):Journal of Pharmacognosy and Phytochemistry. 2019;SP1:653-656.
30. Bajad GB, Dahale MH, Nandeshwar VN. Performance of different coriander varieties for seed yield. Journal of Krishi Vigyan. 2017;5(2):132-137.
31. Singh R, Bassi G, Singh DILBAG. Influence of sowing time and leaf cuttings on the seed yield and quality components of palak (*Beta vulgaris* var. *bengalensis*). Indian Journal of Agricultural Sciences. 2013;83(4):410-4.
32. Sharma PCD, Rahman MM, Mollah MAH, Islam MS. Influence of method and date of planting on the production of lettuce. Bangladesh Journal of Agricultural Research. 2009;34(1):75-80.
33. Singh AK, Singh H, Rai OP, Singh G, Singh VP, Singh NP, Singh R. Effect of sowing dates and varieties for higher productivity of Indian mustard (*Brassica juncea* L.). Journal of Applied and Natural Science. 2017;9(2):883-887.
34. Narayan Dr, Malik Ajaz A, Makhdoomi M, Nabi, Ambreen, Hussain, Kaniaw, Khan Dr. Influence of date of sowing and number of cuttings on leaf yield and quality of seed in Palak (*Beta vulgaris* var. bangalensis). Experimental Agriculture. 2018;24. DOI:10.9734/JEAI/2018/42076.
35. Heyduck RF, Guldan SJ, Guzmán I. Effect of sowing date and harvest schedule on organic spinach grown during the winter in high tunnels. Hort Technology. 2019; 29(3):320-329.
36. Kaleri AH, Kaleri AA, Kaleri GA, Wahocho NA, Kaleri SH, Kaleri MK, Kaleri AA, Kaleri SH, Rajput SY. Effect of sowing dates on the growth and yield of lettuce (*Lactuca sativa* L.). International Journal of Information Research and Review. July 2016;03(07):2617-2619.
37. Sowmya PT, Naruka IS, Shaktawat RPS, Kushwah SSEffect of sowing dates and stage of pinching on growth, yield and quality of fenugreek (*Trigonellafoenum-graecum* L.). International Journal of Bio-resource and Stress Management. 2017;8(1):91-95.
38. Dinda NK, Ray M, Sarkar P. Effect of sowing date vis-a-vis variety of rapeseed and Mustard on growth, yield and aphid infestation in Gangetic plains of West Bengal. The Ecoscan. 2015; 9(1&2):21-24.
39. Ayub M, Nadeem MA, Tanveer A, Tahir M, Saqib MTY, Nawaz R. Effect of different sowing methods and times on the growth and yield of fennel *(Foeniculum vulgare* Mill.). Pak. J. Bot. 2008;40(1):259-264.
40. Razzaque MA, Talukder MR, Uddin S, Khan SI, Hossain A. Response of late sowing on the yield and yield contributing character of different varieties of mustard and rapeseed in coastal area of Barguna. Bangladesh Journal of Scientific and Industrial Research. 2007;42(4):441-448.
41. Moosavi SG, Seghatoleslami MJ, Ansarinia E. Effect of sowing date and plant density on yield and yield components of fennel (*Foeniculum vulgare*). International Journal of Biosciences. 2015;6:334-342.
42. Aziz MA, Chakma R, Ahmed M, Rahman AKMM, Roy K. Effect of sowing dates on the growth, development and yield of mustard in the hilly areas. Journal of Experiment Bioscience. 2011;2(1):33-6.

43. Ghobadi ME, Ghobadi M. The effects of sowing dates and densities on yield and yield components of coriander (*Coriandrum sativum* L.). International Journal of Agricultural and Biosystems Engineering. 2010;4(10):725-728.
44. Sarkar RK, Jana JC, Datta S. Effect of different sowing times and spacings on growth, yield and quality of water spinach under terai region of West Bengal. Journal of Applied and Natural Science. 2014; 6(2):489-494.
45. Shirani RAD, AH, Bitarafan Z, Rahmani F, Taherkhani T, Aghdam AM, Nasresfahani S. Effects of planting date on spring rapeseed (*Brassica napus* L.) cultivars under different irrigation regimes. Turkish Journal of Field Crops. 2014;19(2):153-157.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/93170