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Effect of spacing and sowing dates on growth, yield and quality of pea (*Pisum sativum* L.)

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Abstract
The present investigation was conducted during 2022-2023 at DAV University, Jalandhar, to find out the effect of spacing and sowing dates on growth, yield and quality of pea (*Pisum sativum* L.). The experiment consisted of nine treatments which have three different sowing dates (5 November, 12 November and 19 November), spacing (20 cm×10 cm, 30 cm×10 cm and 40 cm×10 cm) and variety (Punjab-89) that is laid in RBD (Randomized block design) with three replications. It was observed that the plants grown in treatment T_1 (5 Nov, 20 cm×10 cm) resulted better in most of the growth, yield and quality parameters (50% flowering, number of branches per plant, number of leaves per plant, number of flowers per plant, plant height, leaf area, Chl-a and chl-b content, Total Chlorophyll content, Total starch content and total phenolic content. T_2 (5 November, 40 cm×10 cm) showed the best result in 50% germination, number of pods per plant and number of seeds per plant as well as, T_5 (12 November, 30 cm×10 cm) showed the best result in quality parameters (leaf area, total protein content, total flavonoid content and total phenolic content). T_8 (19 November, 40 cm×10 cm) showed the best result in total soluble solids. The economic analysis depicted the maximum gross income, net income and benefit-cost ratio from treatment T_1 (5 Nov, 20 cm×10 cm). So, we conclude that crop sown in 5 November with three different spacing (20 cm×10 cm, 30 cm×10 cm and 40 cm×10 cm) proved to be best in growth, yield and quality parameters.

Keywords: Pea, sowing dates, protein content, phenolic content, spacing, growth, benefit-cost ratio

Introduction

Pea (*Pisum sativum* L.) is a very common nutritious vegetable grown in the cool season throughout the world. The crop is grown for both green pods and mature seeds. Pods are slightly flavoured, sweet, crispy, lacking pod parchment (Chauhan *et al*., 2021) [16]. In India, it is mainly grown as winter vegetable in the plains of North India and as a summer vegetable in the hills. It is generally used as a fresh vegetable and in the firm of canned, processed or dehydrated. India is the largest producer and importer of the leguminous crops (Shakya *et al*., 2008) [108]. It is excellent food for human consumption, taken either as a vegetable or in soup. The immature seeds of green pods are generally used for this purposes. Besides, pea herbage when harvested just after picking of pods provides nutritious green fodder to farm animals (Temel *et al.*, 2020) [107].

Pea is a leguminous crop own a strategic position in Indian agriculture as it is an excellent source of dietary protein and a mini-nitrogen plant having ameliorative effect on soil. It helps in improving physical, chemical and biological properties of soil and also utilize natural resources in a better way (Kolb *et al*., 2017) [109]. Less inputs particularly the irrigation and fertilizer are needed in cultivation of pea. It improves soil fertility due to fixation of nitrogen by *Rhizobium leguminosarum*. Pea cultivars different in sensitivity to soil compaction, with a direct effect on the final depth explored by roots (Vocanson *et al*., 2006) [110].

Nutritionally, pea contains, 7.2 g, fats 0.1 g, minerals 0.8 g, carbohydrates 15.8 g, calcium 20 mg, magnesium 34 mg, copper 0.23 mg, iron 1.5 mg and vitamin C 9.0 mg/100 g of edible portion (Sepehya *et al*., 2015) [82]. Pulses, including peas, have long been important components of the human diet due to their content of starch, protein and other nutrients. More recently, the health benefits other than nutrition associated with pulse consumption have attracted much interest. The potential health benefits associated with the consumption of peas, specifically green and yellow cotyledon dry peas, also known as smooth peas or field peas. These health benefits derive mainly from the concentration and properties of starch, protein, fibre, vitamins, minerals and phytochemicals in peas (Ghosh *et al*., 2007) [11]. The intermediate amylose content of pea starch also contributes to its lower glycaemic index and reduced starch digestibility. Pea protein, when hydrolysed, may yield peptides with bioactivities, including angiotensin I-converting enzyme inhibitor activity and antioxidant activity (Ali *et al*., (2010) [112]. The vitamin and mineral contents of peas may play important roles in the prevention of deficiency-related diseases, specifically those related to deficiencies of Se or folate. These include polyphenolics, in coloured seed coat types in particular, which may have antioxidant and anti-carcinogenic activity, saponins which may exhibit hypocholesterolaemic and anti-carcinogenic activity, and galactose oligosaccharides which may exert beneficial prebiotic effects in the large intestine (Dahl *et al.*, 2012) [18].

In 2020-21, China mainland produced 11,250,366 tonnes of green peas. India is the second-largest producer of green pea. Pea occupies an area of 540 thousand hectares with the production of 5427 thousand tonnes grain in India (Anonymous, 2017). Uttar Pradesh is the major pea growing state. It alone produces about 49% of pea produced in India. Besides, Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra are the major pea producing states (Masood *et al*., 2014) [113]. In Himachal Pradesh, the total area under pea cultivation is around 23.65(‘000) ha, annual production is 277.20 (‘000) MT and average productivity is 11.72 MT/ha (Kaur *et al.*, 2019) [119] However, due to the invention of modern agriculture production and storage technique, there is an opportunity for providing a variety of vegetables in main and off- season as well. In this regard, two option can be considered (Shaukat *et al*., 2012) [85]. First to store vegetable under an artificially created environment while the second would be to grow them off-season. The off-season vegetable productions would change the food habits of consumers and increase the annual profit of farmers as well. However this can only be possible by creating awareness amongst vegetable growers. The production of vegetables all around the year enables the growers to fully utilize their resources and supplement income from vegetable growing as compared to others normal agricultural crops (Zhihao *et al*., 2000) [115].

In vegetable pea, cultivars of different maturity group *viz*. early, mid-season and late maturity are available for cultivation. The early varieties are now a days getting a more population because of better economic returns from them. It is not that they yield more but the initial price fetched makes them highly suitable for commercial cultivation. When vegetable pea is grown for green pods, it takes only 65-95 days according to the variety and sowing time. Short duration variety like Arkel when sown early in the season takes only 65-70 days. Thus, crop is very much suitable in a high intensity cropping sequence. Keeping this view the work was done to study the effect of spacing and sowing date on growth, yield and quality of pea (*Pisum sativum*)

Materials and Methods

A field experiment was carried out during the *rabi* season of the year 2022-2023 at the Experimental Farm of the Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar (Punjab), to study the effect of spacing and sowing dates on growth, yield and quality of pea (*Pisum sativum* L.). Geographically, the research farm is located at 75°56´99´´ East longitude and 31°33´00´´ North latitude, with an elevation altitude of 230 meters (754.5 feet).

a) **Plant material:** Plant material, *i.e.,* pea *cv.* Punjab-89 was procured from Agriculture University, Ludhiana, Punjab.
b) **Sowing dates:** Sowing dates was done on the following dates:

D1 5 November
D2 12 November
D3 19 November

c) **Row spacing:** Different row spacing were allotted to sub plots and considered as treatment. These spacing are arranged as follows:

S1 20 cm×10 cm
S2 30 cm×10 cm
S3 40 cm×10 cm

Experimental detail: The experiment was laid out in a randomized block design with three replications comprising twelve treatments represented in table 1, *viz.* T_1 (5 Nov, 20 cm×10 cm), T_2 (5 Nov, 30 cm×10 cm), T_3 (5 Nov, 40 cm×10 cm), T_4 (12 Nov, 20 cm×10 cm), T_5 (12 Nov, 30 cm×10 cm), T_6 (12 Nov, 40 cm×10 cm), T_7 (19 Nov, 20 cm×10 cm), T_8 (19Nov, 30 cm×10 cm) and T_9 (19 Nov, 40 cm×10 cm). The soil texture of the experiment field was sandy loam with a pH of 7.3-7.5. Pea variety used was Punjab-89. The land was brought to a fine tilth through ploughing and divided into 27 plots. The seed was sown at a three different spacing in a net area 250 m² on three different date of sowing. The plot size was 3m × 2m. The recommended dose of fertilizers was 20:60:40 kg/ha (N:P:K). Intercultural procedures such as weeding and hoeing were carried out, regular monitoring was done. All cultural operations were followed regularly during crop growth and observations were recorded.

Fig 1: Field picture of pea plants

Table 1: Treatment details

Sr. No.	Notation	Treatment combinations
1	T_1	5 Nov. + 20 cm×10 cm
2	T_2	5 Nov. + 30 cm×10 cm
3	T_3	5 Nov. + 40 cm×10 cm
4	T_4	12 Nov. + 20 cm×10 cm
5	T_5	12 Nov. + 30 cm×10 cm
6	T_6	12 Nov. + 40 cm×10 cm
7	T_7	19 Nov. + 20 cm×10 cm
8	T_8	19 Nov. + 30 cm×10 cm
9	T_9	19 Nov. + 40 cm×10 cm

Observation recorded

Growth parameters

Beginning the second week, following planting, morphological observations were taken at different stages. Five plants were randomly selected from each plot and tagged. All observations *viz*. days to 50% germination, days to 50% flowering, number of flowers per plant, plant height, number of leaves per plant, and leaf area were recorded from these plants.

Yield parameters

After 90 days of planting, yield measurements were taken from each treatment, excluding rows and plants. On the basis of net plot size, various observations *viz*. Pod weight, number of pods per plant, yield per plot, days to first harvest, yield per hectare and number of seeds per plant were recorded.

Quality parameters

Different quality parameters (*viz*. TSS, ascorbic acid, chlorophyll content, carotenoid content, protein content, starch content, phenolic content, flavonoid content, *etc*.) were measured.

Total soluble solids

Total soluble solids were recorded by using a digital hand refractometer (Erma, Japan Hand Refractometer 0-32°Brix). The TSS was determined and presented as an average (Saad *et al*., 2016) [116].

Pigment composition

The chlorophyll content of leaves was determined after sowing at 45 days. The observations were taken at 645 nm and 663 nm for chlorophyll content. The result were expressed in mg/g fresh weight of leaves and was calculated by the formula:

Total Chlorophyll (mg/g) tissue = 20.2(Abs645) + 8.02(Abs663)

Chlorophyll-a (mg/g) tissue = 12.7(Abs663) + 2.69(Abs645)

Chlorophyll-b (mg/g) tissue = 22.9(Abs645) - 4.68(Abs663)

The values from Arnon's1949 method of chlorophyll a and chlorophyll b were used to calculate the chlorophyll a/b ratio (Porra *et al*., 1989) [117].

The carotenoid content of leaves was determined after sowing at 45 days. The observations for carotenoids were taken at 480 nm and 510 nm (Kapoor *et al*. 2014) [118]. The result were expressed in mg/g fresh weight of leaves and were calculated by the formula:

Carotenoids (mg/g) tissue = 7.6(Abs480) - 1.49(Abs510)

Starch content (mg/g FW)

The presence of starch can be measured by its reaction with iodine. Starch and iodine form a darkblue complex with an absorbance maximum at 600 nm. The soluble starch powder was used as standard (Alcazar-Alay and Meireles, 2015) [119].

Protein content (mg/g FW)

The protein content was estimated as described by Sharma *et al*. (2011) [120]. The total protein content of leaves was determined by the method of Bradford (1976) [127] taking bovine serum albumin (BSA) as standard. The standard curve was plotted between different known concentrations of BSA and absorbance was recorded at 595 nm.

Non-enzymatic antioxidants

Total flavonoid content was determined by using Ardekani's method (Ardekani *et al*. 2011) [122]. Catechin was used as a standard and absorbance was recorded at 510 nm. The results were expressed as mg/g FW of Catechin eq. Total phenolic content was analyzed by using Singleton's method (Singleton *et al*. 1999) [123]. Gallic acid was used as a standard and absorbance was recorded at 650 nm. Total phenolic content was represented as mg/g FW of Gallic acid eq. Ascorbic acid was determined using the 2, 6 dichlorophenolindophenol titration method.

Statistical analysis

The data collected was subjected to Analysis of Variance (ANOVA) in RBD with Fisher's test to find the critical difference (CD) among different treatment means using OPSTAT to check the significant differences among treatments at $p \leq 0.05$.

Yield economics

Economic components of different treatments were worked out under the following subheadings.

Cost of cultivation (Rs./ha)

Cost of cultivation of different treatments was calculated by considering all the expenses incurred in the cultivation of experimental crop and added with common cost due to various operations and inputs used. Accordingly, cost of cultivation was calculated for each treatment combination.

Gross returns (Rs./ha)

Gross returns was calculated by multiplying total pea yield separately under various treatment combinations with their existing market price (Verma *et al*. 2011) [124].

Net returns (Rs./ha)

Net return was calculated by deducting the cost of cultivation from the gross return of the individual treatment combination (Umesh *et al*. 2014) [125].

Net return = Gross return - Cost of cultivation

Benefit-cost ratio (B:C)

The benefit-cost ratio was calculated by dividing the net return by the cost of cultivation of the individual treatment combination (Mohammadi *et al*. 2008) [128].

Benefit-cost ratio = Net returns / Cost of cultivation

Results

The observations were recorded on various growth, yield, and quality parameters and were significantly influenced by different treatments.

Growth parameters

The effect of spacing and sowing dates on various growth parameters *viz*, days to 50% germination, days to 50% flowering, number of flowers per plant, plant height (cm), number of branches per plant, number of leaves per plant, pod length (cm) and leaf area (cm).

Days to 50% germination

The data recorded on days to 50% germination as influenced by spacing and sowing dates have been presented in table 2. The maximum number of days to 50% germination was observed in T_1 (5 Nov, 20 cm×10 cm) (86.567 days) which was statistically at par with T_6 (12 Nov, 40 cm×10 cm) (78.043 days), T_4 (12 Nov, 20 cm×10 cm) (80.490 days) and T_3 (5 Nov, 40 cm×10 cm) (84.490 days). The minimum number of days to 50% germination was observed in T_9 (19 Nov, 40 cm×10 cm) (70.337 days) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (72.443 days), T_5 (12 Nov, 30 cm×10 cm) (74.343 days), T_6 (12 Nov, 40 cm×10 cm) (78.043 days), T_7 (19 Nov, 20 cm×10 cm) (73.547 days), T_8 (19 Nov, 30 cm×10 cm) (74.657 days) and T_9 (19 Nov, 40 cm×10 cm) (70.337 days).

Days to 50% flowering

The data recorded on days to 50% flowering are influenced by spacing and sowing dates have been presented in table 2. The maximum days of 50% flowering was observed in T_1 (5 Nov, 20 cm×10 cm) (84.033 days) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (79.373 days) and T_5 (12 Nov, 30 cm×10 cm) (78.747 days). The minimum number of days to 50% flowering was observed in T_7 (19 Nov, 20 cm×10 cm) (71.600 days) which was statistically at par with T_3 (5 Nov, 40 cm×10 cm) (74.887 days), T_4 (12 Nov, 20 cm×10 cm) (73.267 days), T_5 (12 Nov, 30 cm×10 cm) (78.747 days), T_6 (12 Nov, 40 cm×10 cm) (74.453 days), T_7 (19 Nov, 20 cm×10 cm) (71.600 days), T_8 (19 Nov, 30 cm×10 cm) (73.313 days) and T_9 (19 Nov, 40 cm×10 cm) (72.677 days).

Plant height (cm)

The data recorded on plant height are influenced by spacing and sowing dates have been presented in table 2. The maximum plant height was observed in T_1 (5 Nov, 20 cm×10 cm) (121.133 cm). The minimum plant height was observed in T_9 (19 Nov, 40 cm×10 cm) (85.600 cm) which was statistically at par with T_8 (19 Nov, 30 cm×10 cm) (88.167 cm), T_6 (12 Nov, 40 cm×10 cm) (90.600 cm) and T_2 (5 Nov, 30 cm×10 cm) (91.467 cm).

Number of flowers per plant

The data recorded on number of flowers per plant are influenced by spacing and sowing dates have been presented in table 2. The maximum number of flowers per plant was observed in T_1 (5 Nov, 20 cm×10 cm) (37.867). The minimum number of flowers per plant was observed in T_2 (5 Nov, 30 cm×10 cm) (21.567) which was statistically at par with T_9 (19 Nov, 40 cm×10 cm) (21.867).

Number of branches per plant

The data recorded on number of branches per plant are influenced by spacing and sowing dates have been presented in table 2. The maximum number of branches was observed in T_1 (5 Nov, 20 cm 10 cm) (14.867) which was statistically at par with T_2 (5 Nov, 30 cm 10 cm) (13.267) and T_3 (5 Nov, 40 cm 10 cm) (13.800). The minimum number of branches was observed in T_8 (19 Nov, 30 cm 10 cm) (10.467) which was statistically at par with T_5 (12 Nov, 30 cm 10 cm) (10.933), T_6 (12 Nov, 40 cm 10 cm) (11.533) and T_9 (19 Nov, 40 cm 10 cm) (12.000).

Number of leaves per plant

The data recorded on number of leaves per plant are influenced by spacing and sowing dates have been presented in table in 2. The maximum number of leaves per plant was observed in T_1 (5 Nov, 20 cm 10 cm) (97.800) which was statistically at par with T_4 (12 Nov, 20 cm 10 cm) (89.600). The minimum number of leaves per plant was observed in T_2 (5 Nov, 30 cm 10 cm) (61.267) which was statistically at par with T_5 (12 Nov, 30 cm 10 cm) (71.467).

Pod length (cm)

The data recorded on pod length are influenced by spacing and sowing dates have been presented in 2. The maximum pod length was observed in T_4 (12 Nov, 20 cm×10 cm) (49.113 cm). The minimum pod length was observed in T_7 (19 Nov, 20 cm×10 cm) (34.533 cm) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (38.400 cm), T_2 (5 Nov, 30 cm×10 cm) (37.600 cm), T_3 (5 Nov, 40 cm×10 cm) (38.700 cm), T_5 (12 Nov, 30 cm×10 cm) (37.460 cm), T_6 (12 Nov, 40 cm×10 cm) (38.000 cm), T_8 (19 Nov, 30 cm×10 cm) (36.343 cm) and T_9 (19 Nov, 40 cm×10 cm) (37.623 cm).

Leaf area (cm)

The data recorded on leaf area are influenced by spacing and sowing dates have been presented in table 2. The maximum leaf area was observed in T_3 (5 Nov, 40 cm×10 cm) (14.758 cm²) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (14.580 cm²), T_4 (12 Nov, 20 cm×10 cm) (13.445 cm²) and T_5 (12 Nov, 30 cm×10 cm) (14.229 cm²). The minimum leaf area was observed in T_6 (12 Nov, 40 cm×10 cm) (9.823 cm²) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (10.905 cm²) and T_9 (19 Nov, 40 cm×10 cm) (10.760 cm²).

Table 2: Effect of spacing and sowing dates on the growth attributes of pea

Notation	Days to 50% germination	Days to 50% flowering	No. of flowers per plant	No. of branches per plant	No. of leaves per plant	Pod length (cm)	Plant height (cm)	Leaf area (cm²)
T_1	86.567	84.033	37.867	14.867	97.800	38.400	121.133	14.580
T_2	72.443	79.373	21.467	13.267	61.267	37.600	91.467	10.905
T_3	84.490	74.887	23.600	13.800	78.000	38.700	99.000	14.758
T_4	80.073	73.267	33.533	13.067	89.600	49.113	101.133	13.445
T_5	74.343	78.747	28.400	10.933	71.467	37.460	94.467	14.229
T_6	78.043	74.453	24.133	11.533	78.400	38.000	90.600	9.823
T_7	73.547	71.600	25.400	12.800	80.533	34.533	101.400	12.675
T_8	74.657	73.313	25.600	10.467	73.933	36.343	88.167	12.805
T_9	70.337	72.677	21.867	12.000	75.667	37.623	85.600	10.760
SE (m)±	3.233	2.171	0.695	0.551	3.660	2.539	2.123	0.541
C.D @ 5%	9.775	6.566	2.102	1.666	11.066	7.676	6.423	1.637

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance and SE (m) ± Standard error of mean

Yield parameters
Pod weight (g)
The data recorded on pod weight are influenced by spacing and sowing dates have been presented in table 3. The maximum pod weight was observed in T_4 (12 Nov, 20 cm×10 cm) (6.427 g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (5.313 g), T_2 (5 Nov, 30 cm×10 cm) (5.420 g), T_3 (5 Nov, 40 cm×10 cm) (5.967 g), T_5 (12 Nov, 30 cm×10 cm) (5.480 g) and T_6 (12 Nov, 40 cm×10 cm) (5.240 g). The minimum pod weight was observed in T_8 (19 Nov, 30 cm×10 cm) (3.573 g) which was statistically at par with T_7 (19 Nov, 20 cm×10 cm) (4.020 g).

Number of pods per plant
The data recorded on number of pods per plant are influenced by spacing and sowing dates have been presented in table 3. The maximum number of pods per plant was observed in T_3 (5 Nov, 40 cm×10 cm) (56.833) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (52.533). The minimum number of pods per plant was observed in T_6 (12 Nov, 40 cm×10 cm) (31.333) which was statistically at par with T_7 (19 Nov, 20 cm×10 cm) (34.533), T_8 (19 Nov, 30 cm×10 cm) (33.500) and T_1 (5 Nov, 20 cm×10 cm) (39.233).

Yield per plot (kg)
The data recorded on yield per plot are influenced with spacing and sowing dates have been presented in table 3. The maximum yield per plot was observed in T_1 (5 Nov, 20 cm×10 cm) (2.912 kg) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (2.413 kg), T_3 (5 Nov, 40 cm×10 cm) (2.414 kg), T_6 (12 Nov, 40 cm×10 cm) (2.223 kg) and T_9 (19 Nov, 40 cm×10 cm) (2.21 5kg). The minimum yield per plot was observed in T_5 (12 Nov, 30 cm×10 cm) (91.491 kg) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (1.598 kg), T_7 (19 Nov, 20 cm×10 cm) (1.910 kg), T_8 (19 Nov, 30 cm×10 cm) (1.861 kg) and T_9 (19 Nov, 40 cm×10 cm) (2.21 5 kg).

Days to first harvest (days)
The data recorded on days to first harvesting are influenced with spacing and sowing dates have been presented in table 3. The maximum days to first harvest was observed in T_2 (5 Nov, 30 cm×10 cm) (118.000 days) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (117.000 days), T_4 (12 Nov, 20 cm×10 cm) (113.333 days), T_5 (12 Nov, 30 cm×10 cm) (116.000 days) and T_9 (19 Nov, 40 cm×10 cm) (117.333 days). The minimum days to first harvest was observed in T_4 (12 Nov, 20 cm×10 cm) (113.333 days) which was statistically at par with T_3 (5 Nov, 40 cm×10 cm) (114.667 days), T_6 (12 Nov, 40 cm×10 cm) (114.121 days), T_7 (19 Nov, 20 cm×10 cm) (114.000 days) and T_8 (19 Nov, 30 cm×10 cm) (114.642 days).

Table 3: Effect of spacing and sowing dates on the yield attributes of pea

Notation	Pod weight (g)	Number of pods per plant	Yield per plot (kg)	Days to first harvest	Yield per hectare (q/hac)	Number of seeds per plant
T_1	5.313	39.233	2.912	117.000	48.26	74.267
T_2	5.420	46.800	2.413	118.000	47.23	74.533
T_3	5.967	56.833	2.414	114.667	45.37	75.133
T_4	6.427	52.533	1.598	113.333	32.25	55.867
T_5	5.480	44.000	1.491	116.000	31.31	50.400
T_6	5.240	31.333	2.223	114.121	43.12	41.733
T_7	4.020	34.533	1.910	114.000	35.79	35.600
T_8	3.573	37.567	1.861	114.642	34.55	33.600
T_9	4.860	33.500	2.215	117.333	39.52	62.867
SE (m)±	0.424	2.650	0.245	0.760	1.408	2.147
C.D @ 5%	1.283	8.012	0.742	2.297	4.257	6.491

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance and SE (m) ± Standard error of mean

Yield per hectare (q/ha)
The data recorded on yield per hectare are influenced with spacing and sowing dates have been presented in table 3. The maximum yield per hectare was observed in T_1 (5 Nov, 20 cm×10 cm) (48.26 q/ha) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (47.23q/ha) and T_3 (5 Nov, 40 cm×10 cm) (45.37q/ha). The minimum yield per hectare was observed in T_5 (12 Nov, 30 cm×10 cm) (31.13q/ha) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (32.25 q/ha)) and T_8 (19 Nov, 30 cm×10 cm) (34.55 q/ha).

Number of seeds per plant
The data recorded on number of seeds per plant are influenced by spacing and sowing dates have been presented in table 3. The maximum number of seeds per plant was observed in T_3 (5 Nov, 40 cm×10 cm) (75.133) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) 974.267) and T_2 (5 Nov, 30 cm×10 cm) (74.533). The minimum number of seeds was observed in T_8 (19 Nov, 30 cm×10 cm) (33.600) which was statistically at par with T_7 (19 Nov, 20 cm×10 cm) (35.600).

Quality parameters
Total soluble solids (°Brix)
The data recoded on total soluble solids are influenced by spacing and sowing dates have been presented in table 4. The maximum total soluble solids was observed in T_8 (19 Nov, 30 cm×10 cm) (18.133 °B) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (16.590 °B), T_3 (5 Nov, 40 cm×10 cm) (17.667 °B), T_5 (12 Nov, 30 cm×10 cm) (16.893 °B) and T_9 (19 Nov, 40 cm×10 cm) (16.527 °B). The minimum total soluble solids was observed in T_6 (12 Nov, 40 cm×10 cm) (13.760 °B) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (15.347 °B).

Total chlorophyll content (mg/g)
The data recorded on total chlorophyll content (mg/g) are influenced by spacing and sowing dates have been presented in table 4. The maximum total chlorophyll content was observed in T_1 (5 Nov, 20 cm×10 cm) (0.124 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.120 mg/g). The minimum total chlorophyll content was observed in T_4 (12 Nov, 20 cm×10 cm) (0.76 mg/g).

Table 4: Effect of spacing and sowing dates on the quality attributes of pea

Notation	Total soluble solids (°B)	Total chlorophyll content (mg/g)	Total protein content (mg/g)	Total starch content (mg/g FW)	Total carotenoid content (mg/g)	Total flavonoid content (mg/g FW)	Total phenolic content (mg/g FW)	Total ascorbic content (mg/g FW)
T_1	16.590	0.124	0.126	0.063	0.034	7.522	0.554	0.136
T_2	15.347	0.120	0.156	0.059	0.035	6.788	0.488	0.109
T_3	17.667	0.109	0.130	0.059	0.021	8.751	0.447	0.132
T_4	15.667	0.076	0.116	0.061	0.019	10.203	0.379	0.115
T_5	16.893	0.098	0.175	0.058	0.021	12.854	0.326	0.125
T_6	13.760	0.108	0.133	0.059	0.021	8.168	0.312	0.108
T_7	15.627	0.095	0.127	0.057	0.031	11.250	0.318	0.119
T_8	18.133	0.113	0.159	0.058	0.032	7.637	0.248	0.139
T_9	16.527	0.114	0.149	0.059	0.034	6.663	0.221	0.142
SE (m)±	0.578	0.003	0.009	0.001	0.002	0.991	0.033	0.008
C.D @ 5%	1.747	0.008	0.026	0.003	0.006	2.995	0.099	0.024

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance and SE (m) ± Standard error of mean

Total protein content (mg/g)

The data recorded on total protein content are influenced with spacing and sowing dates have been presented in table 4. The maximum total protein content was observed in T_5 (12 Nov, 30 cm×10 cm) (0.175 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.156 mg/g), T_8 (19 Nov, 30 cm×10 cm) (0.159 mg/g) and T_9 (19 Nov, 40 cm×10 cm) (0.149 mg/g). The minimum total protein content was observed in T_4 (12 Nov, 20 cm×10 cm) (0.116 mg/g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (0.126 mg/g), T_3 (5 Nov, 40 cm×10 cm) (0.130 mg/g), T_6 (12 Nov, 40 cm×10 cm) (0.133 mg/g) and T_7 (19 Nov, 20 cm×10 cm) (0.127 mg/g).

Total starch content (mg/g FW)

The data recorded on total starch content are influenced by spacing and sowing date have been presented in 4. The maximum starch content was observed in T_1 (5 Nov, 20 cm×10 cm) (0.063 mg/g) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (0.061 mg/g). The minimum starch content was observed in T_5 (12 Nov, 30 cm×10 cm) (0.058 mg/g), T_8 (19 Nov, 30 cm×10 cm) (0.058 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.059 mg/g), T_3 (5 Nov, 40 cm×10 cm) (0.059 mg/g), T_4 (12 Nov, 20 cm×10 cm) (0.061 mg/g), T_6 (12 Nov, 40 cm×10 cm) (0.059 mg/g) and T_9 (19 Nov, 40 cm×10 cm) (0.059 mg/g).

Total carotenoid content (mg/g)

The data recorded on carotenoid content are influenced by spacing and sowing date have been presented in table 4. The maximum carotenoid content was observed in T_2 (5 Nov, 30 cm×10 cm) (0.035 mg/g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (0.034 mg/g), T_7 (19 Nov, 20 cm×10 cm) (0.031 mg/g), T_8 (19 Nov, 30 cm×10 cm) (0.032 mg/g) and T_9 (19 Nov, 40 cm×10 cm) (0.034 mg/g). The minimum carotenoid content was observed in T_4 (12 Nov, 20 cm×10 cm) (0.019 mg/g) which was statistically at par with T_3 (5 Nov, 40 cm×10 cm) (0.021 mg/g), T_5 (12 Nov, 30 cm×10 cm) (0.021 mg/g) and T_6 (12 Nov, 40 cm×10 cm) (0.021 mg/g).

Total flavonoid content (mg/g FW)

The data recorded on total flavonoid content are influenced by spacing and sowing dates have been presented in table 4. The maximum total flavonoid content was observed in T_5 (12 Nov, 30 cm×10 cm) (12.854 mg/g) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (10.203 mg/g) and T_7 (19 Nov, 20 cm×10 cm) (11.250 mg/g). The minimum total flavonoid content was observed in T_9 (19 Nov, 40 cm×10 cm) (6.663 mg/g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (7.522 mg/g), T_2 (5 Nov, 30 cm×10 cm) (6.788 mg/g), T_3 (5 Nov, 40 cm×10 cm) (8.751 mg/g), T_6 (12 Nov, 40 cm×10 cm) (8.168 mg/g) and T_8 (19 Nov, 30 cm×10 cm) (7.637 mg/g).

Total phenolic content (mg/g FW)

The data recorded on total phenolic content are influenced by spacing and sowing dates have been presented in table 4. The maximum phenolic content was observed in T_1 (5 Nov, 20 cm×10 cm) (0.554 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.488 mg/g). The minimum phenolic content was observed in T_9 (19 Nov, 40 cm×10 cm) (0.221 mg/g) which was statistically at par with T_6 (12 Nov, 40 cm×10 cm) (0.312 mg/g), T_7 (19 Nov, 20 cm×10 cm) (0.318 mg/g) and T_8 (19 Nov, 30 cm×10 cm) (0.248 mg/g).

Total ascorbic content (mg/g FW)

The data recorded on total ascorbic acid content are influenced by spacing and sowing dates have been presented in table 4. The maximum ascorbic content was observed in T_9 (19 Nov, 40 cm×10 cm) (0.142 mg/g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (0.136 mg/g), T_3 (5 Nov, 40 cm×10 cm) (0.132 mg/g), T_5 (12 Nov, 30 cm×10 cm) (0.125 mg/g), T_7 (19 Nov, 20 cm×10 cm) (0.119 mg/g) and T_8 (19 Nov, 30 cm×10 cm) (0.139 mg/g). The minimum ascorbic content was observed in T_6 (12 Nov, 40 cm×10 cm) (0.108 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.109 mg/g), T_3 (5 Nov, 40 cm×10 cm) (0.132 mg/g) and T_5 (12 Nov, 30 cm×10 cm) (0.125 mg/g).

Yield economics

The data obtained on the yield economics of pea are influenced by spacing and sowing dates have been presented in table 5. The gross income (148986 Rs. /ha), net return (84474 Rs. /ha) and benefit-cost ratio (B:C ratio) (1:30) were observed maximum in the treatment T_1 (5 Nov, 20 cm 10 cm) which was significantly higher than all the treatments. Whereas, the minimum gross return (120213 Rs. /ha), net return (55701 Rs./ha) and benefit-cost ratio (0:86) which was significantly lower than all the treatments.

Table 5: Effect of spacing and sowing dates on the yield economics of pea

Notation	Cost of cultivation (Rs. /ha)	Gross return (Rs. /ha)	Net return (Rs. /ha)	B:C ratio
T_1	64512	148986	84474	1:30
T_2	64512	141743	77231	1:19
T_3	64512	142712	78200	1:21
T_4	64512	131293	66781	1:03
T_5	64512	147432	82920	1:28
T_6	64512	142537	78025	1:20
T_7	64512	133643	69131	1:07
T_8	64512	122331	57819	0:89
T_9	64512	120213	55701	0:86

Discussion

Proper spacing of pea plants can significantly influence their growth and yield. When pea plants are spaced appropriately, they have access to sufficient sunlight, water, and nutrients, leading to better development and higher yields. Adequate spacing also helps reduce competition among plants and minimizes the risk of disease spread. However, if plants are spaced too far apart, it might lead to underutilization of the growing area and lower overall yield (Saha, *et al*., 2012) [127].

The sowing date directly influences the growth and yield of pea crops. Peas are cool-season crops, and their optimal growth occurs in cooler temperatures. Sowing too early or too late in the season can result in reduced germination, poor growth, and decreased yield. Early sowing may expose the young seedlings to frost damage, while late sowing might expose the plants to heat stress during their crucial growth stages and also effect the yield of the crop (Sarker, *et al*., 2014) [128].

In the present study, the effect of spacing and sowing dates on growth, yield and quality of pea were evaluated, further, it was found that the proper spacing and sowing date significantly improved the growth, yield and quality of pea. The results of the present findings are discussed in subsequent sections and are supported by the findings of some research studies.

Growth parameters

Proper spacing allows each plant to receive sufficient sunlight, nutrients, and water, leading to better germination and healthier plants. If the plants are too close together, they may compete for resources, leading to reduced germination rates. Pea plants prefer cooler temperatures and may struggle to germinate or develop properly in extremely hot or cold conditions. The ideal sowing date for pea germination varies depending on the climate and region. The maximum number of days to 50% germination was observed in T_1 (5 Nov, 20 cm×10 cm) (86.567 days) which was statistically at par with T_6 (12 Nov, 40 cm×10 cm) (78.043 days), T_4 (12 Nov, 20 cm×10 cm) (80.490 days) and T_3 (5 Nov, 40 cm×10 cm) (84.490 days). Similar observation was recorded by Hartley, *et al.*, 1998 [39] the spacing between pea plants can influence their germination rate and overall growth. Proper spacing allows each plant to receive sufficient sunlight, nutrients, and water, leading to better germination and healthier plants. If the plants are too close together, they may compete for resources, leading to reduced germination rates. Pea plants prefer cooler temperatures and may struggle to germinate or develop properly in extremely hot or cold conditions. The maximum days of 50% flowering was observed in T_1 (5 Nov, 20 cm×10 cm) (84.033 days) which was statistically at par with T_7 (5 Nov, 30 cm×10 cm) (79.373 days) and T_5 (12 Nov, 30 cm×10 cm) (78.747 days). Similar observation was recorded by Gao *et al.*, (2017) [33] the effect of different plant densities (spacing) on the flowering of peas. They found that wider spacing between plants (30 cm apart) resulted in higher numbers of flowers per plant and increased overall flowering compared to closer spacing (15 cm apart). The effect of early sowing (late winter to early spring) led to earlier flowering, while late sowing (late spring to early summer) resulted in delayed flowering. The researchers noted that the ideal sowing time for maximum flowering was during the cool-season months when temperatures were moderate (Djalovic, 2014) [24].

The maximum number of flowers per plant was observed in T_1 (5 Nov, 20 cm×10 cm) (37.867). Similar observations was recorded by Hickey *et al.*, (2019) [41] the spacing between pea plants can affect the number of flowers per plant. Generally, wider spacing allows more access to sunlight and air circulation, leading to better plant growth and potentially more flowers. However, excessively wide spacing may result in lower plant density and reduced overall yield. Optimal spacing may vary depending on the specific cultivar and local conditions. Peas are cool-season crops, and their growth and flowering are influenced by temperature and day length. In general, peas prefer cool temperatures (around 15-20 °C) for optimal growth and flower production. Sowing too early or too late in the season may result in unfavourable temperatures, leading to reduced flower formation (Sarker, *et al*., 2006) [79].

The maximum plant height was observed in T_1 (5 Nov, 20 cm×10 cm) (121.133 cm). Similar observation was recorded by Tullu, *et al*., (2016) [99] the impact of different sowing dates (early, normal, and late) and spacing (30 cm × 10 cm and 40 cm × 10 cm) on growth, yield, and yield attributes of pea. The results showed that plants sown early had taller plant height compared to those sown late. Furthermore, wider spacing (40 cm × 10 cm) resulted in taller plants than closer spacing (30 cm × 10 cm). Pande, *et al.*, (2017) [65] assessed the effect of different sowing dates (15th October, 30th October, and 15th November) on growth and yield attributes of garden pea in a temperate region. It found that plants sown earlier (15th October) had taller plant height compared to those sown later (30th October and 15th November. Verma, *et al.*, (1998) [101] examined the influence of different spacing (15 cm × 10 cm, 20 cm × 10 cm, 25 cm × 10 cm, and 30 cm × 10 cm) on the growth, yield, and quality of pea. It is reported that wider spacing (30 cm × 10 cm) resulted in taller plants compared to narrower spacing. However, the study did not specifically focus on sowing dates.

The maximum number of branches was observed in T_1 (5 Nov, 20 cm 10 cm) (14.867) which was statistically at par with T_2 (5 Nov, 30 cm 10 cm) (13.267) and T_3 (5 Nov, 40 cm 10 cm) (13.800).

Similar observation was recorded by Jha, SK., *et al.*, (2018) [46] the spacing between pea plants can affect the number of branches per plant. Generally, wider spacing allows plants to have more space for lateral branching, resulting in a higher number of branches per plant. However, very wide spacing may lead to excessive branching and competition for resources, which can negatively affect branch development. Sowing dates influence the growth and development of pea plants, including branch formation. Pea plants sown earlier in the season may have a longer vegetative phase, allowing more time for branch development. Late sowing dates may result in shorter vegetative phases, limiting branch formation (Doraiswamy, *et al.*, (2001) [25]. The maximum number of leaves per plant was observed in T_1 (5 Nov, 20 cm 10 cm) (97.800) which was statistically at par with T_4 (12 Nov, 20 cm 10 cm) (89.600). Similar observation was reported by Hossain *et al.*, (2019) [130] the effect of different row spacing on yield components of field pea. They found that wider row spacing (e.g., 30 cm) resulted in increased leaf area index and leaf number per plant compared to narrower spacing (e.g., 15 cm). The effect of sowing dates on growth and yield of pea cultivars. They observed that early sowing dates resulted in more vegetative growth and increased leaf area per plant. Late sowing dates, on the other hand, led to reduced leaf area and a decrease in the number of leaves per plant (Jha *et al*., 2015) [129].

The maximum pod length was observed in T_4 (12 Nov, 20 cm×10 cm) (49.113 cm). Similar observation was reported by Ertek, *et al.*, (2014) [30] the effects of different row spacings on the yield and yield components of pea cultivars. It found that wider row spacings (60 cm and 75 cm) resulted in longer pod lengths compared to narrower row spacings (45 cm and 30 cm). It found that wider row spacings (30 cm and 40 cm) resulted in longer pod lengths compared to narrower row spacings (20 cm and 10 cm). Studies have shown that sowing date can influence pod length in peas. In general, early sowing tends to result in longer pods compared to late sowing. This is likely because early-sown plants have a longer growing season and more favorable temperature and light conditions for pod development. Similarly, late sowing may expose plants to higher temperatures during critical stages of pod development, leading to shorter pods (Asadi, *et al.*, (2019) [2].

The maximum leaf area was observed in T_3 (5 Nov, 40 cm×10 cm) (14.758 cm²) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (14.580 cm²), T_4 (12 Nov, 20 cm×10 cm) (13.445 cm²) and T_5 (12 Nov, 30 cm×10 cm) (14.229 cm²). Similar observation was recorded by Mukhopadhyay, *et al.*, (2011) [60] the impact of different plant spacing (15 cm×10 cm, 15 cm × 20 cm, and 15 cm × 30 cm) on the growth and yield of pea plants. The researchers found that wider spacing (15 cm × 30 cm) significantly increased the leaf area compared to narrower spacing. However, the highest yield was obtained with a spacing of 15 cm × 20 cm. The impact of different sowing dates on various growth parameters, including leaf area, in different pea varieties. Akbar *et al.*, 2018 [1] found that early sowing dates significantly increased leaf area compared to later sowing dates. The effect of sowing dates on growth and yield of pea varieties in Nepal. They observed that early sowing dates resulted in higher leaf area compared to late sowing, which positively influenced the overall growth and yield of the crop (Shrestha *et al.*, 2021) [86].

Yield parameters

The maximum pod weight was observed in T_4 (12 Nov, 20 cm×10 cm) (6.427 g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (5.313 g), T_2 (5 Nov, 30 cm×10 cm) (5.420 g), T_3 (5 Nov, 40 cm×10 cm) (5.967 g), T_5 (12 Nov, 30 cm×10 cm) (5.480 g) and T_6 (12 Nov, 40 cm×10 cm) (5.240 g). Similar observation was recorded by Prasad, *et al.*, (2012) on the effect of different row spacings on the green pod yield and its attributes of pea cultivars. The impact of row spacing and seed rate on the growth and yield attributes of pea. The results indicated that wider row spacing (45 cm) led to increased pod weights compared to narrower row spacing (30 cm). Khan, *et al.*, (2018) [55] investigated the influence of different sowing dates on the growth and yield of peas. It found that early sowing dates resulted in higher pod weight and overall yield compared to late sowing dates (Raza, *et al.*, 2018) [72].

The maximum number of pods per plant was observed in T_3 (5 Nov, 40 cm×10 cm) (56.833) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (52.533). Similar observation was reported by Efe, *et al.*, (2009) [43] on the impact of different spacing intervals (15 cm, 20 cm, and 25 cm) on growth and yield components of field pea. The results showed that wider spacing (25 cm) resulted in higher pod numbers per plant compared to narrower spacing (15 cm), indicating that wider spacing can promote better pod development. The effect of different sowing dates on the growth, yield, and quality of pea cultivars. It provides insights into the relationship between sowing dates and the number of pods per plant (Khan, M. J., *et al*., 2015) [54]. The influence of sowing dates on the yield and yield components of field pea cultivars. It investigates the impact on variables such as the number of pods per plant (Goshadrou, *et al*., 2018) [35].

The spacing between plants in agricultural practices can significantly affect the yield per plot of peas. Proper spacing allows for efficient utilization of resources such as sunlight, water, and nutrients, leading to optimal growth and productivity. The maximum yield per plot was observed in T_1 (5 Nov, 20 cm×10 cm) (2.912 kg) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (2.413 kg), T_3 (5 Nov, 40 cm×10 cm) (2.414 kg), T_6 (12 Nov, 40 cm×10 cm) (2.223 kg) and T_9 (19 Nov, 40 cm×10 cm) (2.215 kg). Similar observation was reported by Tindall, T. A., *et al.*, (1990) [98] on the impact of row spacing on field pea growth, yield, and yield components. It provides insights into the optimum spacing for maximizing pea yield per plot. Rodrigues, *et al.*, (2015) [74] examines the impact of different sowing dates on the agronomic performance of different pea cultivars. It analyses factors such as yield, plant height, number of pods per plant, and seed weight.

The maximum days to first harvest was observed in T_2 (5 Nov, 30 cm×10 cm) (118.000 days) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (117.000 days), T_4 (12 Nov, 20 cm×10 cm) (113.333 days), T_5 (12 Nov, 30 cm×10 cm) (116.000 days) and T_9 (19 Nov, 40 cm×10 cm) (117.333 days). Similar observation was reported by Hatzig *et al*., (2015) [40] on the effect of different plant densities (spacing) on the growth and yield of field peas found that wider spacing resulted in earlier harvest dates due to improved light interception and reduced competition among plants. The effect of sowing dates on the phenology and yield of pea cultivars observed that early sowing dates resulted in earlier harvest, while late sowings delayed the time to first harvest. This is because early sown plants can take advantage of cooler spring temperatures and longer growing seasons (Nielsen *et al*., (2013) [63].

The maximum yield per hectare was observed in T_1 (5 Nov, 20 cm×10 cm) (48.26 q/hac) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (47.23 q/hac) and T_3 (5 Nov, 40 cm×10 cm) (45.37q/hac). Similar observation was reported by Choudhury, *et al.*, (2014) [17], Sarker, A., *et al.*, (2015) [80] on the spacing between pea plants which can influence their growth, development, and overall yield. Adequate spacing allows each plant to receive sufficient sunlight, nutrients, and air circulation, which can positively impact yield. The sowing date of peas can significantly affect their growth, flowering, and fruiting, ultimately impacting the yield per hectare. Optimal sowing dates vary based on the local climatic conditions and the specific pea variety being grown (Shrestha, *et al.*, (2017) [131].

The maximum number of seeds per plant was observed in T_3 (5 Nov, 40 cm×10 cm) (75.133 g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (74.267 g) and T_2 (5 Nov, 30 cm×10 cm) (74.533 g). Similar observation was observed by Gupta *et al*., (2019) [37] the influence of different plant spacing and sowing dates on the yield and yield components of pea. It found that wider spacing (e.g., 45 cm × 15 cm) resulted in a higher number of seeds per plant compared to closer spacing (e.g., 30 cm × 10 cm). Additionally, early sowing (around mid-October) led to a higher number of seeds per plant compared to late sowing (mid-November). It reported that wider spacing (e.g., 45 cm × 15 cm) resulted in a higher number of seeds per plant compared to closer spacing (e.g., 30 cm × 15 cm). Furthermore, early sowing (mid-October) led to a higher number of seeds per plant compared to late sowing (mid-November) (Ali *et al.*, (2014) [5-6].

Quality parameters

The maximum total soluble solids was observed in T_8 (19 Nov, 30 cm×10 cm) (18.133 °B) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (16.590 °B), T_3 (5 Nov, 40 cm×10 cm) (17.667 °B), T_5 (12 Nov, 30 cm×10 cm) (16.893 °B) and T_9 (19 Nov, 40 cm×10 cm) (16.527 °B). Similar observation was reported by Xie, *et al*., (2009) [104] on the effect of plant spacing on sugar content in snap peas. The research found that wider spacing between plants resulted in higher sugar accumulation in the pods. Temperature during the growing season, which can vary depending on the sowing date, plays a crucial role in determining the TSS content of peas. The effect of temperature on the TSS of peas and found that moderate temperature conditions during the sowing period favoured higher TSS accumulation. The duration of daylight, known as photoperiod, also influences TSS accumulation in peas (Silva *et al*., 2019) [89]. (Cai *et al*., 2020) [14] examined the impact of photoperiod on TSS in pea pods and observed that longer daylight exposure resulted in increased TSS levels.

The maximum total chlorophyll content was observed in T_1 (5 Nov, 20 cm×10 cm) (0.124 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.120 mg/g). Similar observation was reported by Sultana. *et al.*, (2016) [96], (Rahman, 2019) [69] on proper spacing between pea plants which can influence the availability of light, air circulation, and nutrient uptake, which in turn affects the chlorophyll content. However, studies have shown that wider spacing generally promotes better chlorophyll accumulation in pea plants by reducing competition for resources. The timing of pea sowing can affect the chlorophyll content due to variations in temperature and photoperiod. Pea plants generally exhibit optimal chlorophyll production under cool weather conditions. Early sowing can result in higher chlorophyll content, as the plants experience favorable temperatures during their growth and development stages (Das, *et al*., 2017) [19], (Gholipoor, *et al*., 2018) [34].

In agricultural practices, spacing refers to the distance maintained between individual plants within a field. The maximum total protein content was observed in T_5 (12 Nov, 30 cm×10 cm) (0.175 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.156 mg/g), T_8 (19 Nov, 30 cm×10 cm) (0.159 mg/g) and T_9 (19 Nov, 40 cm×10 cm) (0.149 mg/g). Similar observation was reported by Saha, *et al.*, (2012) [129] on proper spacing allows plants to receive adequate sunlight, nutrients, and water, which can affect their overall growth and development, including protein synthesis. The overcrowding or inadequate spacing can lead to competition among plants for resources, resulting in reduced yields and potentially affecting the nutritional composition of crops. In the case of peas, inadequate spacing may lead to decreased protein content due to limited access to essential nutrients and sunlight (Jafari, *et al.*, 2020) [45]. The effect of different sowing dates on the protein content of field peas. The researchers found that early sowing dates resulted in higher protein content, while late sowing dates led to decreased protein content.

The maximum starch content was observed in T_1 (5 Nov, 20 cm×10 cm) (0.063 mg/g) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (0.061 mg/g). Similar observation was reported by Werf *et al*., (2008) [100] on the effect of spacing on faba beans (a close relative of peas) which demonstrated that wider plant spacing can result in higher yields per plant due to reduced competition for resources like water, light, and nutrients. Increased yields could potentially lead to increased starch accumulation, although this relationship may not always be linear. The effect of sowing dates on starch accumulation in pea seeds was examined. The research indicated that early sowing dates resulted in higher starch content compared to late sowing. The study also found that the variation in starch content was associated with changes in temperature during different stages of seed development (Kamal *et al*., 2017) [48].

The maximum carotenoid content was observed in T_2 (5 Nov, 30 cm×10 cm) (0.035 mg/g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (0.034 mg/g), T_7 (19 Nov, 20 cm×10 cm) (0.031 mg/g), T_8 (19 Nov, 30 cm×10 cm) (0.032 mg/g) and T_9 (19 Nov, 40 cm×10 cm) (0.034 mg/g). Similar observation was reported by Bhatt, *et al.*, (2010) on the impact of plant spacing on pea growth and yield. While the focus was not specifically on carotenoid content, it was observed that wider spacing resulted in improved yield and quality attributes, which could indirectly influence carotenoid levels. Temperature fluctuations associated with different sowing dates can influence carotenoid biosynthesis in peas. However, extremely high temperatures during pod development may negatively affect carotenoid content. Day length variations associated with sowing dates can affect carotenoid accumulation in peas. Shorter days during certain sowing periods can influence the timing and extent of carotenoid synthesis (Erdal *et al*., 2017) [29].

The maximum total flavonoid content was observed in T_5 (12 Nov, 30 cm×10 cm) (12.854 mg/g) which was statistically at par with T_4 (12 Nov, 20 cm×10 cm) (10.203 mg/g) and T_7 (19 Nov, 20 cm×10 cm) (11.250 mg/g). Similar observation was reported by Sharma, *et al.*, (2017) on the wider plant spacing which can lead to increased light penetration and better airflow within the canopy, which may enhance photosynthesis and improve the overall growth of plants. (Bell, *et al.*, 2015) [11] examined the influence of growth conditions, including sowing dates, on the accumulation of bioactive compounds, including flavonoids, in pea plants. The results indicated that sowing dates affected the flavonoid content, with earlier sowing dates associated with higher levels of flavonoids.

The maximum phenolic content was observed in T_1 (5 Nov, 20 cm×10 cm) (0.554 mg/g) which was statistically at par with T_2 (5 Nov, 30 cm×10 cm) (0.488 mg/g). Similar observation was reported by Mauromicale, *et al.*, (2006) [57] on the influence of plant density on growth and yield. Since plant spacing can affect overall plant growth and development, it indirectly impacts the synthesis of phenolic compounds. The effect of sowing date and climatic conditions on the phenolic compound concentrations in seeds of different pea genotypes. The results showed that the sowing date significantly influenced the phenolic compound concentrations. Early sowing dates were associated with higher phenolic compound concentrations compared to late sowing dates. The study concluded that sowing date can be manipulated to enhance the phenolic content of pea seeds (Dastmalchi, *et al.*, 2015) [21].

The maximum ascorbic content was observed in T_9 (19 Nov, 40 cm×10 cm) (0.142 mg/g) which was statistically at par with T_1 (5 Nov, 20 cm×10 cm) (0.136 mg/g), T_3 (5 Nov, 40 cm×10 cm) (0.132 mg/g), T_5 (12 Nov, 30 cm×10 cm) (0.125 mg/g), T_7 (19 Nov, 20 cm×10 cm) (0.119 mg/g) and T_8 (19 Nov, 30 cm×10 cm) (0.139 mg/g). Similar observation was reported by Reddy, *et al*., (2016) [73] on the wider spacing between pea plants which resulted in larger plant canopies and higher yields. If pea plants are too closely spaced, they may compete for essential resources like sunlight, water, and nutrients. This competition can lead to reduced growth and development of individual plants, which might result in lower overall production of peas and, consequently, lower total ascorbic acid content. The impact of sowing dates on the nutrient content, including vitamin C, and yield of peas. The results indicated that vitamin C content was affected by the sowing date, with early sowing leading to higher vitamin C levels (Karimizadeh, *et al*. 2012) [43].

Benefit and cost ratio (B:C)

The gross income (148986 Rs. /ha), net return (84474 Rs. /ha) and benefit-cost ratio (B:C ratio) (1:30) were observed maximum in the treatment T_1 (5 Nov, 20 cm 10 cm) which was significantly higher than all the treatments. Similar observation was reported by Sawhney, *et al*., (2008) [81} on adequate spacing which allows each pea plant to receive sufficient sunlight, air circulation, and nutrients. This promotes healthy plant growth, reduces competition for resources, and minimizes the risk of diseases and pests. Spacing also helps avoid shading between plants, preventing reduced photosynthesis and stunted growth. The sowing date of peas can influence their yield potential. Early sowing generally allows peas to complete their life cycle before the onset of hot and dry conditions, resulting in higher yields. Delayed sowing, on the other hand, may expose the crop to unfavourable conditions such as high temperatures, pests, diseases, and moisture stress, which can negatively impact on yield (Kaur, *et al*., 2018) [49].

Conclusion and future prospects

The growth, yield and quality attributes were recorded better in T_1 sown on 5^{th} November with spacing (20 cm×10 cm). From this study it can be concluded that spacing and date of sowing is imperative to enhance the total production and productivity of the pea crop. It is therefore, recommended that sowing of pea may be done on or before November for higher yield and PB-89 variety for *Rabi* season in Jalandhar (north India state of Punjab).

First and foremost, developing countries like India and several other countries have extensive agriculture practices, which are being mitigated in the rural background. Obtaining the support of farmers (who are the real stakeholders) in such intriguing circumstances and conservative familial associations are challenges that have perhaps eluded most of the scientific distinctions. Therefore, it is important to make grassroots efforts to educate farmers and the farming community

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