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Effect of Date of Sowing and Spacing on Growth and Yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki

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ABSTRACT

The present investigation was conducted during winter 2018 at DAV University, Jalandhar to study the effect of different dates of sowing viz. 15 September, 1 October, and 15 October and spacing viz. 45 cm x 10 cm, 45 cm x 20 cm and 45 cm x 30 cm on growth and yield of radish cv. Pusa Chetki. The experiment was conducted in Factorial Randomized Block Design with three replications. Observations were recorded on root length, root width, number of leaves/plant, leaf length, leaf width, petiole length, petiole width, root weight/plant, root yield/ plot, plant height, root cracking/plot, root forking/plot, root biomass percentage and leaf biomass percentage. Analysis of Variance (ANOVA) revealed significant differences among date of sowing for all the characters except root yield/plot. Significant differences were observed for all the characters among spacing. Interaction effect of date of sowing and spacing resulted significance difference for all the character under study except root length and petiole length. It was observed that plants sown on 1 October resulted in superior performance for most of the traits studied. Among spacing, desirable results were observed at closer spacing of 45 cm × 10 cm. Considering the interaction of sowing dates and spacing it was found that plants sown on 1 October with the spacing of 45 cm × 10 cm can resulted in superior performance with respect to growth and yield parameters of radish cv. Pusa Chetki.

Keywords: *Pusa Chetki, Date of sowing, Spacing, Root cracking, Root forking, Root yield*

INTRODUCTION

Radish (*Raphanus Sativus* L.) is a one of the most popular cool season root vegetables belonging to family Brassicaceae. It was probably originated in Central or Western China and Indo-Pak sub-continent. Radish is grown for its young tender fleshy tuberous roots which are consumed either raw as salad or cooked as a vegetable. It is a good source of vitamin C and supplies a variety of minerals. About 100 g of edible radish consists of 1.0 mg of protein, 94 mg of water, 0.7 mg of fiber, 4.0 mg of carbohydrates, 0.1 mg of fat, 42 mg of calcium and 1 mg of iron (USDA, 2016). In India it is grown all around the year throughout the country.

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It is cultivated in India over an area of 208 hectare with annual production of 3218 MT (Anonymous, 2018a). The present area under radish production in Punjab is 27.60 ha with a production of about 628.58 thousand tones (Anonymous, 2018a). There are few recommendations that sowing date and plant density have brought classical changes in growth and root yield of radish crop with economical returns (Lavanya et al., 2017). However, the suitable time of sowing varies with the locality. Radish planting date influences crop production, including the vegetative and reproductive growth periods as well as the balance between them, which affects yield. Ideal radish sowing times vary depending on environment and variety. Growers often manipulate sowing times for better growth and yields (Alam et al., 2010, & Sandler et al., 2015). The use of spacing in crop production is very important, because it reduces competition between plants and weeds. Increased spacing reduces the number of plants per hectare thus affecting the yield. However decreased spacing increases plant population and yield per unit area up to a certain limit, beyond which the yield decreases due to limitation in natural resources required for plant growth. Proper sowing time and spacing depend on the varieties and prevailing environment. Therefore the selection of right type of varieties for sowing at optimum time and spacing is the key factor for successful radish production. Pusa Chetki is one the recommended variety for Punjab region. The recommended time of sowing for this variety is April-August. The roots sown in the month of April-August will be available in the market in the month of May-September. However, it will not be available after October month. Since radish can be grown throughout the year, it can also be sown successfully throughout the year in the plains of Northern India. The time of sowing should also be adjusted so as to synchronize the time of harvest with market demand. To meet the market requirement of this variety after the month of October, we need to standardize the optimum date of sowing and spacing for this variety. Keeping in view the above facts, the present investigation was executed with the objectives to study the effect of planting geometry, sowing dates and the interaction effect of plant geometry and sowing dates on yield and yield contributing traits of radish.

MATERIALS AND METHODS

The experiment was carried out on radish during winter season, 2018 at the Agricultural Farm of DAV University, Sarmastpur, Jalandhar. The farm is situated at elevation 243 meters above mean sea level and located in 31.33 latitude and 75.58 longitudes above the mean sea level which falls under the transgangetic plains of Punjab. The experiment was laid out in Factorial Randomized Complete Block Design with three replications. Three dates of sowing i.e., 15th September, 1st October and 15th October three plant spacing 45 cm×10 cm, 45 cm×20 cm, 45 cm× 30 cm and their interaction were studied. The cultural operations were carried out as and when required. Five competitive plants were selected randomly from each plot avoiding the border rows for the purpose of recording observations. The data was recorded on varying characters like, Root length (cm), Root width (cm), number of leaves, leaf length (cm), leaf width (cm), petiole length (cm), petiole width (cm), root weight (g), root yield (kg/plot). 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 (1985).

RESULTS AND DISCUSSION

Analysis of Variance (ANOVA) revealed significant differences among date of sowing for all the characters except root yield/plot. Significant differences were observed for all the characters among spacing and interaction effect of date of sowing and spacing resulted significance difference for all the character under study except root length and petiole length (Table 1).

Root length (cm)

Data presented in Table 2 revealed that maximum root length (35.79 cm) was observed in D_3 (15 October) which was statistically higher than all other date of sowing. Smallest root length (24.41 cm) was observed in D_1 (15 September) which was statistically smaller than all other sowing date. The increased root length with the delayed sowing can be attributed to gradual decrease in temperature which favours the growth and development of radish. The present findings are in line with Pervez et al. 2004; Alam et al. 2010; Lavanya et al. 2014 and Sahu et al. 2018 who also reported that root length is influenced by sowing time under different climatic conditions.

Effect of different spacing on root length (cm) showed that S_3 (45 cm × 30 cm) produced longest roots (33.12 cm) which were statistically longer than the roots of plants grown in S_2 (45 cm × 20 cm) and S_1 (45 cm × 10 cm). Maximum root length was observed in widest spacing. This could be due to the fact that increased spacing provides enough space for growth and have less competition compared to other plants sown at narrow spacings. These findings corroborates with the findings of earlier researchers *viz.*, Ghormade et al. 1989; Kabir et al. 2013 and Sahu et al. 2018. Interaction effect of date of sowing and spacing on root length was not significant (Table 3). Non significant differences for root length among interaction effect of date of sowing and spacing under different climatic conditions by earlier researchers *viz.*, Ghormade et al. 1989; Alam et al. 2010 and Sahu et al. 2018.

Root width (cm)

Maximum root width (4.66 cm) was observed in roots produced by the plants sown at D_2 (1 October) date of sowing which was significantly higher than the roots of plants sown at all other date of sowing i.e. D_1 (15 September) and D_3 (15 October) which resulted root width to the tune of 4.43 cm and 4.15 cm, respectively (Table 2). There was variable trend of root width with respect to date of sowing as it was observed maximum at 1 October date of sowing. The findings are in line with the findings of Sirkar et al. (1998); Kabir et al. (2013) and Sahu et al. (2018) who also reported significant influence of date of sowing on root diameter with variable trend under different environmental conditions.

Effects of spacing on root width indicated that S_3 (45 cm × 30 cm) resulted in widest roots and was statistically at par with roots of plants produced at S_1 (45 cm × 10 cm) i.e. 4.61 cm. Plants raised at spacing of S_2 (45 cm × 20 cm) resulted in narrowest roots with root width of 4.00 cm which was significantly lower than other spacings (Table 2). The findings are confirmed by the findings of Kolota and Oriowski (1984); Lenka et al. (1990) and Ali (2016).

Among interaction effects (Table 3) it was observed that widest roots (5.26 cm) were obtained in case of D_1S_3 (15 September × 45 cm × 30 cm) which were significantly broader than the roots produced by the plants raised at all other interaction effects. Narrowest root (3.45 cm) was produced by the plants raised under interaction D_3S_2 (15 October × 45 cm × 20 cm) which was again significantly lower than the roots produced by the plants raised in other interactions. The findings are confirmed by the findings of Kolota and Oriowski (1984); Lenka et al. (1990) and Ali (2016). The increased root width could be due to more vigorous vegetative growth in the plants sown at 15 September, resulting in more photosynthates translocation from leaves to root in radish (Alam, et al., 2010) and higher root width at wider spacing might be due to reduction in competition for light, moisture and nutrients (Patel et al., 2015). These findings are in accordance to the findings of Sahu et al. (2018).

Number of leaves per plant

Highest number of leaves/ plant (15.70) was observed in D_2 (1 October) which was significantly higher than number of leaves per plant observed in plants sown at other date of sowing i.e. D_1 (15 September) 14.21 and D_3 (15 October) 13.87. Lowest numbers of leaves per plant (13.87) were produced in D_3 (15 October) which was significantly lower than number of leaves/ plant observed in other date of sowing (Table 2). Number of leaves per plant also affects the yield in radish. Maximum number of leaves per plant was observed in 1 October sowing. This could be attributed to higher photosynthesis during this period. The finding is in line with the findings of earlier researcher's *viz*., Alam, et al. 2010 and Sahu et al. 2018 who also reported significant difference among date of sowing for number of leaves/plant.

Spacing also significantly affected number of leaves per plant. Highest number of leaves per plant (15.05) was observed in spacing S_3 (45 cm × 30 cm) which was significantly higher than the number of leaves per plant produced by plants raised in other spacings. Lowest number of leaves per plant (14.15) was observed in S_1 (45 cm × 10 cm) which was significantly lower than number of leaves/ plant observed in other plant spacings. Increase in number of leaves per plant was observed with the increase in spacing. This could be due to reduced competition for nutrients and water between plants in the increased spacing. The findings are confirmed by the findings of Kabir et al. 2013, Khan et al. 2016 and Sahu et al. 2018.

Among interaction effects (Table 3) highest number of leaves per plant (15.70) was observed in $D_2 \times S_1$ (1 October × 45 cm × 10 cm) which was statistically at par with $D_2 \times S_3$ (1 October × 45 cm × 30 cm) 15.20, $D_1 \times S_3$ (15 September × 45 cm × 30 cm) 15.13, and $D_3 \times S_3$ (15 October × 45 cm × 30 cm) 14.83. Lowest number of leaves per plant (13.30) were observed in $D_1 \times S_1$ (15 September × 45 cm × 10 cm) which was statistically at par with $D_3 \times S_3$ (15 October × 45 cm × 30 cm) 14.83. Similar results were obtained by Kabir et al. 2013 and Lavanya et al. 2017 at different environmental conditions.

Leaf length (cm)

The plants sown at D_1 (15 September) produced longest leaves (39.15 cm) which was significantly longer than the plants sown at all other date of sowing i.e. D_2 (1 October) (34.94 cm) and D_3 (15 October) (28.90 cm). Shortest leaves were observed in the plants sown at D_3 (15 October) which was also significantly lower than other date of sowing (Table 2). It was observed that there was decrease in leaf length with the delay in sowing. This may be due to increased growing period when planted earlier. Similar results were obtained under different climatic conditions by Ghormade et al. 1989; Kanwar, 1993; Gill and Gill, 1995 and Lavanya et al. 2017.

Among spacing, longest leaves (35.60 cm) were observed in spacing S_1 (45 cm × 10 cm) which were significantly longest than leaf length observed in other spacings i.e. 34.02 cm in S_2 (45 cm × 20 cm) and 33.22 cm in S_3 (45 cm × 30 cm). Smallest leaves (33.22 cm) were observed in S_3 (45 cm × 30 cm) which were significantly smaller than other plant spacing. Increased spacing resulted in shorter leaves. This could be due to the fact that the decreased spacing limits the space for the lateral growth of the plant which causes the plant to grow vertically thus increasing the leaf length. The findings are in accordance with the findings of Tripathi et al. 2017 who also reported longer leaves in narrow plant spacing.

Interaction effects of date of sowing and spacing revealed that longest leaves (40.90 cm) were observed in plants grown in $D_1 \times S_1$ (15 September × 45 cm × 10 cm) and $D_1 \times S_3$ (15 September × 45 cm × 30 cm) interactions (Table 3). Plants grown in all other interactions produced significantly smaller leaves. Smallest leaves (27.48 cm) were produced under interaction $D_3 \times S_3$ (15 October × 45 cm × 30 cm) which was statistically at par with leaves produced by plants grown in interaction $D_3 \times S_2$ (15 October × 45 cm × 20 cm) which produced leaf length of 28.27 cm. Longest leaves were observed in plants sown on 15 September in spacing of 45 cm × 10 cm and 15 September in a spacing of 45 cm × 30 cm. Thus it can be inferred that sowing on 15 September provided extended growing period resulting in more growth and increased leaf length. Similar results were obtained under different climatic conditions Ghormade et al. 1989; Kanwar, 1993; Gill and Gill, 1995 and Lavanya et al. 2017.

Leaf width (cm)

Observations recorded on leaf width (cm) revealed significant difference among date of sowing, spacing and their interaction effects. It was observed that broadest leaf width (10.28 cm) was produced by the plants sown at D_1 (15 September) date of sowing which was statistically higher than the leaf of plants sown at other date of sowing. Narrow leaves (8.58 cm) were observed in plants sown on D_3 (15 October) which was statistically smaller than all other date of sowing (Table 2). Delayed sowing resulted in decreased leaf width. It was observed that plants with broadest leaves were produced by the plants sown on 15 September. This can be attributed to the extended growing period when planted earlier, resulting in increased leaf width 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 researchers *viz*., Lavanya et al. 2017.

Effect of different spacing on leaf width (cm) revealed that S_1 (45 cm × 10 cm) resulted in plants with broadest leaf width (9.94 cm) which were statistically at par with the leaf of plants grown in S_3 (45 cm × 30 cm) which produced 9.44 cm broad leaf. Plants with smallest leaf were observed in spacing S_2 (45 cm × 20 cm) which produced plants with leaf width of 8.99 cm. Similar result were reported by Khan et al. 2016 who also reported that plants produced broader leaves at narrow plant spacing.

It was observed that broadest leaf (10.94 cm) was observed in plants grown in interaction $D_1×S_1$ (15 September × 45 cm × 10 cm) which was statistically at par with the leaf width of plants raised in $D_1×S_3$ (15 September × 45 cm × 30 cm) and $D_2×S_1$ (1 October × 45 cm × 10 cm) which produced the plants with leaf width of 10.79 cm and 10.35 cm, respectively. Smallest leaf width (8.48 cm) was observed in $D_3×S_3$ (15 October × 45 cm × 30 cm). This was statistically at par with leaf width of all the plants except those which were grown in interaction $D_1× S_2$ (15 September × 45 cm × 20 cm) (10.94 cm), $D_1 × S_3$ (15 September × 45 cm × 30 cm) (10.79 cm) and $D_2 × S_1$ (1 October × 45 cm × 10 cm) (10.35 cm) (Table 3). This is in line with the findings of Lavanya et al. 2017 who also observed significant interaction effect of date of sowing and spacing on leaf area.

Petiole length (cm)

Data recorded on effect of date of sowing on petiole length depicted that D_2 (1 October) resulted in plants with highest petiole length (5.45 cm) which was statistically at par with D_1 (15 September) producing plants with 5.16 cm petiole length. However, smallest petiole length was observed in plants sown at D_3 (15 October) i.e. 3.84 cm which was also significantly lower than other treatments under observations. 1 October date of sowing revealed maximum petiole length which was statistically at par with the petiole length of plants sown on 15 September (Table 2). This could be due to extended growing period of early sown plants resulting in the increased petiole length in the plants sown earlier.

Effect of spacing on petiole length suggested that longest petiole (4.95 cm) was observed in plants sown in S_1 (45 cm × 10 cm) which was statically at par with the plants sown in S_2 (45 cm × 20 cm) producing 4.79 cm long petiole. Shortest petiole length (4.37) was produced by the plants sown in S_3 (45 cm × 30 cm) which was significantly lower than the petiole length of plants grown in other spacing. Decreased spacing also resulted in increased petiole length. This could be due to the fact that the decreased spacing limits the space for the lateral growth of the plant causing enhanced vertical growth of plants. Khan et al., 2016 also reported significant effect of spacing on petiole length.

Petiole width (cm)

Largest petiole width (0.99 cm) was observed in plants sown on D_1 (15 September) which was significantly broader than the plants sown at all other date of sowing i.e. D_2 (1 October) and D_3 (15 October) which resulted in plants with petiole width of 0.85 cm and 0.82 cm, respectively (Table 2).

Effect of spacing on petiole width indicated that widest petiole (0.93 cm) was observed in plants grown in S_3 (45 cm × 30 cm) which was significantly broader then the plants grown in other spacings i.e. S_1 (45 cm × 10 cm) and S_2 (45 cm × 20 cm) which produced plants with petiole width of 0.91cm and 0.82 cm, respectively.

It was observed that plants grown in D_1×S_1 (15 September × 45 cm × 10 cm) and D_1×S_3 (15 September × 45 cm × 30 cm) interaction resulted in widest petiole width (1.07 cm), which was statistically at par with the petiole width of plants grown in D_1×S_3 (15 September × 45 cm × 30 cm) (0.97 cm), D_2×S_2 (1 October × 45 cm × 20 cm) (0.88 cm) and D_3×S_1 (15 October × 45 cm × 10 cm) (0.83 cm). Narrowest petiole (0.75 cm) was observed in plants grown in D_3×S_2 (15 October × 45 cm × 20 cm) which was statistically at par with petiole width of plants grown in D_1×S_2 (15 September × 45 cm × 20 cm) (0.82 cm), D_2×S_1 (1 October × 45 cm × 10 cm) (0.82 cm), D_2×S_2 (1 October × 45 cm × 20 cm) (0.88 cm), D_2×S_3 (1 October × 45 cm × 30 cm) (0.76 cm), D_3×S_1 (15 October × 45 cm × 10 cm) (0.83 cm) and D_3×S_3 (15 October × 45 cm × 30 cm) (0.97 cm) (Table 3).

Plants sown on 15 September resulted in maximum petiole width and it was observed to increase with the increased spacing. Interaction effects also revealed maximum petiole width in plants sown on 15 September and spaced at 45 cm x 30 cm. Similar results were observed by Khan et al. 2016.

Root weight (g)

Plants sown at D_2 (1 October) produced highest root weight (358.11g) which was significantly higher than the root weight of plants sown at all other date of sowing i.e. D_3 (15 October) and D_1 (15 September) which produced plants with root weight of 328.33g and 320.66g, respectively (Table 2). Plants sown on 1 October produced maximum root weight. This could be due to the extended growing period of early sown plants resulting in higher root weight.

Effect of spacing on root weight indicated that highest root weight (350.55g) was observed in plants sown at spacing of S_1 (45 cm ×10 cm) which was at par with the root weight of plants grown in spacings i.e. S_3 (45 cm × 30 cm) with root weight of 342.44g. Plants sown in spacing 45 cm x 10 cm resulted in maximum root weight which was at par with the root weight of plants sown in 45 cm x 30 cm spacing. This indicates that plants spaced widely respond well towards the root growth.

Highest root weight (373.66 g) was produced by plants grown in interaction D_2×S_2 (1 October × 45 cm × 20 cm) which was statistically at par with the root weight of the plants raised in D_1×S_1 (15 September × 45 cm × 10 cm) (367.00 g) and D_2×S_1 (1 October × 45 cm × 10 cm) (366.66 g). Lowest root weight (261.66g) was observed in D_1×S_2 (15 September × 45 cm × 20 cm) interaction which was significantly lower than the root weight produced by plants grown in other interactions (Table 3). The findings corroborates with the finding of Sirkar (1998); Ahmed et al., (2003) and Ali (2016).

Root yield/plot (kg)

Highest root yield/ plot (9.15 kg) was observed in plants grown in S_1 (45 cm × 10 cm) which was significantly higher than the plants grown at other spacing i.e. S_2 (45 cm × 20 cm) and S_3 (45 cm × 30 cm) which produced root weight of 5.38 kg and 4.01 kg, respectively (Table 2). Highest root yield/plot was observed with the close spacing. This could be due the increased plant population in the closer plant spacing.

It was observed that plants grown in D_1 × S_1 (15 September × 45cm × 10cm) produced highest roots yield/plot (9.30 kg) which was statistically at par with root yield/plot of the plants raised in D_2 × S_1 (1 October × 45 cm × 10 cm) (9.28 kg) and D_3 × S_1 (15 October × 45 cm × 10 cm) (8.86 kg). Lowest root yield/plot (3.31 kg) was observed in D_2× S_3 (1 October × 45 cm × 30 cm) which was statistically at par with the root yield/plot of D_1 × S_2 (15 September × 45 cm × 20 cm) (4.37 kg), D_1 × S_3 (15 September × 45 cm × 30 cm) (4.27 kg) and D_3 × S_3 (15 October × 45 cm × 30 cm) (4.51 kg) (Table 3).

It was observed that plants sown on 15 September and maintained at a spacing of 45 cm x 10 cm produced highest roots yield/plot which was statistically at par with the plants sown on 1 October at a spacing of 45 cm x 10 cm and plants sown on 15 October at a spacing of 45 cm x 10 cm (Table 3). This clearly indicates greater influence of plant spacing on root yield/ plot. Similar results were obtained under different climatic conditions by Busell (1976); Rehman and Ali (2000) and Lavanya et al. (2014).

Plant height (cm)

Tallest plants (70.38 cm) were observed in D_2 (1 October) which was significantly higher than the height of plants sown at other date of sowing i.e. D_1 (15 September) and D_3 (15 October) which resulted in the plant height of 67.84 cm and 67.84 cm, respectively. Tallest plants were observed when sowing was done on 1 October (Table 2). This again indicates the role of extended growing period of early sown plants which promoted the plant height. Among spacings, S_1 (45 cm × 10 cm) produced tallest plants (70.73 cm) which were significantly taller than the height of plants observed in the treatment of S_2 (45 cm × 20 cm) (66.11 cm) and S_3 (45cm × 30 cm) (67.14 cm). Plants maintained at closer spacing (45 cm × 10 cm) produced tallest plants. This could be due to increase leaf length at closer spacing.

$D_2 \times S_1$ (1 October × 45 cm × 10 cm) resulted in tallest plants with plant height of 73.37 cm which was at par with the height of plants grown in $D_3 \times S_1$ (15 October × 45 cm × 10 cm) producing 71.94 cm tall plants. Shortest plants (62.70 cm) were observed in $D_1 \times S_2$ (15 September × 45 cm × 20 cm), which are significantly shorter than the height of plants grown in other interactions (Table 3). The findings are in corroboration with the findings of Ghormade et al. (1989); Kanwar (1993); Pandita et al. (2005) and Lavanya et al. (2014).

Root cracking/ plot

It was noticed that lowest splitting and cracking (0.25) was observed in plants sown on D_2 (1 October) which was significantly lesser then all other date of sowing i.e. D_3 (15 October) and D_1 (15 September) which resulted in 0.62 and 0.28 cracked roots/plot, respectively (Table 2). Least root cracking was observed in the plants sown earlier, whereas delayed sowing resulted in significant higher cracking. This indicates that early sown plants are exposed to desirable climatic conditions. This promotes healthy root development.

Effect of spacing on root cracking/plot showed that S_1 (45 cm × 10 cm) resulted in minimum cracked roots (0.15) which were significantly lower than the root cracking observed in plants grown in other spacings i.e. S_2 (45 cm × 20 cm) and S_3 (45 cm × 30 cm) resulting in 0.67 and 0.33 root cracking/plot, respectively. Plants grown in closer spacing produced lowest number of cracked roots which indicates that dense sowing influenced in a positive manner for growth of plant. Interaction effect of date of sowing and spacing on cracking also revealed that there was no cracking in the root of plants sown early in closer spacing.

Significant effect of interaction of date of sowing and spacing was observed for root cracking/plot ((Table 3). No root cracking was observed in the plants grown in $D_1 \times S_1$ (15 September × 45 cm × 10 cm) interaction. Highest root cracking/plot (1.23) was observed in $D_3 \times S_2$ (15 October × 45 cm × 20 cm) interaction which was significantly higher than the root cracking/plot observed in all other treatment combination. Cracking was maximum when plants were sown on 1 October in a spacing of 45 cm x 30 cm. The contradiction are in accordance to the finding of Kabir et al. (2013) who also reported no branched roots of carrot in early planting and narrow spacing.

Root forking/ plot

Minimum forking (0.15) was observed in plant sown at D_1 (15 September) which was statistically lower then all other date of sowing. Highest forking (0.42) was observed in plants sown at D_3 (15 October) which was statistically at par with forking observed in D_2 (1 October) i.e. 0.36. Early sowing resulted in least root forking whereas delayed sowing resulted in significantly higher forking (Table 2). This indicates the presence of favorable climatic conditions prevailing during that period of sowing which promotes straight and healthy root development.

Data on effect of spacing on forking revealed that S_1 (45 cm × 10 cm) resulted into no forking/plot which was significantly lowest then forking observed in all other spacing. Plants which were grown sown with closer spacing produced no forking which indicates that dense sowing influenced in a positive manner for growth of plant.

No forked roots/plot (0.00) were observed in $D_1 \times S_1$ (15 September × 45 cm × 10 cm), $D_1 \times S_2$ (15 September × 45 cm × 20 cm), $D_2 \times S_1$ (1 October × 45 cm × 10 cm), $D_3 \times S_1$ (15 October × 45 cm × 10 cm), and $D_3 \times S_3$ (15 October × 45 cm × 30 cm) where as $D_2 \times S_2$ (1 October × 45 cm× 20 cm) produced maximum number of forked roots (0.63) which was significantly higher than forked roots/plot observed in all other interactions (Table 3). Interaction of date of sowing and spacing on forking also revealed that there was no forking in the plants sown densely irrespective of date of sowing. Forking was maximum when plants were sown on 1 October with spacing of 45 cm x 20 cm. These findings are in contradiction with the finding of Kabir et al. (2013) who also reported no branched roots of carrot in early planting and narrow spacing.

Root biomass percentage (%)

D_3 (15 October) resulted in highest root biomass (%) i.e. 4.28 which was statistically higher than the root biomass of plants sown at all other date of sowing i.e. D_2 (1 October) and D_1 (15 September) which produced root biomass (%) of 4.14 and 4.01, respectively. Maximum root biomass was observed in plants which were sown late i. e., on 15 October (Table 2). This could be due to the fact that low temperature provide better condition for radish root growth.

Effect of spacing root biomass (%) revealed that plants grown at S_2 (45 cm × 20 cm) produced highest root biomass of 4.57% which was significantly higher than the other spacings i. e., S_3 (45 cm × 30 cm) and S_1 (45 cm × 10 cm) which resulting in 4.32% and 3.55 % root biomass, respectively. Root biomass was observed higher when plants were spaced wider. This could be due the fact that wider spacing provides better root growth by way of reduced inter-plant competition for water and nutrition.

Interaction effect of date of sowing and spacing on root biomass are presented in (Table 3) Plants grown in $D_3 \times S_2$ (15 October × 45 cm × 20 cm) interaction resulted in highest root biomass (%) which was significantly higher than root biomass of other plants grown in all other interactions. Lowest root biomass (2.94%) was produced by the plants grown in interaction $D_1 \times S_1$ (15 September × 45 cm × 10 cm). Interaction effect of date of sowing and spacing also revealed maximum root biomass when plants were sown on 15 October and spaced at 45 cm x 20 cm. The findings corroborate with the findings of Sandler et al. (2015) and Ali (2016).

Leaf biomass percentage (%)

It was noticed that highest leaf biomass (9.04%**)** was observed in plants sown on D_3 (15 October) which was significantly higher than leaf biomass observed in plants sown in all other date of sowing i.e. D_1 (15 September) and D_2 (1 October) which resulted in leaf biomass to the tune of 8.51% and 7.47%, respectively (Table 2). Maximum leaf biomass was observed in plants which were sown late i.e. on 15 October this could be due to the fact that low temperature provide better condition for radish foliage growth.

Effect of spacing on leaf biomass indicated that plants sown with spacing S_2 (45 cm × 20 cm) resulted in highest leaf biomass (8.49%) which was statistically at par with leaf biomass of plants grown at S_1 (45 cm ×10 cm) (8.47%). Leaf biomass was observed higher when plants were spaced closer.

Highest leaf biomass (9.82%) was observed in plants grown in $D_1 \times S_1$ (15 September × 45 cm × 10 cm) which was significantly higher than the leaf biomass of plants grown in other interactions. Lowest leaf biomass (6.75%) was observed in $D_1 \times S_3$ (15 September × 45 cm × 30 cm) interaction which was significantly lower than the leaf biomass of plants grown in other treatment combinations (Table 3). Interaction effect of date of sowing and spacing also revealed maximum leaf biomass when plants were sown on 15 October and spaced at 45 cm x 20 cm. The findings corroborate with the findings of Sandler et al. (2015) and Ali (2016).

Table 1: Analysis of variance for growth and yield parameter of radish

Observations	MSS dates of sowing	MSS spacing	MSS Interaction of dates of sowing and spacing	Error
Root length	327.93*	30.95*	1.73	0.66
Root width	0.58*	1.18*	1.10*	0.04
Number of leaves/plant	4.33*	2.62*	1.33*	0.29
Leaf length	238.00*	13.18*	29.81*	0.62
Leaf blade width	6.52*	2.01*	1.36*	0.30
Petiole length	5.02*	0.80*	0.28	0.09
Petiole width	0.07*	0.03*	0.04*	0.00
Root weight	0.58*	1.18*	1.10*	0.04
Root yield/plot	0.64	63.63*	2.88*	0.55
Plant height	48.20*	52.88*	15.60*	2.24
Root cracking/plot	0.37*	0.63*	0.22*	0.01
Root forking/plot	0.18*	0.90*	0.62*	0.00
Root biomass percentage	0.17*	2.56*	1.48*	0.00
Leaf biomass percentage	5.74*	0.48*	5.30*	0.00

***Significant at 5%**

Table 2: Effect of date of sowing and spacing on growth and yield of radish (*Raphanus sativus L.*) cv. Pusa Chetki

Treatment	Root length (cm)	Root width (cm)	Number of leaves/plant	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Petiole width (cm)	Root weight (g)	Root yield/plot (kg)	Plant height (cm)	Root cracking/plot	Root forking/plot	Root biomass (%)	Leaf biomass (%)
Dates of Sowing														
D_1	**24.41**	**4.43**	**14.21**	**39.15**	**10.28**	**5.16**	**0.99**	**320.66**	**5.96**	**65.75**	**0.28**	**0.15**	**4.01**	**8.51**
D_2	**33.59**	**4.66**	**15.70**	**34.94**	**9.50**	**5.45**	**0.82**	**358.11**	**6.48**	**70.38**	**0.25**	**0.36**	**4.14**	**7.47**
D_3	**35.79**	**4.15**	**13.87**	**28.90**	**8.58**	**3.84**	**0.85**	**328.33**	**6.10**	**67.84**	**0.62**	**0.42**	**4.28**	**9.04**
CD (5%)	**0.80**	**0.19**	**0.54**	**0.78**	**0.54**	**0.30**	**0.01**	**8.43**	**NS**	**1.49**	**0.09**	**0.02**	**0.02**	**0.02**
SE(d)	**0.38**	**0.08**	**0.25**	**0.37**	**0.25**	**0.14**	**0.00**	**3.97**	**0.34**	**0.70**	**0.04**	**0.04**	**0.01**	**0.01**
Plant spacing														
S_1	**31.25**	**4.61**	**14.15**	**35.60**	**9.94**	**4.95**	**0.91**	**350.55**	**9.15**	**70.73**	**0.15**	**0.00**	**3.55**	**8.47**
S_2	**29.41**	**4.00**	**14.08**	**34.02**	**8.99**	**4.79**	**0.82**	**316.11**	**5.38**	**66.11**	**0.67**	**0.63**	**4.57**	**8.49**
S_3	**33.12**	**4.63**	**15.05**	**33.22**	**9.44**	**4.37**	**0.93**	**342.44**	**4.01**	**67.14**	**0.33**	**0.31**	**4.32**	**8.08**
CD (5%)	**0.80**	**0.19**	**0.54**	**0.78**	**0.54**	**0.30**	**0.01**	**8.43**	**0.74**	**1.49**	**0.07**	**0.56**	**0.02**	**0.02**
SE(d)	**0.38**	**0.08**	**0.25**	**0.37**	**025**	**0.14**	**0.00**	**3.97**	**0.34**	**0.70**	**0.04**	**0.02**	**0.01**	**0.01**

Table 3: Effect of interaction of date of sowing and spacing on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki

Treatment	Root length (cm)	Root width (cm)	Number of leaves/plant	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Petiole width (cm)	Root weight (g)	Root yield/plot (kg)	Plant height (cm)	Root cracking/plot	Root forking/plot	Root biomass (%)	Leaf biomass (%)
D_1 X S_1	24.57	4.31	13.30	40.90	10.94	5.56	1.07	367.00	9.30	66.87	0.00	0.00	2.94	9.82
D_1 X S_2	22.17	3.71	14.20	35.65	9.12	5.34	0.82	261.66	4.37	62.70	0.40	0.00	4.52	8.97
D_1 X S_3	26.48	5.26	15.13	40.90	10.79	5.26	1.07	333.33	4.27	67.70	0.46	0.46	4.56	6.75
D_2 X S_1	34.10	4.68	15.70	34.94	10.35	5.45	0.82	366.66	9.28	73.37	0.16	0.00	3.75	6.86
D_2 X S_2	31.16	4.83	14.73	38.14	9.10	5.26	0.88	373.66	6.84	70.10	0.40	0.63	3.94	6.94
D_2 X S_3	35.52	4.47	15.20	31.29	9.06	4.47	0.76	334.00	3.31	67.66	0.20	0.46	4.74	8.63
D_3 X S_1	35.10	4.85	13.87	30.96	8.52	3.84	0.83	318.00	8.86	71.94	0.30	0.00	3.94	8.73
D_3 X S_2	34.90	3.45	13.33	28.27	8.76	3.78	0.75	313.00	4.93	65.54	1.23	1.26	5.25	9.55
D_3 X S_3	37.36	4.16	14.83	27.48	8.48	3.91	0.97	354.00	4.51	66.05	0.33	0.00	3.66	8.85
CD (5%)	N.S	0.32	0.94	1.36	0.94	N.S	0.23	14.61	1.28	2.59	0.16	0.09	0.04	0.03
SE(d)	0.66	0.15	0.44	0.64	0.44	0.25	0.01	6.89	0.60	1.22	0.07	0.04	0.02	0.01

CONCLUSION

The results obtained in the present investigation concluded that date of sowing and spacing individually and their interactions, significantly affect the growth and yield attributes of radish. Plants sown on 1 October resulted in superior performance for most of the traits studied. Among the spacing, desirable results were observed at closer spacing of 45 cm × 10 cm. considering the interaction of sowing dates and spacing it can be concluded that plants sown on 1 October with the spacing of 45 cm × 10 cm can result in superior performance with respect to growth and yield parameters of radish variety Pusa Chetki in Jalandhar region.

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