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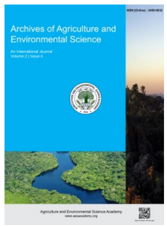

ORIGINAL RESEARCH ARTICLE

Effect of plant spacing and sowing dates on the growth and yield of radish (*Raphanus sativus*) in Rupandehi district, Nepal

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ABSTRACT

A field experiment was conducted from mid-April to mid-June 2022 in Rupandehi to evaluate the growth and yield of radish maintained in varied plant spacing at differed sowing dates. The study was aimed to compare the growth, production and economics of radish in Rupandehi district under different plant spacing and sowing dates and to evaluate the interaction between these two factors. Four plants spacing (10 cm, 20 cm, 30 cm and 40 cm) with constant row spacing was maintained at two sowing dates (Chaitra 29 and Baisakh 14). The treatments were arranged in two factorial Randomized Complete Block Design (RCBD) with 3 replications. The data were collected on 30 DAS and 45 DAS. The obtained data were recorded and analyzed using MS-Excel and R-studio, respectively. The results revealed that the highest yield was obtained from plant spacing of 20 cm (28.20 t/ha). However, individual plant weight was higher in wider spacing. Plant spacing of 20 cm showed significantly highest plant height (24.52 cm), number of leaves per plant (22.37) and leaf length (23.36 cm). Leaf blade width (10.67 cm) and petiole length (3.05 cm) was significantly highest in plant spacing of 30 cm. Early sowing date showed significantly better results for all growth and yield parameters and yield except leaf blade width. Higher gross return, net return and B:C ratio was observed in plant spacing of 20 cm and early sowing date. The study concluded that plant spacing of 20 cm and earlier sowing date was ideal for maximum growth and yield of radish in Rupandehi district.

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INTRODUCTION

Radish (*Raphanus sativus*) is worldwide grown popular vegetable belonging to the family Cruciferae. In Nepal, radish is ranked as the 5th important vegetable crop cultivated in 16,808 ha with a production of 257,335 Mt and productivity of 15.31 Mt/ha (MOALD, 2021). Rupandehi is one of the important district on the context of vegetable production in Nepal and radish is one of the major vegetable crops produced in Rupandehi district. Rupandehi district accounted for 4,082 Mt/ha yield of radish in 2019/20 (MOALD, 2021). But the production of radish is at declining trend from 2017/18 to 2019/20 (MOALD, 2021). The production and productivity of radish in Nepal is lower than that of SAARC countries. The decrease in national production of radish resulted in import of radish from neighbouring countries which is not desirable economically. The farmers involved in the vegetable farming follows traditional practices and are unaware of improved agronomic practices and techniques (Thapa, 2017). A good radish production practice includes proper sowing dates and spacing for the production of quality vegetable. An appropriate sowing date is very important to enhance the production as the adjustment in sowing dates can be widely used to prevent the infestation of disease and pests (Alam *et al.*, 2010; Sandler *et al.*, 2015). The variation in sowing dates has its influence on the vegetative characters (Patrick, 2006) as the temperature, humidity and other climatic factors varies accordingly. The late sowing of radish results in the decrease in important growth traits such as plant height, number of leaves, leaf length and so on (Ramesh, 2012). The difference in sowing time also affects the germination of seeds (Sumrah *et al.*, 2003). The yield of radish depends upon its vegetative and reproductive characters which is ultimately dependent upon climatic factors during growing season (Ramesh, 2012). An appropriate sowing time ensures the climatic requirement which results in higher yield. The delay in sowing causes reduction in yield (Galovi, 2007). The fulfillment of light requirement is necessary for obtaining optimum yield of radish. Photoperiod affects the biomass portioning which ultimately determines the yield of radish (Pell *et al.*, 1993). The experiment conducted with 10 varieties at four different sowing dates showed variation in the root length at different planting time (Pandey *et al.*, 2009). Thus, the sowing times can be manipulated for better growth and yield (Alam *et al.*, 2010; Sandler *et al.*, 2015). In addition to this, spacing plays a very important role in determining the yield and quality of crops as plant geometry influences the competition between crops for water, light and nutrients. Proper plant geometry reduces the intraspecific competition and prevents the shading effect. The experiment conducted in Hariyana showed the decrease in germination percentage with closer spacing (Pandita *et al.*, 2005). The experiment conducted on varying spacing on radish resulted the variation in the plant height with variation in each spacing (Pervez *et al.*, 2004) (El-Desuki *et al.*, 2005). Closer spacing results in the intraspecific as well as interspecific competition for space, moisture and nutrients which results in suppressed growth of cultivated crops. Wider spacing reduces the spread of pests and diseases which causes poor vegetative growth of radish (Ahmad, 2003). Closer spacing results in competition for light which is an important determinant of growth of radish. The better vegetative growth ensures the required photosynthetic translocation from leaves to roots which increases the root yield of radish. As compared to closer spacing, wider spacing produced higher root girth and root weight (Sharma and Kanavjia, 1994). The reproductive characters and root girth are negatively affected with increase in plant density. Wider spacing provides better chances for root development by reducing intraspecific competition for light, space, moisture and nutrients (Hussain *et al.*, 2008). In the experiment conducted in White Icicle variety of radish, the root: shoot ratio was found to decrease in close spacing as compared to wider spacing (El-Desuki *et al.*, 2005). A trial conducted in Ethiopia concluded that the days to maturity was reduced with closer spacing but the yield also decreased along with the time (Mengistu and Yamoah, 2010).

Since, the farmers are not aware of simple and proper agronomic practices such as proper spacing and appropriate sowing dates, the productivity of radish is below the maximum potential in Nepal. The radish cultivation is done as per the feasibility of farmers without considering the appropriate sowing date. In many cases, the production of radish is limited due to delayed sowing. Most of the root crops are broadcasted freely after land preparation without maintaining the proper spacing which causes competition among the crops. Thus, this results in the production of poor-quality roots such as small size, cracked roots, etc. Moreover, very less research has been conducted on root crops in Nepal as compared to other commodities which further restricts the extension of proper agronomic practices. Thus, the production of radish is declining over years. Thereby, this research attempts to show the influence of plant spacing and sowing date on the yield and quality of radish to help farmers understand the significance of proper agronomic practices.

MATERIALS AND METHODS

Description of experimental site

The experiment was conducted in Siddharthanagar municipality of Rupandehi district. It lies in 25 km south of Butwal city and 25 km east of popular heritage site Lumbini (27°30' N latitude and 83°27' E longitude) and at 120m above sea level. A farmer's field was selected within the vegetable cultivation area with an area enough to conduct the required trials. The topography of area was plain terai with proper irrigation facilities.

Experimental treatment, design and layout

The experiment was conducted in two factorial Randomized Complete Block Design (RCBD) with three replications. It comprised of total eight treatment with two factors; Factor I being sowing dates (29th Chaitra and 14th Baisakh) and Factor II being plant spacing (40 cm, 30 cm, 20 cm and 10 cm). A net plot size of 3.6 m×1m was maintained and 10 sample plants were selected from each plot for data collection.

Cultivation procedure

In the selected field, one deep ploughing followed by light harrowing was done. Then, FYM @1000 Kg/ ropani and basal fertilizers (Urea @10 kg/ropani (half dose), DAP @9 kg/ ropani (full dose) and MOP @3 kg/ ropani (full dose)) were applied to field. Next, significant plots were made and levelling was done. Radish of variety Forty Days was obtained from registered agrovet in Butwal, Rupandehi. The seeds of radish were sown on Chaitra 29^{th} and Baisakh 14^{th} maintaining a constant row spacing but varied plant spacing as mentioned. Remaining half dose of urea was applied at 25 DAS. All management practices were done as and when necessary. Harvesting was done at 45 DAS.

Data collection

The days to emergence of seeds was recorded when more than 50% of seeds germinate. The data for growth parameters were recorded at 30 DAS and 45 DAS. The data for yield parameters were recorded at 45 DAS.

Economic analysis

Net return, gross return and B:C ratio was calculated for economic analysis of radish cultivation.

Statistical analysis

All the collected data was entered into MS- Excel and further subjected to analysis of variance (ANOVA). R-Studio was used as the inferential and descriptive statistical tool. All the data analyzed were put to DMRT for mean comparison by selecting 5% level of significance. The ANOVA tables were obtained for the parameters to discuss and infer results with the support of some relevant literatures.

RESULTS AND DISCUSSION

Days to emergence

There was no significant difference in days to emergence due to plant spacing. The days to emergence for radish seeds sown on Chaitra 29 was 5 days for germination whereas for the seeds sown on Baisakh 14, it took 7 days for germination. Thus, days to emergence was found to be lower in early sowing as compared to late sowing. In general, the delay in sowing results in the increase in germination period. It may be due to the unfavourable climatic conditions prevailed during late sowing interfering with seed germination (Singh and Yadhav, 1989) (Hessayon, 1985).

Growth parameters

Growth parameters showed significant differences for both sowing date and plant spacing as shown in Table 1. Earlier sowing date resulted in highest growth parameters such as plant height (23.99 cm), number of leaves/plant (21.24), leaf length (22.79 cm) and petiole length (3.11 cm) at 45 DAS as shown in Table 1. The higher plant height for earlier date of sowing was probably due to more suitable climatic condition. Similar results were obtained influenced by sowing time under different climatic conditions (Gill and Gill, 1995). The number of leaves/plants was significantly higher for earlier date of sowing than later date of sowing for all observations. It may be due to longer growing period of plant when sown earlier (Joshi *et al.*, 1975). The plants showed higher number of leaves/plant for earlier sowing probably due to more climatic suitability and more photosynthetic activities during the period (Alam *et al.*, 2010). The higher leaf length at earlier sowing may be due to longer growing period. Similar results were obtained under different sowing date by (Gill and Gill, 1995) (Lavanya *et al*, 2017). But leaf blade width (10.92 cm) was found to be significantly higher at later sowing date. Lavanya *et al.* (2017) reported that delay in sowing causes decrease in leaf blade width but the observed result from our observation showed completely inverse results. It may be due to variability in season and prevailing climatic factors. Delay in sowing date causes decrease in petiole length as supported by (Khan *et al.*, 2016).

Among plant spacing, plant height (24.52 cm) was significantly highest for plant spacing of 20 cm at 45 DAS. The higher plant height for plant spacing of 20 cm was possibly due to availability of water and nutrients and less intra competition. Closer spacing interferes with the lateral growth as higher plant density causes more competition for space (Pandita *et al.*, 2005). Similarly, plant spacing of 20 cm showed significantly highest number of leaves/plant (22.37) and leaf length (23.36 cm) at 45 DAS. Likewise, plant spacing of 30 cm showed significantly highest leaf blade width (10.67 cm) and petiole length (3.05 cm) at 45 DAS. However, plant spacing of 40 cm significantly resulted in lowest plant height (18.18 cm), number of leaves/plant (12.77), leaf length (17.45 cm), leaf blade width (7.55 cm) and petiole length (2.42 cm) at 30 DAS. Radish crop has an erect growing habit. The increase in number of leaves/plant with wider spacing may be due to availability of more space, nutrients, moisture and light (El-Desuki *et al.*, 2005). The leaf and petiole length were found to be higher in case of closer spacing. It may be due to the availability of space for lateral growth in wider spacing. In closer spacing, lateral growth is limited due to space hence crop grows vertically in erect position resulting longer leaves and petiole (Tripathi *et al.*, 2017). Closer spacing produced greater leaf blade width as compared to wider spacing which is in accordance with (Khan *et al.*, 2016).

Table 1. Effect of different plant spacing and sowing date on growth parameters of radish cv forty days.

Treatments	Plant height (cm)		Number of leaves		Leaf length (cm)		Leaf blade width cm)		Petiole length (cm)	
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
Plant spacing										
10 cm	20.03[a]	23.63[a]	12.22[b]	15.50[c]	19.19[a]	22.43[a]	8.64[a]	10.42[a]	2.47[b]	2.83[ab]
20 cm	20.32[a]	24.52[a]	16.02[a]	22.37[a]	19.44[a]	23.36[a]	8.66[a]	10.41[a]	2.73[a]	2.99[a]
30 cm	19.96[a]	23.61[a]	16.32[a]	21.85[a]	19.17[a]	22.43[a]	8.91[a]	10.67[a]	2.74[a]	3.05[a]
40 cm	18.18[b]	21.76[b]	12.77[b]	17.30[b]	17.45[b]	20.46[b]	7.55[b]	9.67[b]	2.42[b]	2.72[b]
SEm(±)	0.009	0.010	0.010	0.010	0.009	0.011	0.007	0.005	0.002	0.002
LSD	1.172	1.301	1.277	1.286	1.168	1.319	0.908	0.697	0.241	0.256
F-probability	**	**	***	***	**	**	*	*	*	*
CV (%)	4.826	4.493	7.20	5.39	5.015	4.804	8.685	5.469	7.534	7.133
Sowing date										
Chaitra 29	20.24[a]	23.99[a]	15.87[a]	21.24[a]	19.43[a]	22.79[a]	7.61[b]	9.67[b]	2.84[a]	3.11[a]
Baisakh 14	19.01[b]	22.77[b]	12.78[b]	17.27[b]	18.20[b]	21.54[b]	9.27[a]	10.92[a]	2.33[b]	2.69[b]
SEm(±)	0.019	0.021	0.021	0.021	0.019	0.022	0.015	0.011	0.004	0.004
LSD	0.829	0.920	0.903	0.909	0.826	0.932	0.642	0.493	0.170	0.181
F-probability	**	*	***	***	**	*	***	***	***	***
CV (%)	4.826	4.493	7.20	5.39	5.015	4.804	8.685	5.469	7.534	7.133
Grand Mean	19.63	23.38	14.33	19.25	18.81	22.17	8.44	10.29	2.59	2.90
Interaction effect										
SEm(±)	0.004	0.005	0.005	-	0.004	0.005	0.003	0.002	0.001	0.001
LSD	1.658**	1.840**	1.807*	-	1.652**	1.865**	1.284*	0.986*	0.341***	0.362**

Table 2. Effect of different plant spacing and sowing date on yield parameters and yield of radish cv forty days.

Treatments	Root weight (g)	Fresh leaf weight (g)	Root length (cm)	Root circumference (cm)	Yield (t/ha)
Plant spacing					
10 cm	55.43[d]	81.50[c]	17.98[a]	9.66[d]	27.71[b]
20 cm	112.81[b]	104.91[b]	14.94[b]	10.83[c]	28.20[a]
30 cm	108.58[c]	103.58[b]	14.67[c]	11.36[b]	18.09[c]
40 cm	126.28[a]	118.91[a]	12.54[d]	13.05[a]	15.78[d]
SEm(±)	0.009	0.024	0.001	0.001215	0.002
LSD	1.174	2.958	0.195	0.144	0.345
F-probablity	***	***	***	***	***
CV (%)	0.941	2.337	1.051	1.03	1.24
Sowing date					
Chaitra 29	109.90[a]	106.25[a]	17.19[a]	12.31[a]	24.46[a]
Baisakh 14	91.65[b]	98.20[b]	12.87[b]	10.13[b]	20.43[b]
SEm(±)	0.019	0.049	0.003	0.002	0.005
LSD	0.830	2.092	0.138	0.102	0.244
F-probablity	***	***	***	***	***
CV (%)	0.941	2.337	1.051	1.03	1.24
Grand Mean	100.77	102.22	15.03	11.22	22.45
Interaction effect					
SEm(±)	0.004	0.012	0.0008	0.0006	0.0014
LSD	1.661***	4.184*	0.276***	0.204***	0.489***

Table 3. Effect of different spacing and sowing date on economic factors of radish cv forty days.

Treatments	Cost of cultivation (NRs.ha^{-1})	Net returns (NRs.ha^{-1})	Gross returns (NRs.ha^{-1})	B:C ratio
Plant spacing				
10 cm	228022.36	603477.6[b]	831500.0[b]	3.65[b]
20 cm	228022.36	618102.6[a]	846125.0[a]	3.71[a]
30 cm	228022.36	314894.3[c]	542916.7[c]	2.38[c]
40 cm	228022.36	245540.1[d]	473562.5[d]	2.07[d]
LSD	0	10383.96	10383.96	0.046
F-probablity	ns	***	***	***
CV (%)	0	1.88	1.25	1.27
Sowing date				
Chaitra 29	228022.36	505873.5[a]	733895.8[a]	3.22[a]
Baisakh 14	228022.36	385133.9[b]	613156.2[b]	2.68[b]
LSD	0	7342.56	7342.56	0.032
F-probablity	ns	***	***	***
CV (%)	0	1.88	1.25	1.27
Grand Mean	228022.36	445503.7	673526	2.95

DAS= days after sowing; treatment means followed by common letter(s) within column are not significantly different among each other based on DMRT at 5% level of significance.

Yield parameters and Yield

Highly significant differences were observed in yield parameters and yield due to plant spacing and sowing dates as shown in Table 2. In all yield parameters, earlier sowing date (Chaitra 29) produced significantly highest results as compared to later sowing date (Baisakh 14). The highest root weight (109.90 gm), fresh leaf weight (106.25 gm), root length (17.19 cm) and root circumference (12.31 cm) were observed at earlier sowing date. Similarly, earlier sowing date resulted in significant highest yield (24.46 t/ha). Delay in sowing decreased root weight due to unfavourable climatic conditions (Lavanya *et al.*, 2017). Earlier sowing date resulted in higher fresh leaf weight which may be due to favourable climatic conditions and longer growing period resulting more number of leaves/plant. Earlier sowing date also resulted in higher root length and higher root circumference. Earlier sowing date produced better yield than late sowing. These results are in correspondence with (Alam *et al.*, 2010).

Among plant spacing, root weight (126.28 g), fresh leaf weight (118.91 g) and root circumference (13.05 cm) were significantly higher in plant spacing of 40 cm. Wider spacing resulted in greater root weight as compared to narrow spacing. It may be due to less intraspecific competition in wider spacing which enables proper growth of root. Wider spacing resulted in greater fresh leaf weight as compared to closer spacing. It may be due to a greater number of leaves/plant produced by wider spacing Joshi *et al.* (1975). Wider spacing resulted in highest root circumference as compared to closer spacing. It may be due to the availability of space for lateral growth of root. However, this result was in contrast with (Khan *et al.*, 2016). The root length (17.98 cm) was significantly highest in plant spacing of 10 cm. The highest root length in closer spacing may be due to intraspecific competition foe space, nutrients and moisture as a result of dense plant population. This result is however in contrast with (Ghormade *et al.*, 1989). The highest yield (28.20 t/ha) was significantly resulted by plant spacing of 20 cm. Likewise, plant spacing of 10 cm produced significantly lowest root weight (55.43 gm), fresh leaf weight (81.50 gm) and root circumference (9.66 cm). The lowest root length (12.54 cm) was observed in plant spacing of 40 cm. plant spacing of 40 cm significantly resulted in lowest yield (15.78 t/ha). Although plant population was higher in plant spacing of 10 cm the highest yield was obtained in plant spacing of 20 cm. This may be due to the poor characteristics of root in individual plant in narrow spacing of 10 cm. Plant spacing of 20 cm may had resulted in highest yield due to optimum root characteristics. This result was in accordance with Chettri *et al.* (2019). Although individual plant weight was higher in wider spacing but the plant population per unit area was higher in case of plant spacing of 20 cm which resulted in greater yield per hectare. Similar result was obtained by Sharma *et al.* (2013).

Economic analysis

Since all inputs incurred were equal for all plots so there is no significant difference in cost of cultivation in individual plots. The gross return (NRs. 733895.8), net return (NRs. 505873.5) and B:C ratio (3.22) was significantly higher for earlier sowing date compared to late sowing date as shown in Table 3. Among plant spacing, 20 cm plant spacing gave significantly highest gross returns (NRs. 846125.0), net returns (NRs. 618102.6) and B:C ratio (3.71) whereas plant spacing of 40 cm gave lowest gross returns (NRs. 473562.5), net returns (NRs. 245540.1) and B:C ratio (2.07).

Conclusion

The results revealed that the highest yield was obtained from plant spacing of 20 cm (28.20 t/ha) and 10 cm (27.71 t/ha) followed by 30 cm and 40 cm. It is because the plant population per unit area was greater in 20 cm as compared to 40 cm which resulted in higher yield per hectare. However, individual plant weight was higher in wider spacing. Similarly, early sowing date gave higher yield (24.46 t/ha) as compared to later sowing date (20.43 t/ha). Delay in sowing resulted in gradual decrease of yield in radish. Root length (17.98 cm) was significantly highest in plant spacing of 10 cm while plant spacing of 40 cm showed significantly highest root weight (126.28 g), fresh leaf weight (118.91 g) and root circumference (13.05 cm). There was significant difference in growth parameters including plant height, number of leaves per plant, leaf length, leaf blade width and petiole length. Plant spacing of 20 cm showed significantly highest plant height (24.52 cm), number of leaves per plant (22.37) and leaf length (23.36 cm). Leaf blade width (10.67 cm) and petiole length (3.05 cm) was significantly highest in plant spacing of 30 cm. Early sowing date showed significantly better results for all growth and yield parameters except leaf blade width. Higher gross return, net return and the benefit cost ratio was observed in plant spacing of 20 cm followed by 10 cm and early sowing date. Thus, it is recommended to plant earlier and maintain plant spacing of 20 cm for higher yield of radish in Rupandehi district for off-seasonal cultivation.

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