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# Effect of Varied Fertiliser Levels and Varied Planting Dates on Yield, Quality and Economics of Rat Tail Radish (*Raphanus sativus* var. *caudatus*)

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***Authors' contributions***

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

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## ABSTRACT

Rat-tail radishes are the edible seed pods, or siliques, of ancient radish plants. Increased use of fertilisers is probably the most important single factor that has enabled crop production to increase significantly in recent years. The study investigated the impact of fertiliser doses in different planting times on yield, quality and economics of rat tail radish (*Raphanus sativus* var. *caudatus*). An experiment was conducted during the winter season of the year 2021-22 at the Hi-tech Unit, Department of Horticulture, under the Rajasthan College of Agriculture, Udaipur, India. The location of the experiment being situated at 24°35'N and 74°42'E latitude (585.5 meters above mean sea level), was very much convenient for the cultivation of rat tail radish at a temperature of 15-24 °C during the rabi season. Twelve treatments comprising various combinations of 4 levels of RDF, *viz.,* $N_0$-0%, $N_1$-75%, $N_2$-100% and $N_3$-125% RDF and three planting times, *viz.,* $D_1$-15.10.2021, $D_2$-30.10.2021 and $D_3$-15.11.2021, were selected. All the treatments for the chosen species were evaluated with three replications under the factorial randomised block design (RBD). According to the experimental results, various levels of RDF (recommended dose of fertiliser), planting times and their combinations significantly affected the yield, quality and economics of rat tail radish. Among the treatments, $T_4$-$D_1N_3$ (125% recommended dose of fertilizer with 15th October sowing) recorded significantly superior performance in terms of pod length (29.69 cm), pod diameter (5.80 mm), pod weight (5.42 g), pod yield per plant (0.35 kg), pod yield per hectare (128.27 q), and quality parameters such as total soluble solids (7.18 °Brix), total dry matter (10.17%), protein content (3.20%), and chlorophyll content (total 10.21 mg/g). This treatment also yielded the highest economic returns, with a gross return of ₹1,67,602.64/ha, the net return of ₹1,13,348.90/ha, and a benefit-cost ratio of 2.09. While the lowest values for all parameters were observed under $T_9$-$D_3N_0$ (0% RDF with 15th November sowing), indicating poor crop performance under late sowing and no fertiliser application. These findings highlight the importance of optimal nutrient management and timely sowing for maximising productivity and profitability.

*Keywords: Rat tail radish; fertiliser doses; planting time; yield; quality and economics.*

## 1. INTRODUCTION

Rat tail radish (*Raphanus sativus* var. *caudatus),* which is locally known as Mougri, belongs to the family Brassicaceae, having the chromosome number of 2n=18. It is believed to originate from Southeast Asia and China. Rat tail radish are small, slender and elongated pod, averaging 15 to 30 cm in length, and has a cylindrical, spindly shape, tapering slightly at both ends. The light green pods are smooth, pencil-thin and firm, sometimes displaying a knobbed appearance. Some kinds have dark purple pods or a variegated surface of green and purple. When consumed fresh, the pods are crispy and crunchy with a succulent, snap-like quality reminiscent of fresh chilli peppers. Consuming younger pods is suggested since they have a more sensitive feel. Older pods develop a fibrous, chewy nature. Rat tail radish contains a milder, peppery flavour compared to underground radish roots and has a delicate, vegetal pungency mixed with a subtle spiciness. In addition to the pods, some rat-tail radish varieties have edible pink or white flowers, and the young leaves can be consumed.

Rat-tail radishes are the edible seed pods, or siliques, of ancient radish plants. Rat tail radish plants can reach 60 to 121 cm in height in warm, sunny weather and are heavy producers, easy-to-grow, disease and pest-resistant and attractive ornamental additions to gardens. The crisp, spicy pods are normally harvested 45 to 50 days after sowing and are eaten raw or mildly cooked. Rat tail radishes are sold by a variety of names in markets across the world, including aerial radishes, podded radishes, spicy beans, and serpentine beans, and there are many distinct types with various pod colouration and appearance.

Rat-tail radishes have a peppery, pungent flavour well suited for raw or lightly cooked preparations, including steaming, frying, stir-frying, and boiling. The pods can be consumed straight, out of hand, or served on appetiser plates with dips. Salads, dressings, and sauces may all benefit from rat-tail radishes, which can also be sliced and used as a taco topper. In addition to fresh preparations, rat tail radishes can be utilised in recipes calling for root radishes and will retain their crisp nature, but throughout the cooking process, some of the flavours will be lost. The pods can be served as a side dish sautéed with butter and garlic, roasted with other vegetables, stir-fried as a crisp main dish, or blended into curries, soups, and stews. As a crunchy, sour snack and condiment, the pods can also be pickled with spices. Rat tail radishes pair well with chilli peppers, eggplant, mushrooms, carrots, broccoli, meats such as poultry, beef, and pork, seafood including shrimp, crab, fish, and scallops, and spices such as turmeric, cardamom, ginger, cumin, and cinnamon. When kept in the crisper drawer of the refrigerator, whole, unwashed pods will last for several weeks.

Nutritionally, rat tail radishes are a good source of vitamin C to strengthen the immune system, folic acid to develop red blood cells, and potassium to balance fluid levels within the body. In human diets, it provides a rich source of vitamin A, vitamin C, minerals, and carbohydrates. Breeding improvement for many cultivars and F1 hybrids has focused on size, colour, and shape of the root as well as resistance and horticultural traits (Arro & Labate, 2022). The pods also include magnesium, which helps to govern nerve function, calcium, which helps to protect bones and teeth, copper, which helps to maintain a healthy metabolism, and other vitamins like $B_6$ and riboflavin. Besides this, the pods of rat tail radish contain 92.3% moisture, 1.3%t protein, 0.3% fat, 1.1% fibre, 4.3% carbohydrates and 0.7% minerals. Pods also contain 7.8 mg calcium and 2.4 mg phosphorus per 100 g of edible portion (Sadhu and Sarkar 2003).

Increased use of fertilisers is probably the most important single factor that has enabled crop production to increase significantly in recent years. The role of nitrogen is regarded as a crucial component of protein, nucleic acids, chlorophyll, and some key enzymes, among the primary essential elements required by plants for appropriate growth, development, and production. On a global scale, nitrogen is agriculture's most widely used fertiliser nutrient. Studies have shown that crops use only 50% of the applied N effectively, while the rest is lost through various pathways to the surrounding environment (Govindasamy et al., 2023; Yu et al., 2022). Phosphorus is a macro element that plants require for growth and development. Its shortage results in poor growth of plants, and they remain immature. Hence, for the production of rat tail radish, optimum fertiliser is essential. An optimum sowing date in a particular ecological setting enables the accumulation of the desired growing degree days necessary for proper growth and development of the crop. To improve quality and production, it's critical to choose the best sowing date. The crop of radish sown on 15$^{th}$ September has shown significantly longer leaves than the crop grown at other dates (Lavanya et al. 2017).

Therefore, an experiment was made to study the impact of fertiliser doses in different planting times on yield, quality and economics of rat tail radish (*Raphanus sativus* var. *caudatus*).

## 2. MATERIALS AND METHODS

The present investigation was conducted at the Hi-tech Unit, Department of Horticulture, under Rajasthan College of Agriculture, Udaipur, India, during the winter season of the year 2021-22 on rat tail radish. The location of the experiment being situated at 24°35'N and 74°42'E latitude (585.5 meters above mean sea level), was very convenient for the cultivation of rat tail radish at a temperature of 15-24 °C during the rabi season. Seeds of local variety, "Marwadi Queen", were sown in the recommended spacing of 60 x 45 cm between rows and plants. The entire dose of phosphorus and potassium and half the dose of nitrogen were applied at the time of last ploughing. Whereas, the half dose of nitrogen was broadcast at 25 days after sowing along with life-saving irrigation. Among the four NPK combinations, our study was focused on $N_0$ (control: 0% RDF of 80-60-60), $N_1$ (75% RDF of 80-60-60), $N_2$ (100% RDF of 80-60-60), and $N_3$ (125% RDF of 80-60-60). A uniform application of different doses of NPK fertilisers (nitrogen through urea, phosphorus through di-ammonium phosphate and potassium through murate of potash) according to the treatments has been implicated in all the replications. The entire dose of phosphorus and potassium, along with the half dose of nitrogen, has been applied at the time of last ploughing. Whereas, the rest half of the nitrogen was broadcast at 25 days after sowing. Five plants were selected randomly from each plot to record the observation including length of the pod (cm), diameter of the pod (mm), pod weight (g), pod yield per plant (kg), pod yield per plot (kg), pod yield per hectare (q), TSS ($^0$Brix), total dry matter (%), protein content (%), chlorophyll a ( mg/g), chlorophyll b ( mg/g) and total chlorophyll (mg/g). The data were recorded for the evaluation of different treatments in rat tail radish and were statistically analysed by using the standard procedure of Panse and Sukhatme (1995) for analysis of variance of Factorial RBD in order to test the significance of experimental findings. The experiment comprised of 12 treatment combinations of 4 levels of RDF and 3 planting times include $T_1$- $D_1N_0$ (0% RDF at 15.10.2021), $T_2$- $D_1N_1$ (75% RDF at 15.10.2021), $T_3$- $D_1N_2$ (100% RDF at 15.10.2021), $T_4$- $D_1N_3$ (125% RDF at 15.10.2021), $T_5$- $D_2N_0$ (0% RDF at 30.10.2021), $T_6$ - $D_2N_1$ (75% RDF at 30.10.2021), $T_7$- $D_2N_2$ (100% RDF at 30.10.2021), $T_8$- $D_2N_3$ (125% RDF at 30.10.2021), $T_9$- $D_3N_0$ (0% RDF at 15.11.2021), $T_{10}$- $D_3N_1$ (75% RDF at 15.11.2021), $T_{11}$- $D_3N_2$ (100% RDF at 15.11.2021) and $T_{12}$- $D_3N_3$ (125% RDF at 15.11.2021).

## 3. RESULTS AND DISCUSSION

The results (Table 1) from the experiments have shown a significant influence of different levels of RDF of NPK on maximum values of length of pod (28.29 cm), diameter of the pod (5.80 mm), pod weight (5.42 g), pod yield per plant (0.35 kg), pod yield per plot (8.86 kg) and pod yield per hectare (128.27 q) with the treatment $N_3$ (125% RDF). While, the minimum values in length of pod (24.53 cm), diameter of the pod (4.72 mm), pod weight (4.50 g), pod yield per plant (0.24 kg), pod yield per plot (7.32 kg) and pod yield per hectare (108.56 q) for these parameters were found with treatment $N_0$ (0% RDF). This might be due to the various yield attributes like number of pods, weight of pods per plant and seed yield per plant showed their additive effect in influencing the yield per hectare distinctly with the increase in the rate of fertilizer application and it was interesting to note that each additional level of fertilizer brought a corresponding significant increase in yield and other parameters. Similar findings were also reported in cabbage (Hiwale 2010; Bibi et al., 2016), broccoli (Katiyar 2012) and radish (Panwar et al., 2001; Shukla et al., 2013; Kumar et al., 2013; Baloch 2014; Tripathi 2017).

Variation in planting time has also been found to contribute significant influence on maximum length of pod (27.07 cm), diameter of the pod (5.69 mm), pod weight (5.20 g), pod yield per plant (0.32 kg), pod yield per plot (8.58 kg) and pod yield per hectare (124.90 q) with the treatment $D_1$(15$^{th}$ Oct. sowing). However, the minimum values in length of pod (25.75 cm), diameter of the pod (4.75 mm), pod weight (4.69 g), pod yield per plant (0.28 kg), pod yield per plot (7.38 kg) and pod yield per hectare (110.03 q) for these parameters were found with the treatment $D_3$ (15$^{th}$ Nov. sowing). The increase in yield at the earliest date of planting may be due to the fact that early planting dates had improved yield attributes, *viz.,* increased number of pods, weight of pods per plant, which favorably resulted in higher yield per plant and other parameters. Similar results were found in carrot (Mengistu and Yamoah 2010), radish (Warade et al., 2004; Lavanya 2017; Sahu et al., 2018; Al-jubeori et al., 2019; Singh et al. 2021), broccoli (Madumathi 2017) have been reported.

The effect of interaction between levels of RDF and planting times on maximum length of pod, diameter of the pod, pod weight, pod yield per plant, pod yield per plot and pod yield per hectare was found to be significant. The maximum values of length of pod (29.69 cm), diameter of the pod (6.30 mm), pod weight (5.57 g), pod yield per plant (0.40 kg), pod yield per plot (10.05 kg) and pod yield per hectare (139.89 q) with the treatment $D_1N_3$ (125% RDF and 15$^{th}$ Oct. sowing). Whereas, the minimum values of length of pod (24.09 cm), diameter of the pod (4.29 mm), pod weight (4.13 g), pod yield per plant (0.22 kg), pod yield per plot (6.81 kg) and pod yield per hectare (103.64 q) with the treatment $D_3N_0$ (0% RDF and 15$^{th}$ Nov. sowing) respectively.

The outcomes have shown (Table 2) a significant influence of different levels of RDF on highest TSS (6.62 °Brix), total dry matter (9.75%), protein content (2.74%) and chlorophyll *a*, *b* and total chlorophyll (7.53, 10.71 and 9.55 mg/g) was obtained with the treatment $N_3$ (125% RDF). However, the minimum TSS (5.10 °Brix), total dry matter (8.25%), protein content (1.96%) and chlorophyll *a*, *b,* and total chlorophyll (5.75, 9.49 and 8.38 mg/g) were observed in the treatment $N_0$ (0% RDF). Our results of getting better plant performance with increasing rate of NPK are alike to the findings of previously conducted experiments in broccoli (Basumatary et al., 2017).

Planting time also had a significant effect on TSS (6.28 °Brix), total dry matter (9.64%), protein content (2.80%) and chlorophyll *a*, *b* and total chlorophyll (7.13, 10.58 and 9.56 mg/g) maximum was found in treatment $D_1$ (15$^{th}$ Oct. sowing). While the minimum TSS (5.50 °Brix), total dry matter (8.45%), protein content (1.81%) and chlorophyll *a*, *b* and total chlorophyll (5.56, 9.30 and 8.22 mg/g) which was reported in treatment $D_3$ (15$^{th}$ Nov. sowing).

The effect of interaction between levels of RDF and planting times on TSS, total dry matter, protein content and chlorophyll *a*, *b* and total chlorophyll was found to be significant.

**Table 1. Impact of various levels of RDF, planting times and their combinations on length of pod, diameter of pod, pod weight, pod yield per plant, pod yield per plot and pod yield per ha of rat tail radish**

| Treatment | Length of the Pod (cm) | Diameter of the Pod (mm) | Pod Weight (g) | Pod yield per plant (kg) | Pod yield per plot (kg) | Pod yield per ha (q) |
|---|---|---|---|---|---|---|
| **RDF** | | | | | | |
| **$N_0$** | 24.53 | 4.72 | 4.50 | 0.24 | 7.32 | 108.56 |
| **$N_1$** | 25.64 | 5.05 | 4.82 | 0.27 | 7.57 | 112.32 |
| **$N_2$** | 26.62 | 5.58 | 5.26 | 0.31 | 8.03 | 118.22 |
| **$N_3$** | 28.29 | 5.80 | 5.42 | 0.35 | 8.86 | 128.27 |
| **SEm±** | 0.12 | 0.01 | 0.01 | 0.01 | 0.14 | 0.78 |
| **CD at 5%** | 0.34 | 0.04 | 0.04 | 0.02 | 0.39 | 2.23 |
| **Planting time** | | | | | | |
| **$D_1$** | 27.07 | 5.69 | 5.20 | 0.32 | 8.58 | 124.90 |
| **$D_2$** | 25.99 | 5.42 | 5.11 | 0.29 | 7.88 | 115.60 |
| **$D_3$** | 25.75 | 4.75 | 4.69 | 0.28 | 7.38 | 110.03 |
| **SEm±** | 0.09 | 0.01 | 0.01 | 0.01 | 0.11 | 0.61 |
| **CD at 5%** | 0.26 | 0.03 | 0.03 | 0.02 | 0.30 | 1.73 |
| **N x D** | | | | | | |
| **$T_1$ - $D_1N_0$** | 24.93 | 5.08 | 4.72 | 0.26 | 7.54 | 113.34 |
| **$T_2$ - $D_1$ $N_1$** | 26.27 | 5.34 | 4.98 | 0.28 | 7.94 | 118.45 |
| **$T_3$ - $D_1$ $N_2$** | 27.40 | 6.05 | 5.53 | 0.33 | 8.77 | 127.91 |
| **$T_4$ - $D_1$ $N_3$** | 29.69 | 6.30 | 5.57 | 0.40 | 10.05 | 139.89 |
| **$T_5$ - $D_2$ $N_0$** | 24.58 | 4.80 | 4.65 | 0.25 | 7.60 | 108.71 |
| **$T_6$ - $D_2$ $N_1$** | 25.35 | 5.17 | 4.93 | 0.27 | 7.64 | 112.52 |
| **$T_7$ - $D_2$ $N_2$** | 26.44 | 5.76 | 5.35 | 0.29 | 7.88 | 116.74 |
| **$T_8$ - $D_2$ $N_3$** | 27.59 | 5.95 | 5.51 | 0.34 | 8.40 | 124.44 |
| **$T_9$ - $D_3$ $N_0$** | 24.09 | 4.29 | 4.13 | 0.22 | 6.81 | 103.64 |
| **$T_{10}$ - $D_3$ $N_1$** | 25.31 | 4.64 | 4.55 | 0.27 | 7.14 | 105.99 |
| **$T_{11}$ - $D_3$ $N_2$** | 26.01 | 4.93 | 4.90 | 0.30 | 7.45 | 110.01 |
| **$T_{12}$ - $D_3$ $N_3$** | 27.59 | 5.14 | 5.18 | 0.31 | 8.14 | 120.47 |
| **SEm±** | 0.21 | 0.02 | 0.02 | 0.01 | 0.24 | 1.36 |
| **CD at 5%** | 0.59 | 0.07 | 0.07 | 0.03 | 0.68 | 3.86 |

**Table 2. Impact of various levels of RDF, planting times and their combinations on TSS, Total dry matter, Protein content, Chlorophyll *a*, Chlorophyll *b* and Total chlorophyll of rat tail radish**

| Treatment | T.S.S. (°Brix) | Total D.M. (%) | Protein content (%) | Chlorophyll *a* (mg/g) | Chlorophyll *b* (mg/g) | Total Chlorophyll (mg/g) |
|---|---|---|---|---|---|---|
| **RDF** | | | | | | |
| **$N_0$** | 5.10 | 8.25 | 1.96 | 5.75 | 9.49 | 8.38 |
| **$N_1$** | 5.61 | 9.00 | 2.36 | 6.17 | 9.99 | 8.80 |
| **$N_2$** | 6.11 | 9.29 | 2.64 | 6.45 | 10.07 | 9.03 |
| **$N_3$** | 6.62 | 9.75 | 2.74 | 7.53 | 10.71 | 9.55 |
| **SEm±** | 0.09 | 0.23 | 0.02 | 0.08 | 0.09 | 0.10 |
| **CD at 5%** | 0.25 | 0.66 | 0.07 | 0.22 | 0.25 | 0.28 |
| **Planting time** | | | | | | |
| **$D_1$** | 6.28 | 9.64 | 2.80 | 7.13 | 10.58 | 9.56 |
| **$D_2$** | 5.80 | 9.13 | 2.66 | 6.74 | 10.33 | 9.03 |
| **$D_3$** | 5.50 | 8.45 | 1.81 | 5.56 | 9.30 | 8.22 |
| **SEm±** | 0.07 | 0.18 | 0.02 | 0.06 | 0.07 | 0.08 |
| **CD at 5%** | 0.19 | 0.51 | 0.05 | 0.17 | 0.19 | 0.21 |
| **N x D** | | | | | | |
| **$T_1$ - $D_1N_0$** | 5.63 | 9.44 | 2.23 | 6.44 | 10.14 | 8.95 |
| **$T_2$ - $D_1$ $N_1$** | 5.92 | 9.34 | 2.68 | 6.77 | 10.49 | 9.54 |
| **$T_3$ - $D_1$ $N_2$** | 6.37 | 9.64 | 3.09 | 6.76 | 10.43 | 9.54 |
| **$T_4$ - $D_1$ $N_3$** | 7.18 | 10.17 | 3.20 | 8.53 | 11.26 | 10.21 |
| **$T_5$ - $D_2$ $N_0$** | 5.30 | 8.71 | 2.25 | 5.81 | 9.46 | 8.35 |
| **$T_6$ - $D_2$ $N_1$** | 5.57 | 8.64 | 2.66 | 6.35 | 10.18 | 8.67 |
| **$T_7$ - $D_2$ $N_2$** | 6.03 | 9.21 | 2.83 | 7.04 | 10.33 | 9.11 |
| **$T_8$ - $D_2$ $N_3$** | 6.28 | 9.96 | 2.90 | 7.76 | 11.33 | 10.00 |
| **$T_9$ - $D_3$ $N_0$** | 4.37 | 6.61 | 1.41 | 4.99 | 8.88 | 7.83 |
| **$T_{10}$ - $D_3$ $N_1$** | 5.33 | 9.01 | 1.74 | 5.39 | 9.30 | 8.20 |
| **$T_{11}$ - $D_3$ $N_2$** | 5.94 | 9.03 | 1.99 | 5.55 | 9.46 | 8.43 |
| **$T_{12}$ - $D_3$ $N_3$** | 6.39 | 9.13 | 2.11 | 6.29 | 9.56 | 8.43 |
| **SEm±** | 0.15 | 0.40 | 0.04 | 0.14 | 0.15 | 0.17 |
| **CD at 5%** | 0.43 | 1.14 | 0.11 | 0.38 | 0.43 | 0.48 |

**Table 3. Impact of various levels of RDF, planting times and their combinations on the economics of rat-tail radish**

| Treatment | Cost of Cultivation (Rs/ha.) | Gross Return (Rs/ha.) | Net Return (Rs/ha.) | B:C |
|---|---|---|---|---|
| **RDF** | | | | |
| **$N_0$** | 47680 | 128405.27 | 80725.27 | 1.65 |
| **$N_1$** | 52041.58 | 134940.23 | 82898.65 | 1.59 |
| **$N_2$** | 53147.66 | 141738.44 | 88590.78 | 1.67 |
| **$N_3$** | 54253.74 | 153204.11 | 98950.37 | 1.82 |
| **SEm±** | | 694.06 | 694.06 | 0.01 |
| **CD at 5%** | | 1974.87 | 1974.87 | 0.04 |
| **Planting time** | | | | |
| **$D_1$** | 47680 | 149704.85 | 97924.11 | 1.89 |
| **$D_2$** | 47680 | 138004.61 | 86223.87 | 1.66 |
| **$D_3$** | 47680 | 131006.57 | 79225.83 | 1.50 |
| **SEm±** | | 537.61 | 537.61 | 0.01 |
| **CD at 5%** | | 1529.73 | 1529.73 | 0.03 |
| **N x D** | | | | |
| **$T_1$ - $D_1N_0$** | 47680 | 135604.08 | 87924.08 | 1.84 |
| **$T_2$ - $D_1$ $N_1$** | 52041.58 | 142409.72 | 90368.14 | 1.74 |
| **$T_3$ - $D_1$ $N_2$** | 53147.66 | 153202.96 | 100055.30 | 1.88 |
| **$T_4$ - $D_1$ $N_3$** | 54253.74 | 167602.64 | 113348.90 | 2.09 |
| **$T_5$ - $D_2$ $N_0$** | 47680 | 127605.20 | 79925.20 | 1.68 |
| **$T_6$ - $D_2$ $N_1$** | 52041.58 | 136003.08 | 83961.50 | 1.61 |
| **$T_7$ - $D_2$ $N_2$** | 53147.66 | 139604.88 | 86457.22 | 1.63 |
| **$T_8$ - $D_2$ $N_3$** | 54253.74 | 148805.28 | 94551.54 | 1.74 |
| **$T_9$ - $D_3$ $N_0$** | 47680 | 122006.52 | 74326.52 | 1.42 |
| **$T_{10}$ - $D_3$ $N_1$** | 52041.58 | 126407.88 | 74366.30 | 1.43 |
| **$T_{11}$ - $D_3$ $N_2$** | 53147.66 | 132407.48 | 79259.82 | 1.49 |
| **$T_{12}$ - $D_3$ $N_3$** | 54253.74 | 143204.40 | 88950.66 | 1.64 |

The maximum values for TSS (7.18 °Brix), total dry matter (10.17%), protein content (3.20%) and chlorophyll *a*, *b* and total chlorophyll (8.53, 11.26 and 10.21 mg/g) was recorded with the treatment $D_1N_3$ (RDF 125% and 15$^{th}$ Oct. sowing), Moreover, the minimum values for TSS (4.37 °Brix), total dry matter (6.61%), protein content (1.41%) and chlorophyll *a*, *b* and total chlorophyll (4.99, 8.88 and 7.83 mg/g) was reported with the treatment $D_3N_0$ (0% RDF and 15$^{th}$ Nov. sowing).

The economic aspects of cultivation are always associated with the package practices of any agricultural crop. Higher profits and lower cultivation costs are expedient for getting higher returns. Economic evaluation of different treatments for rat-tail radish under a hectare area has been depicted in Table 3. Economic analysis showed that the application of 125% RDF under treatment $N_3$ registered the highest benefit-cost ratio of 1.82. These findings are in agreement with Kumar et al., 2013 in radish, Parmar et al., 2015 in okra and Gessesew et al., 2015 in onion. In planting times, the highest benefit-cost ratio of 1.89 was found with the treatment $D_1$ (15$^{th}$ Oct. sowing). The higher net return per rupee investment of Rs. 97924.11 was registered in treatment $D_1$ (15$^{th}$ Oct. sowing). Economic analysis also showed that among different levels of RDF and planting times, treatment $D_1N_3$ (125% RDF and 15$^{th}$ Oct. sowing) significantly resulted in higher gross return (Rs. 167602.64), maximum net return (Rs. 113348.90) and benefit: cost ratio of 2.09.

## 4. CONCLUSION

On the basis of results from the present experimental study, it may be concluded that among the different levels of RDF, treatment $N_3$ (125% RDF) was found significantly better in terms of yield, quality and economics of rat tail radish. In different planting times, $D_1$ (15$^{th}$ Oct. sowing) had a significant impact on yield, quality and economic parameters of rat tail radish. Different levels of RDF and planting time also had a significant effect on the performance of rat tail radish; treatment $D_1N_3$ (125% RDF and 15$^{th}$ Oct. sowing) was found to have the best in terms of yield and quality parameters of rat tail radish than the rest of the treatments. Economic analysis showed that application of $D_1N_3$ (125% RDF and 15th Oct. sowing) was the most economically feasible as it produced higher gross return, maximum net return and benefit cost ratio.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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