Effect of Nitrogen Fertilizer and Irrigation Levels on Growth and Yield of Radish (*Raphanus sativus* L.) Under Increased Temperature Conditions

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Abstract – *Increased temperatures and water scarcity significantly impact crop growth. Radish (Raphanus sativus), a key vegetable, faces challenges from rising temperatures due to global warming. To explore the effects of nitrogen fertilizer and irrigation under increased temperature, a pot experiment was conducted with three nitrogen levels (recommended by the Department of Agriculture, 150%, and 200% of the recommended) and three irrigation levels (field capacity, 150%, and 200% of field capacity) under increased (35-36°C) and ambient (32-33°C) temperatures. The control treatment was the recommended nitrogen and field capacity irrigation under ambient temperature. The experiment was on Completely Randomized Design (CRD), with three replicates. Growth and yield parameters were recorded periodically. ANOVA and Duncan's Multiple Range Test (P<0.05) analyzed the data. Results indicated that under increased temperature, applying 150% of the recommended nitrogen with irrigation at 150% field capacity improved growth and yield. However, under ambient temperatures, growth and yield increased with the recommended nitrogen level and 150%, but declined at 200%. This suggests that higher nitrogen benefits radish growth under increased temperature but becomes harmful beyond 150%. Therefore farmers are advised to use higher nitrogen (150% of the recommended level) to cope with increased temperature due to global warming.*

Keywords: *Field capacity, Nitrogen fertilizer, Radish, Temperature stress, Yield*

1 INTRODUCTION

Radish (*Raphanus sativus* L.) belongs to the Cruciferae family and is a rapidly growing herbaceous plant. Its edible part is the fleshy root, commonly consumed either as a salad or a cooked vegetable. In every 100 grams of this edible portion, radish consists of approximately 95.5% water, along with 1.0 grams of protein, 0.1 grams of fat, 30.6 grams of carbohydrates, 0.7 grams of fiber, and 0.8 grams of ash. Radish enjoys popularity as one of the prominent root vegetables in Sri Lanka, cultivated in various regions of the country. There's significant potential for increasing both the quality and quantity of radish to enhance its export volume. Several factors influence radish yield, including temperature, water availability, and nutrient management.

Global warming presents a substantial threat to the world, arising from natural processes and human activities, resulting in rapid climatic changes. Climate change can lead to abnormal weather patterns affecting agricultural production through temperature fluctuations and water availability alterations (Syaukat, 2011). This is especially concerning for developing countries, where agriculture relies heavily on climate conditions. Furthermore, climate change exacerbates hunger and food security issues by increasing the risk of crop failure and livestock loss (Syaukat, 2011). With the world's population expected to reach nine to ten billion by 2050, there's a growing demand for increased food production. However, crops are confronted with challenges posed by rising temperatures and water stress, which disrupt cellular and developmental processes, leading to significant reductions in crop yields (Huq *et al.*, 2020). According to the Intergovernmental Panel on Climate Change (IPCC), global mean temperatures are projected to increase by 0.2°C per decade in the coming years (IPCC expert meeting report, 2007). Studies based on the HadCM3 general circulation model suggest that temperatures in Sri Lanka will rise in the future, with Anuradhapura predicted to experience a 2°C increase by the 2050s compared to the baseline temperature of 1961-1990 (De Silva *et al.* 2007). Additionally, decreased rainfall is anticipated in many parts of Sri Lanka, particularly in the dry zone (De Silva, 2006). High temperatures and water stress during the vegetative and reproductive phases significantly impact crop growth (Nishyma, 1970). Therefore, implementing measures to mitigate temperature and water stress on crop growth and yield is of utmost importance.

Fertilization is crucial for vegetable production to ensure optimal yield and quality (Zhang *et al.* 2015). Among the essential nutrients, nitrogen plays a pivotal role in plant growth, development, and yield (Singh *et al.* 2003). Nitrogen significantly influences root characteristics, leaf number/weight per plant, and the number of marketable roots (Soundа*et al.* 1998). Additionally, nitrogen applications have been found to progressively increase root yield in carrots (Ali *et al.* 2003). In radish cultivation, nitrogen fertilizer is essential, especially in the early stages, to promote robust root development (Patel, 2016). Nitrogen also enhances vegetative growth, fosters quality foliage, and supports carbohydrate synthesis (Patel, 2016). Many studies have indicated that the highest plant growth in radish occurs with the highest nitrogen rates (Piotr *et al.* 2011). Nitrogen is essential for increasing a plant's ability to tolerate high-temperature conditions (Waraich, 2012). However, excessive nitrogen application can lead to reduced crop yield (Chen *et al.* 2004) and nitrate leaching, which can contribute to groundwater pollution (Wang *et al.* 2002). Therefore, determining the effective nitrogen application levels is crucial in crop cultivation to optimize growth and yield while minimizing environmental impacts.

This present study was conducted to assess the impact of varying nitrogen fertilizer levels and irrigation regimes on growth parameters (plant height, number of leaves, leaf area) and yield parameters (fresh tuber weight, tuber length) under two temperature conditions: increased temperature (35-36 ^{0}C) and ambient temperature (32-33°C)under controlled conditions.

2.METHODOLOGY

Pot experiments were conducted at the Open University of Sri Lanka, Nawala during 2019-2020 under two distinct temperature conditions: a net house with an average ambient temperature of approximately 32-33°C and a polytunnel with temperatures ranging from 35-36°C. The polytunnel employed a top-vent roof design (as depicted in Fig.1). To regulate the temperature inside the polytunnel, automatic ventilation fans were activated whenever the temperature exceeded the thermostat's predetermined maximum setting. These fans operated until the temperature inside the polytunnel returned to the preset maximum temperature. The polytunnel structure was constructed using 120-micron gauge polyvinyl chloride (PVC) sheeting, ensuring more than 90% light transmittance. It had a semi-circular elongated shape with an open space at the top, facilitating natural air circulation.

Fig. 1: Front view of the polytunnel

The plant house utilized a sturdy rigid wall frame for its structure, with the roof constructed from a 120-micron gauge polyvinyl chloride (PVC) sheet, ensuring excellent light transmittance of over 90% (Fig. 2). To provide shade and protect the plants, a UV-stabilized polyethylene shade net was employed, which effectively blocked 50% of the sunlight. This shade net was used to cover the sides of the plant house and was supported by fiberglass hoops, secured in place using clothespins.

Fig. 2: Front view of the plant house

Throughout the growing season, daily measurements of relative humidity and light intensity were conducted inside both the polytunnel and the net house to assess potential significant differences between the two environments.

The increased temperature condition, set at 35-36°C, was selected based on findings from the Intergovernmental Panel on Climate Change (IPCC, 2007) and the HadCM3 (UK) projections for Sri Lankan air temperature in 2050, specifically for the A2 scenario of the IPCC (De Silva *et al.* 2007; De Silva, 2006). To further analyze temperature variations, observations were made over a 24-hour period inside both the polytunnel and the nethouse. The radish variety used in this experiment was *Beeraluraabu*. The experimental layout followed a Completely Randomized Design with three replications. The soil utilized in the study was Reddish Brown Earth soil (Alfisols)with a sandy loam texture.

The experimental treatments consisted of three nitrogen fertilizer levels, namely the recommended level of nitrogen (N1), 150% of the recommended level of nitrogen (N2), and 200% of the recommended level of nitrogen (N3), in combination with three irrigation levels: field capacity (I1), 150% of field capacity (I2), and 200% of field capacity (I3).

Plastic pots,25 cm in height and 28.5 cm in diameter, were employed for this experiment. Prior to commencing the experiment, the soil underwent a preparatory process. This involved the removal of stones and crop residues, followed by thorough mixing, air drying, and crushing to prevent waterlogging conditions. The pots were prepared by first placing a layer of washed gravel with a 1cm diameter at the bottom to aid drainage and prevent excessive water accumulation. Each pot was then filled with soil to achieve the desired waterlogging conditions. The bottom of the pot featured holes to facilitate drainage and prevent media from becoming waterlogged due to excessive water application. Approximately 8.5 kg of soil was incrementally added to each pot to ensure uniform packing (Fig. 3).

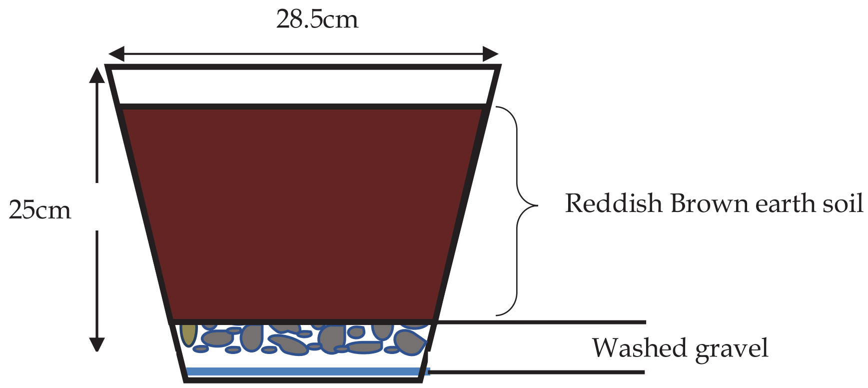

Fig. 3: Designed pot used for the study

The details of all the treatments which are used in this study were furnished below (Table 1)

Table 1: Different treatments used to identify the interaction effect of nitrogen fertilizers and irrigation amount on growth and yield of radish and nitrate leachate.

Factors	Increased temperature condition (35- 36^{0}C)	Ambient temperature condition (32- 33 ^{0}C)
Factor 1 (Different levelof nitrogen)	100% of recommended level (N1)	100% of recommended level (N1)
	150% of recommended level (N2)	150% of recommended level (N2)
	200% of recommended level (N3)	200% of recommended level (N3)
Factor2 (Different level of field capacity)	100% of field capacity (I1)	100% of field capacity (I1)
	150% of field capacity (I2)	150% of field capacity (I2)
	200% of field capacity (I3)	200% of field capacity (I3)

The plants receive watering once every three days. An additional set of 27 pots were positioned inside both the net house and the polytunnel (three extra pots for each treatment, without fertilizer and plants) to quantify the weight loss in the growing medium due to evaporation. Prior to irrigation, all pots, including those in the polytunnel and the net house, were initially weighed to ensure a consistent weight in each pot. The irrigation followed the field capacity guidelines, with three replicates. Based on the observed weight losses, the necessary amount of water for each pot was calculated. Other management practices adhered to the recommendations provided by the Department of Agriculture in Sri Lanka. Parameters such as plant height, number of leaves, and leaf area were recorded on a weekly basis. The length, fresh weight, and dry weight of the radish tubers were determined at the end of the experiment when the radishes were harvested.

Table 2: Growth and yield parameters of radish (*Raphanus sativus*) collected in the study

	Radish	
Growth Parameters		**unit**
• Plant height	The height of the plants within each replicate was measured in centimeters by assessing the distance from the ground level to the tip of the growing shoot. Subsequently, the average height was calculated for each treatment.	cm
• Number of leaves	Number of leaves counted in three replicates of each treatment and taken as a mean value	-
• Area of leaf	Randomly selected 5 leaves taken from each replicate and Grid counting method was used	cm^2
Yield Parameters		**unit**
• Fresh weight of root	The fresh weight of the roots was determined using an electronic balance. After removing the leafy portions and eliminating any soil or debris, the weights of the roots in all three replicates were measured, and the mean value was calculated for each treatment.	g

The data underwent statistical analysis (ANOVA), and distinctions between the means were assessed for significance using a revised Least Significant Difference (LSD) test at the 0.05 significance level, as outlined by Snedecor and Cochran (1989).

3 RESULTS AND DISCUSSION

There are no statistically significant differences (P>0.05) that were observed in terms of relative humidity and light intensity between the polytunnel and the net house. It was observed that the temperature within the net house consistently remained below the maximum temperature threshold established for the polytunnel. Throughout the day, the temperature inside the net house exhibited diurnal variations in line with observed data. Notably, the temperature within the polytunnel consistently exceeded the ambient temperature within the net house (Fig.4).

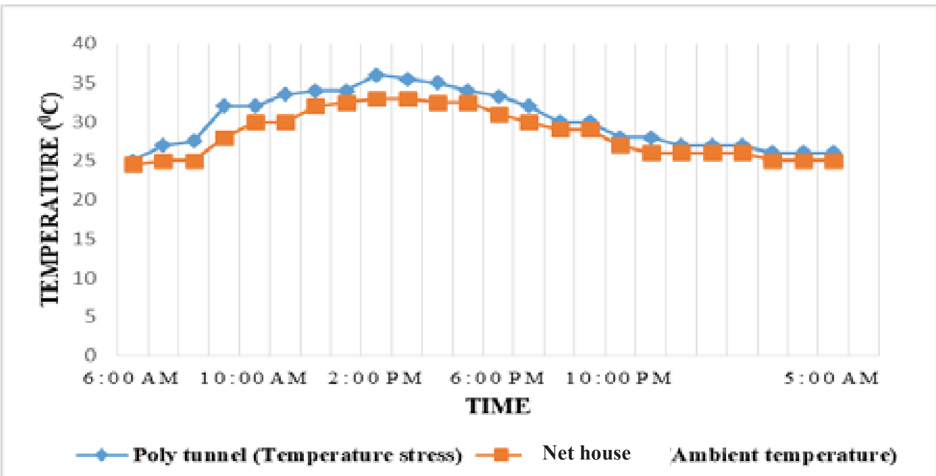

Fig.4. Temperature variations inside of the poly tunnel and net house

Growth Parameters

- ***Plant height***

The data concerning plant height, as depicted in Fig.5, revealed a significant difference among treatments ($p<0.05$). The tallest plants were observed under the treatment with 150% nitrogen and irrigation at 100% field capacity under ambient temperature conditions. These results were statistically on par with the plants treated with 150% nitrogen and irrigated to 150% of field capacity under ambient temperature conditions, as well as the treatments involving 150% nitrogen and irrigation to 100% field capacity under increased temperature conditions.

The data illustrates that as the application of nitrogen fertilizer increased the height of radish plants. It also showed an increase in height within the range from the recommended nitrogen level to 150% of the recommended nitrogen level, followed by a decrease in height at the 200% nitrogen level (Fig. 5). This observed increase in plant height in response to nitrogen fertilizer application may be attributed to an enhanced ability to tolerate higher temperatures. These findings align with the results reported by Rupp and Hubner

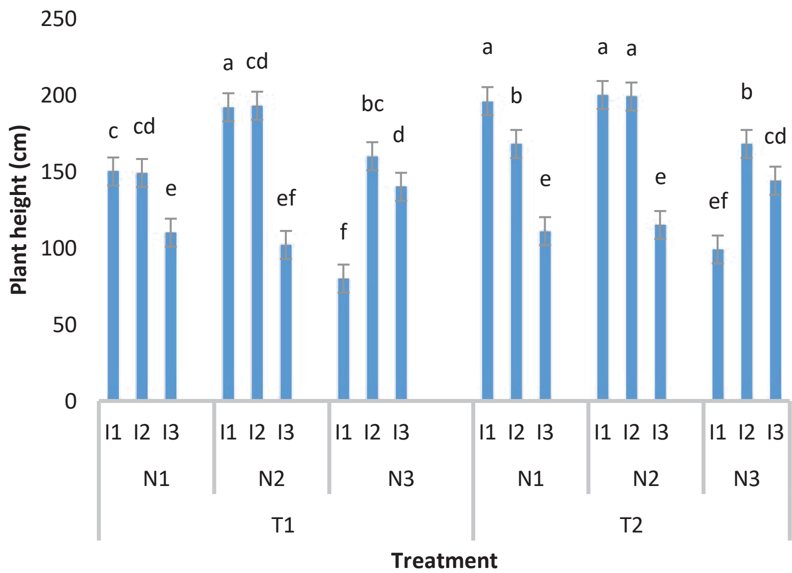

Fig. 5: Effect of different level of nitrogen fertilizer application and irrigation level on height of radish (*Raphanus sativus*) under 35-36 ºC (increased temperature condition) and 32 -33 ºC (ambient temperature condition)

Note: Values followed by same letter are not significantly different at p =0.05 level

- ***Number of leaves***

According to the analyzed data, it was evident that the interaction effect of nitrogen fertilizer and irrigation levels had a significant impact ($p<<0.05$) on the number of leaves. Treatments involving 150% of the recommended nitrogen level, coupled with irrigation to 100% of field capacity or 150% of field capacity, exhibited a higher number of leaves under both increased and ambient temperature conditions. In contrast, treatments using 200% of the recommended nitrogen level, in conjunction with irrigation to 100% of field capacity under increased temperature conditions, displayed a lower number of leaves (Fig. 6).

Notably, the number of leaves recorded its highest values with 150% of nitrogen coupled with irrigation to field capacity or 150% of field capacity. However, this number began to decline significantly as nitrogen levels increased, regardless of whether it was under increased or ambient temperature conditions. These outcomes align with the findings reported by Mohidi*et al*. (2015).

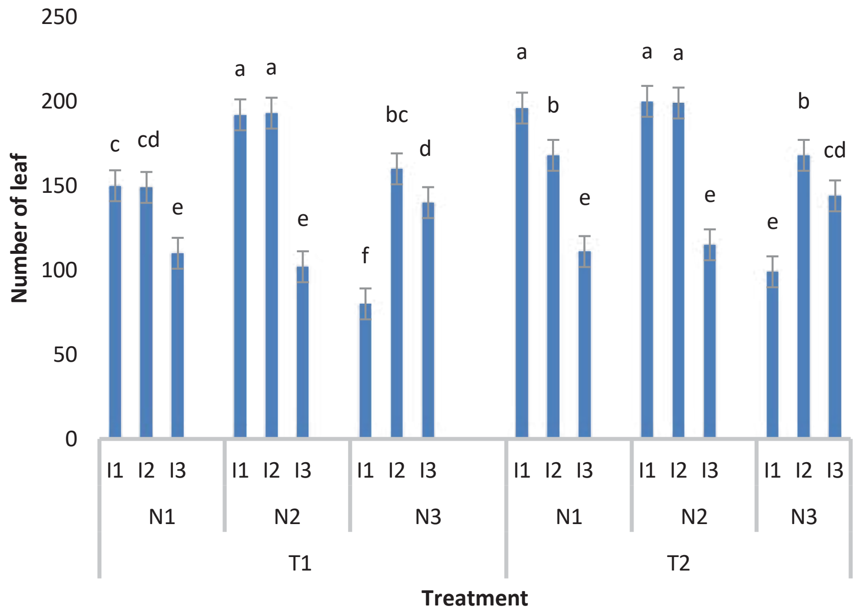

Fig.6: Effect of different level of nitrogen fertilizer application and irrigation level on number of leaves of radish (*Raphanus sativus*) under 35-36 °C (increased temperature condition) and 32 -33 °C (ambient temperature condition)

Note: Values followed by same letter are not significantly different at p =0.05 level

- *Leaf Area*

The application of nitrogen fertilizer and irrigation levels yielded significant variations in leaf area. Among the treatments, those involving 150% of nitrogen with irrigation to field capacity exhibited the highest leaf area, especially under increased temperature conditions. This observation held statistical significance when compared to the treatments applying 150% of nitrogen with irrigation to 150% of field capacity under increased temperature conditions (Fig. 7).

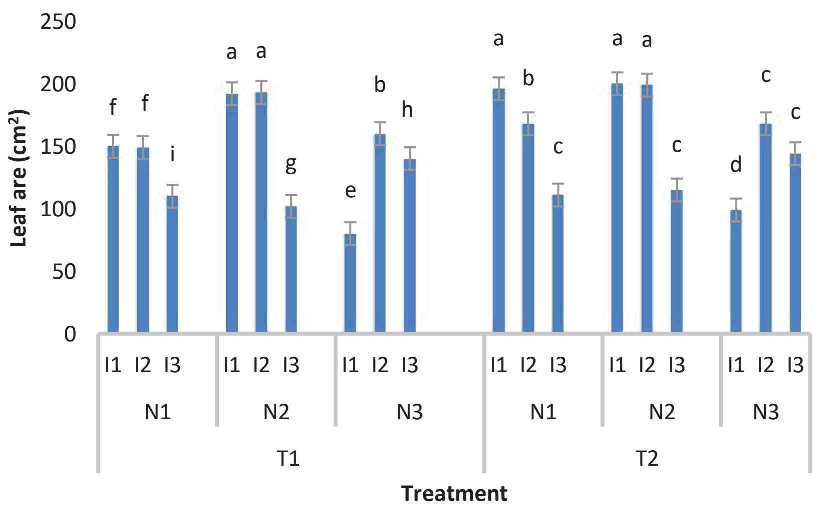

Fig. 7: Effect of different level of nitrogen fertilizer application and irrigation levels on leaf area of radish (*Raphanus sativus*) under 35-36 °C (increased temperature condition) and 32 -33 °C (ambient temperature condition)

Note: Values followed by same letter are not significantly different at p =0.05 level

The study's results indicated a significant reduction in leaf area as the nitrogen level was elevated to 200%. This decline might be attributed to the potentially detrimental effects of high nitrogen levels, potentially reaching toxic levels and impeding plant growth. These findings are consistent with prior research conducted by Rupp and Hubner (1995).

Yield parameters

- ***Length of tuber (cm)***

The analysis of the data highlighted a significant interaction effect between nitrogen fertilizer and irrigation levels on tuber length, both under increased and ambient temperature conditions. The longest tubers were observed when radish plants were fertilized with 150% of the recommended nitrogen level and irrigated to field capacity under increased temperature conditions. However, this result did not exhibit a significant difference when compared to treatments involving 150% of nitrogen with 150% of field capacity under increased temperature conditions, as well as treatments applying the recommended nitrogen level with field capacity, 150% of the recommended nitrogen level with irrigation to field capacity, and 150% of field capacity under ambient temperature conditions (Fig.8). The study's findings suggest that the recommended nitrogen level alone is insufficient to achieve longer tuber lengths under increased temperature conditions.

1- N2I1T2	4- N1I2T1	7- N2I2T1
2- N2I2T2	5- N3I3T1	8- N2I1T1
3- N1I1T2	6- N3I3T2	9- N3I1T2
10- N2I3T2	13- N1I2T2	16- N2I3T1
11- N1I3T2	14- N3I2T1	17- N3I1T2
12- N1I3T1	15- N1I1T1	18- N3I1T1

Fig. 8: Effect of different level of nitrogen fertilizer application and irrigation levels on length of tuber of radish (*Raphanus sativus*) under 35-36 ^{o}C (increased temperature condition) and 32 -33 ^{o}C (ambient temperature condition)

- ***Weight of tuber (g)***

The radish yields were notably affected by the interplay of nitrogen fertilizer and irrigation levels, whether under increased or ambient temperature conditions. Under the increased temperature condition, the highest fresh tuber weight was achieved when radish plants were fertilized with 150% of the recommended nitrogen level and irrigated to field capacity. Conversely, the lowest value was observed when 200% of the recommended nitrogen level was used in conjunction with irrigation to field capacity (Fig. 9).

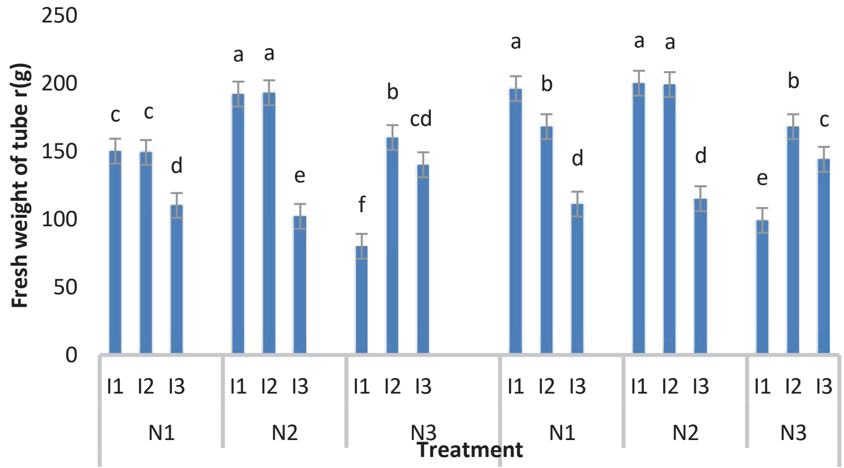

Fig.9: Interaction effect of different level of nitrogen fertilizer application and irrigation levels on fresh weight of tuber of radish (*Raphanus sativus*) under 35-36 ^{o}C (increased temperature condition) and 32 -33 ^{o}C (ambient temperature condition)

Note: Values followed by same letter are not significantly different at p =0.05 level

Based on the results, the yield of radishes exhibited an increase with the application of nitrogen fertilizer within the range from 100% of the recommended nitrogen level to 150% of the recommended nitrogen level under increased temperature conditions. However, this yield gradually decreased when the nitrogen application reached 200% of the recommended nitrogen level.

4 CONCLUSIONS

The study found that nitrogen and irrigation levels had a significant impact on both the growth and yield of radish under increased and ambient temperature conditions. The results demonstrated that as the nitrogen fertilizer application increased, the growth and yield of radish showed improvement within the range from the recommended nitrogen level to 150% of the recommended nitrogen level under increased temperature conditions. However, this improvement gradually declined when the nitrogen application reached 200% of the recommended nitrogen level under increased temperature conditions.

In contrast, under ambient temperature conditions, the recommended level of nitrogen fertilizer was sufficient to achieve higher yields, while it resulted in lower yields under increased temperature conditions. Notably, the treatment involving 150% of nitrogen with irrigation to field capacity emerged as the more effective approach for obtaining higher yields under increased temperature conditions. This finding will give a recommendation for farmers growing Radish when temperature increased due to global warming. However, the findings should be confirmed under field conditions prior to giving a concrete recommendation.

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