EFFECT OF GRADED LEVELS OF NPK ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.) cv. PUSA CHETKI

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DEPARTMENT OF VEGETABLE SCIENCE
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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF GRADED LEVELS OF NPK ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.) cv. PUSA CHETKI"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **VEGETABLE SCIENCE** to the College of Horticulture, Mudigere. University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Mr. AHMAD FAWAD SATARI ID No. MH2TAH0211** (satary.fawad@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of degree, diploma, associateship, fellowship or any other similar titles.

Mudigere
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(Mr. Ahmad Fawad Satari)

EFFECT OF GRADED LEVELS OF NPK ON GROWTH AND YIELD OF RADISH (*Raphanus sativus* L.) cv. Pusa Chetki

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ABSTRACT

The study was conducted to find out the optimum nutrient levels of NPK on growth and yield of radish cv. Pusa Chetki in open field condition at Department of Vegetable Science, College of Horticulture, Mudigere, during 2019-2020. The experiment consists of different levels of major nutrients, which were tried in various combinations and assessed for growth and yield parameters. Among different major nutrient levels, T_4 (200:100:50 kg NPK / ha) was recorded significantly maximum plant height (42.71 cm), number of leaves per plant (14.47), leaf length (32.57 cm), leaf width (11.86 cm), spread of the plant (N-S 40.81 cm and E-W 43.93 cm), stem diameter (1.53 cm), fresh weight of leaves, stem and root (70.94, 31.76 and 271.33 g, respectively), dry weight of leaves, stem and root (7.27, 1.63 and 9.89 g / plant, respectively), total dry matter of the plant (18.79 g), leaf area (350.67 cm^2), leaf area index (1.16), absolute growth rate (0.59 g / plant / day @ 31 - 45 DAS), crop growth rate (19.66 g / m^2 / day @ 31 - 45 DAS), net assimilation rate (0.0291 g / dm^2 / day @ 31 - 45 DAS), chlorophyll a & b (0.92 and 0.82 mg / g fr. wt, respectively), total chlorophyll content (1.75 mg / g fr. wt), root length (23.60 cm), root girth (13.13 cm) and root volume (257.00 cc) as compared to control. The maximum root yield per plot (5.00 kg), root yield per hectare (33.33 t) and benefit cost ratio (4.11) were also recorded in T_4 (200:100:50 kg NPK / ha). The above results revealed that application of 200 kg nitrogen, 100 kg phosphorus and 50 kg potassium per hectare were found to be optimum dose of nutrient level for best growth and yield of radish under hill zone of Karnataka.

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ಮೂಲಂಗಿ ತಳಿ ಪೂಸಾ ಚೆಟ್ಕಿಯಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯಲ್ಲಿ ಎನ್‌ಪಿಕೆಯ ಶ್ರೇಣೀಕೃತ ಮಟ್ಟಗಳ ಪರಿಣಾಮ (*ರಘನಸ್ ಸಟೈವಸ್* ಲಿ.)

ಅಹ್ಮದ್ ಫವಾದ್ ಸತರಿ

ಸಾರಾಂಶ

ಮೂಲಂಗಿಯ ತಳಿಯಾದ ಪೂಸಾ ಚೆಟ್ಕಿಯ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯ ಬಗ್ಗೆ ಅತ್ಯುತ್ತಮ ಪೋಷಕಾಂಶಗಳನ್ನು ಕಂಡುಹಿಡಿಯಲು ಈ ಅಧ್ಯಯನವನ್ನು ನಡೆಸಲಾಯಿತು. ೨೦೧೯–೨೦೨೦ರ ಅವಧಿಯಲ್ಲಿ ಮೂಡಿಗೆರೆಯ ತರಕಾರಿ ವಿಜ್ಞಾನ ವಿಭಾಗದ ತೋಟಗಾರಿಕೆ ಕಾಲೇಜಿನ ಮುಖ್ಯ ಕ್ಷೇತ್ರದಲ್ಲಿ ನಡೆದ ಈ ಪ್ರಯೋಗವು ವಿವಿಧ ಹಂತದ ಪೌಷ್ಟಿಕಾಂಶಗಳನ್ನು ಒಳಗೊಂಡಿರುತ್ತದೆ. ಪ್ರಯೋಗವು ಹತ್ತು ಹಂತದ ಪೋಷಕಾಂಶಗಳ ಸಂಯೋಜನೆಗಳಿಂದ ಒಳಗೊಂಡಿರುತ್ತದೆ. ವಿವಿಧ ಪೌಷ್ಟಿಕಾಂಶಗಳ ಮಟ್ಟಗಳಲ್ಲಿ, ಟ ಳ (೨೦೦:೧೦೦:೫೦ ಕೆಜಿ ಎನ್‌ಪಿಕೆ / ಹೆಕ್ಟೇರ್) ಗಮನಾರ್ಹವಾಗಿ ಗರಿಷ್ಠ ಸಸ್ಯದ ಎತ್ತರ (೪೨.೭೧ ಸೆಂ.ಮೀ.), ಪ್ರತಿ ಗಿಡಕ್ಕೆ ಎಲೆಯ ಅಗಲ ಎಲೆಗಳ ಸಂಖ್ಯೆ (೧೪.೪೭ ಸೆಂ.ಮೀ.), ಸಸ್ಯದ ಹರಡುವಿಕೆ (ಉತ್ತರ–ದಕ್ಷಿಣ ೪೦.೮೧ ಸೆಂ.ಮೀ. ಮತ್ತು ಪೂರ್ವ–ಪಶ್ಚಿಮ ೪೩.೯೩ ಸೆಂ.ಮೀ.), ಕಾಂಡದ ವ್ಯಾಸ (೧.೫೩ ಸೆಂ.ಮೀ.), ಎಲೆಗಳ ತಾಜಾ ತೂಕ, ಕಾಂಡ ಮತ್ತು ಬೇರು ಕ್ರಮವಾಗಿ ೭೦.೯೪, ೩೧.೭೬ ಮತ್ತು ೨೭೧.೩೩ ಗ್ರಾಂ. ಎಲೆಗಳ ಒಣ ತೂಕ ಕಾಂಡ ಮತ್ತು ಬೇರು ಕ್ರಮವಾಗಿ೭.೨೭ ೧.೬೩ ಮತ್ತು ೯.೮೯ ಗ್ರಾಂ. / ಸಸ್ಯದ ಒಟ್ಟು ಒಣ ವಸ್ತು (೧೮.೭೯ ಗ್ರಾಂ.), ಎಲೆಗಳ ವಿಸ್ತೀರ್ಣ (೩೫೦.೬೭ ಸೆಂ.ಮೀ.), ಎಲೆ ಪ್ರದೇಶದ ಸೂಚ್ಯಂಕ (೧.೧೬), ಸಂಪೂರ್ಣ ಬೆಳವಣಿಗೆಯ ದರ (೦.೫೯ ಗ್ರಾಂ. ಸಸ್ಯ/ದಿನ ೩೧–೪೫ ಡಿಎಎಸ್), ಬೆಳೆ ಬೆಳವಣಿಗೆಯ ದರ (೧೯.೬೬ ಗ್ರಾಂ. ಮೀ.೨ ದಿನ ೩೧–೪೫ ಡಿಎಎಸ್), ನಿವ್ವಳ ಸಂಯೋಜನೆ ದರ (೦.೦೨೯೧ ಗ್ರಾಂ./ಡಿಎಂ೨ ದಿನ ೩೧–೪೫ ಡಿಎಎಸ್), ಕ್ಲೋರೊಫಿಲ್ ಎ, ಬಿ (೦.೯೨, ೦.೮೨ ಮಿ. ಗ್ರಾಂ./ಗ್ರಾಂ. ಕ್ರಮವಾಗಿ), ಒಟ್ಟು ಕ್ಲೋರೊಫಿಲ್ ಅಂಶ (೧.೭೫ ಮಿ. ಗ್ರಾಂ./ಗ್ರಾಂ.), ಬೇರಿನ ಉದ್ದ (೨೩.೬೦ ಸೆಂ.ಮೀ.), ಮೂಲ ಸುತ್ತಳತೆ (೧೩.೧೩ ಸೆಂ.ಮೀ.) ಮತ್ತು ಬೇರಿನ ಘನ ಅಳತೆ (೨೫೭.೦೦ ಸಿಸಿ) ಕಂಡುಬಂದಿದೆ. ಪ್ರತಿ ಪ್ಲಾಟ್‌ಗೆ ಗರಿಷ್ಠ ಬೇರಿನ ಇಳುವರಿ (೫.೦೦ ಕೆಜಿ), ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ ಗರಿಷ್ಠ ಬೇರಿನ ಇಳುವರಿ (೩೩.೩೩ ಟನ್ನು) ಮತ್ತು ಹೆಚ್ಚು ಲಾಭ ವೆಚ್ಚ ಅನುಪಾತ (೪.೧೧) ಅನ್ನು ಟ ಳ (೨೦೦:೧೦೦:೫೦ ಕೆಜಿ ಎನ್‌ಪಿಕೆ/ ಹೆಕ್ಟೇರ್)ನಲ್ಲಿ ದಾಖಲಿಸಲಾಗಿದೆ. ಮೇಲಿನ ಫಲಿತಾಂಶಗಳ ಆಧಾರದ ಮೇಲೆ ಕರ್ನಾಟಕದ ಗುಡ್ಡಗಾಡು ಪ್ರದೇಶದಲ್ಲಿ ಮೂಲಂಗಿಯ ಉತ್ತಮ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಗಾಗಿ ಹೆಕ್ಟೇರ್‌ಗೆ ೨೦೦ ಕೆ.ಜಿ ಸಾರಜನಕ, ೧೦೦ ಕೆ.ಜಿ ರಂಜಕ ಮತ್ತು ೫೦ ಕೆ.ಜಿ ಪೊಟ್ಯಾಸಿಯಮ್ ಅತ್ಯುತ್ತಮ ಪೌಷ್ಟಿಕಾಂಶದ ಮಟ್ಟವೆಂದು ಕಂಡುಬಂದಿದೆ.

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INTRODUCTION

I INTRODUCTION

Radish (*Raphanus sativus* L.) is one of the most popular root vegetable crop, which is cultivated for its enlarged edible roots. It is a quick growing and short duration vegetable crop suitable for growing both in temperate and tropical climate. Though Western Asia was considered as original home of radish, the variability existing among the cultivated forms in morphology and ecology signifies the multicenter origin of this crop. A wild species are available in Mediterranean region are considered probable progenitors of European radish. The Japanese type would have originated from wild species that remain in coastal region of Japan.

Radish root is a good source of vitamin-C (ascorbic acid) containing 15-40 mg per 100 g of edible portion and supplies a variety of minerals. Trace elements in radish include aluminum, barium, lithium, manganese, silicon, titanium, fluorine and iodine. Tender leaves which are used as greens are rich in vitamin-A and C. Roots are also rich in carbohydrate and protein. Pinked skinned radish is generally richer in ascorbic acid than the white skinned one. The characteristic pungent flavor of radish is due to the presence of volatile isothiocynates (Bose *et al.,* 2000).

Radish is a cool season crop but Asiatic types can tolerate high temperature than temperate types. The roots develop best flavor, texture and size at cooler temperature range of 10-15^{o}C. A long day with high temperature will result in bolting before proper root development. The roots also become hard, pithy and pungent during hot weather. The crop that is growing during main season *viz.,* mid-September to early October does not require any special technique. But in summer and spring season crops, the right cultivar should be selected and sown at proper season. Though radish can be grown on nearly all types of soil, light friable loam soil is found to be the best. In northern hills, the seeds are usually sown in the first fortnight of March until late October or beginning of November. In northern plains, Asiatic types are sown from August to January while European types are sown in September to March. The best sowing time in south Indian hills is from April-June and in plains is October-November.

Radish is mainly cultivated in Maharashtra, Assam, Utter Pradesh, Madhya Pradesh, Himachal Pradesh, Haryana, Jammu and Kashmir. The area under radish in India is 208.55 thousand hectares with an annual production of 3061.29 metric tons. Radish is mainly grown in all districts of Karnataka and the major districts are Bengaluru, Chikkaballapura, Chitradurga, Davanagere, Kolar, Ramanagara and Shivamogga and the area under radish in Karnataka is 5.73 thousand hectares with the production of 67.90 metric tons (Anon, 2018).

It is well documented that growth and yield of plants are greatly influenced by application of wide range of nutrients (Gupta, 2001). According to Mohamed (1984),

most of the farmers usually do not apply any fertilizer or just apply a small amount of urea or organic manures of unspecified quantity resulting in lower crop yield. Plants obtain nutrients from soil, besides water, different inorganic substances that are essential for the general metabolism of the plants. The supply and absorption of inorganic elements needed for growth and development is defined as nutrition and these elements are called plant nutrients.

Nitrogen is abundantly available (70-80%) in the atmosphere, but plants cannot take it directly from the atmosphere. Hence, nitrogen requirement of the plant is generally met out with the use of chemical fertilizers. However, on the other hand some microorganisms are available, which can fix atmospheric nitrogen in the plant roots. The balanced fertilization in radish is important factor to boost yield attributes. Nitrogen is the most deficient element especially in coarse texture sandy soil (Arkery *et al.*, 1956). Availability of nitrogen is important for growing plant as it is major indispensable constituent of protein and nucleic acid. An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs, finally leading to higher productivity. The application of nitrogen with different doses increases plant growth and yield of radish (Sharma, 1992). Deficiency of nitrogen first appears on older leaves due to high mobility of the element. Its deficiency causes interveinal yellowing, development of anthocyanin pigment, rolling of leaves, chlorosis and necrosis (Singh and Srivastava, 1962).

Phosphorus is indispensable constituent of nucleic acids, phospholipids and several enzymes. It is also needed for the transfer of energy within the plant system and is involved in its various metabolic activities, (Yawalker *et al*., 1962). Phosphorus has its beneficial effect on early root development, plant growth, yield and quality. Indian soils have poor to medium status in available phosphorus for crops and remaining part is converted to insoluble phosphorus. Phosphorus plays a key role in the formation of energy bound phosphate (ADP and ATP).

Potassium is one of the three major nutrient elements (N, P and K) required by plants. Potassium imparts vigor and disease resistance to the plant and plays an important role in crop productivity. It functions as an activator of numerous enzymes like pyruvic kinase activity, thus plays important role. It is always involved in the movement of carbohydrate, therefore, accumulation of carbohydrates and soluble nitrogen compound points towards diminishing protein synthesis in case of potassium deficiency. There are evidences of direct involvement of potassium in photosynthesis and its involvement in leaf tissues metabolic activities of chloroplast. It regulates transpiration through opening and closing of the stomata by affecting activities of guard cells (Mandal and Chatterjee, 1973).

There is a need to standardize various agronomic techniques to improve growth and yield in radish. Among the various cultural practices, application recommended doses of fertilizers play an important role in enhancing the root yield.

Keeping the above aspects in view, a study entitled on ‘‘Effect of graded levels of nitrogen, phosphorus and potassium on growth and yield of radish (*Raphanus sativus* L.)’’ was carried out at College of Horticulture, Mudigere with the following objectives:

1. To study the effect of graded levels of NPK on growth and yield of radish.
2. To determine the graded levels of NPK on the nutrient uptake of radish.
3. To work out the economics of radish cultivation as influenced by graded levels of NPK.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

The review of literature pertaining to the research work carried out on the effect of graded levels of nitrogen, phosphorus and potassium on growth and yield of radish and related crops are reviewed in this chapter.

2.1 Effect of nitrogen on growth, yield and nutrient uptake of vegetables

2.1.1 Effect of nitrogen on growth and yield

Anabousi *et al*. (1997) found that among the different doses of nitrogenous fertilizers applied on potato significant increase in plant height, tuber yield, tuber weight and reduction in the tuber dry matter with use of 250 kg N ha^{-1}.

Chowdhury *et al*. (2002) concluded that potato plant reached maximum height (64.17 cm) and foliage coverage (78.17 %) with 50 per cent basal + 50 per cent top dressing in two equal installments at 30 and 50 DAP and the minimum 57.40 cm and 73.90 per cent, respectively at 100 per cent basal dose.

Thapa *et al*. (2003) found that the radish cultivars Japanese white, Pusa Chetki and Ghatal local were supplied with 40, 60, 80 or 120 kg N/ha. The number of leaves per plant, length of leaves and roots, girth of roots and crop yield were highest with the application of 120 kg N/ha. Cultivar Japanese white produced highest yield (45.52 kg/ha), longest roots (47.93 cm) and more number of leaves per plant (52.90).

Maiti *et al*. (2004) studied the effect of graded doses of nitrogen (0, 80, 160 and 240 kg ha^{-1}) on the growth and tuber yield of potato cv. Kufri Jyoti during winter season of 2000 and 2001 in the sandy loam Entisol soil of Gangetic plains of West Bengal. The application of nitrogen influenced the growth attributes and tuber yield of potato in all the stages of growth.

Kanbi and Bhatnagar (2005) revealed that the application of 25 t ha^{-1} organic manure along with 100 per cent recommended dose of nitrogen in inorganic form or more than 50 per cent of recommended dose of nitrogen in inorganic form and remaining parts of nitrogen in castor cake or poultry manure increased the chlorophyll content, tuber yield, tuber dry matter and minimized storage losses in potato.

Love *et al*. (2005) noticed that Summit Russet (newly released variety) showed a strong trend for improved nitrogen use-efficiency when most of the nitrogen was applied early in potato crop.

Moshileh *et al*. (2005) studied the effect of different levels and splits of nitrogen fertilizer in potato. It has been observed that within each nitrogen level, the splitting of N doses significantly increased leaf coverage. The highest percentage of leaf coverage (67.96 %) was obtained with the application of 300 kg N ha^{-1} with three

equal split doses applied at 0, 45 and 60 days after planting during the growing seasons of 2002 and 2003.

Rahemi *et al*. (2005) found that nitrogenous fertilizer affected yield significantly in potato. The higher N fertilizer rate of 225 kg ha^{-1} resulted in 7.5 per cent increase in yield over the lower rate of 175 kg ha^{-1}.

Marguerite *et al*. (2006) found that tuber yield per unit area was increased with increasing nitrogen fertilizer up to suitable level. Also, increase in density led to significant increase in tuber yield of potato.

The increase in plant height, number of leaves per plant and leaf area index was observed with increasing nitrogen levels (0, 125, 187.5 and 250 kg / ha) in potato cv. Kufri Jawahar (Chopra *et al*., 2006). The higher nitrogen (175 kg / ha) in turmeric produced the taller plants (33.6 cm) (Kandiannan and Chandaragir, 2006).

Poljak *et al*. (2007) evaluated the effects of N application on fresh tuber yield and mineral composition as quality indicators of potato cultivars Victoria, Red Star and Remarka. The treatments comprised of four nitrogen rates (100, 150, 200 and 250 kg ha^{-1}) and a control (no fertilizer application). The application of the different N rates had a positive effect on the yield. Production of potato for processing industry, the application of N at rates higher than 150 kg ha^{-1} was not acceptable from the agronomical, ecological and economical point of view.

Tarle *et al.* (2007) reported that the application of nitrogen at 150 kg per ha was most superior over rest of the levels of nitrogen and produced the maximum plant height (56.72 cm), leaves per plant (129.51), tillers per plant (6.53) and leaf area per plant (3331.94 cm^2) in ginger.

Sailaja *et al*. (2007) from Hyderabad reported that the highest fresh and dry weight of roots (320.40 and 40.00 g / plant, respectively), number of roots per plant (15.1), root length (23.50 cm), highest fresh tuberous root yield (11.44 t / ha) and highest dry tuberous root yield (1.43 t / ha) were recorded with application of nitrogen at 40 kg per hectare in medicinal coleus.

Parveen *et al*. (2007) evaluated the response of potato crop to five nitrogen levels (0, 90, 180, 270 and 360 kg N ha^{-1}). There was a steady increase in tuber weight $plant^{-1}$, processing-grade tuber yield, total tuber yield and biomass yield in response to nitrogen application. A variety Kufri chipsona1 produced 23.60 per cent higher tuber yield $plant^{-1}$ than Kufri chipsona-2.

The experiment conducted to study the effect of different levels of nitrogen *viz*., 60, 120 and 180 kg ha^{-1} on growth and yield of potato cv. Kufri Sindhuri. Application of nitrogen at 180 kg ha^{-1} showed the best response of growth traits *viz*.,

number of sprouts (3.91), height of plant (62.77 cm) and number of leaves (55.50) as compared to other treatments (Bose *et al*., 2008).

Janagrad *et al*. (2009) studied the effects of different levels of nitrogen fertilizer (80, 160 and 200 kg N ha^{-1}) on vegetative growth of potato cultivars Agria and Satina. The results showed that Agria was significantly superior in all traits except stem length. As nitrogen level increases auxiliary branch number and plant height were also increased. The maximum stem, leaf biomass and leaf number were achieved with 160 kg N $ha^{-1}$and the highest main stem number was achieved with 80 kg N ha^{-1}. Similarly application of nitrogen led to increase in tuber yield than control (Saeidi *et al*., 2009).

Najm *et al*. (2010) conducted field experiment in Iran to evaluate the effect of cattle manure (5, 10, 15 and 20 t ha^{-1}), nitrogen fertilizer (50, 100 and 150 kg N ha^{-1}) and their interaction on potato growth. At the 75^{th} day after emergence, dry weight of shoots, leaf area index (LAI) and plant height were recorded. The results showed that dry weight of shoots, LAI plant height increased linearly and very significantly in response to the application of manure and nitrogen fertilizer.

Zamil *et al*. (2010) reported that the tuber yield ha^{-1} was significantly and positively correlated with plant height, foliage coverage, and number of stems $hill^{-1}$, fresh weight of haulm $hill^{-1}$, number of tubers $hill^{-1}$ and weight of tubers $hill^{-1}$. Also found a linear relationship between yield of tubers ha^{-1} with the different levels of nitrogen. Hence, results revealed that tuber yield increased with the application of higher levels of nitrogen in potato.

Baishya *et al.* (2010) stated that with the application of 75 per cent recommended dose of fertilizers (RDF) through chemical fertilizers along with 25 per cent recommended dose of nitrogen (RDN) through Farm Yard Manure (FYM) and any or 100 per cent RDF through chemical fertilizers recorded higher values with regard to growth parameters like plant height, number of shoots, number of leaves, fresh and dry weight of shoots per plant in potato crop.

Yassen *et al*. (2011) conducted two field experiments at El –Kassasin region to study the effect of nitrogen fertilizer on growth, tuber yield and chemical composition of potato. Results showed that nitrogen application resulted in an increase in the vegetative growth and tuber yield as compared to untreated plants.

Barghi *et al*. (2012) conducted an experiment with four levels of nitrogen fertilizers (0, 80,160 and 200 kg of N ha^{-1}) in main plots and two varieties of potato including Agria (late maturing) and Satina (early maturing) in sub plots, and concluded that a significant increase in tuber yield was recorded with the increase in the doses of nitrogen.

Zewide *et al*. (2012) studied on the effect of nitrogen rate on yield and yield components of potato. Four rates of nitrogen (0, 55, 110 and 165 kg ha^{-1}) were evaluated. Application of 165 kg N ha^{-1} significantly increased the number of days to physiological maturity by 13 days, days to flowering by 6 days, above ground biomass by 36 per cent, underground biomass by 29.79 per cent, total tuber yield by 60.33 per cent, marketable tuber number by 56.36 per cent, total tuber number by 31.7 per cent and average tuber weight by 22.43 per cent.

Similar studies were conducted to know the influence of nitrogen on potato productivity. The results indicated that an increase in nitrogen fertilizer rate up to 120 kg ha^{-1} increased the potato productivity and yield. Tuber nitrogen content increased with nitrogen fertilizer level, the nitrogen content increased from 1.09 per cent in the treatment NPK up to 1.53 per cent in treatment N_{120}. Nitrogen content in potato foliage was twice as high as that in tubers and continuously increased with the N application, and particularly with higher nitrogen fertilizer rates of 150 kg and 210 kg ha^{-1} (Antons *et al*., 2013).

Rizk *et al*. (2013) studied the response of potato crop to the foliar spraying of urea (2 & 3%) and reported that foliar application of urea increased the vigour of plant. Moreover, the better plant growth was recorded with plants received the higher urea (3%) level. Application of urea within 2-3 per cent as foliar spray was increased tuber yield.

Banjare *et al*. (2014) found that growth and yield parameters of var. Kufri Surya increased with increase in nitrogen levels. Significantly, higher number of tuber $plant^{-1}$ and $plot^{-1}$ as well as tuber yield $plot^{-1}$ and ha^{-1} was recorded with the application of 225 kg N ha^{-1} in potato crop.

Birtukan *et al*. (2016) conducted an experiment to study the effect of different levels of nitrogen on growth and yield of potato. Treatments comprised of four levels of nitrogen (0, 55, 110 and 165 kg N ha^{-1}). The results revealed that highest plant height (71.6cm), number of tubers (13.7 $hill^{-1}$), marketable tuber number (9.79 $hill^{-1}$) and total tuber yield (42.27 t ha^{-1}) were recorded at the combination of 165 kg N ha^{-1}. While, the lowest plant height (44 cm), minimum total tuber number (8.53 $hill^{-1}$) and lowest tuber yield (12.91 t ha^{-1}) was recorded in the control.

Jatav *et al*. (2017) studied on the performance of different varieties of potato under various nitrogen levels for growth, yield and quality of potato. The interaction effect showed that combination of potato variety Kufri Pushkar along with application of nitrogen at 150 kg ha^{-1} proved to be superior over other treatment combinations for growth, yield and economic parameters.

Sriom *et al*. (2017) revealed that the growth characters *viz*., plant height, number of haulms $hill^{-1}$, number of leaves $plant^{-1}$, fresh weight and dry weight of

plant recorded maximum with the application of 200 kg N ha^{-1}. The study revealed that the above treatment obtained maximum yield $plot^{-1}$and yield ha^{-1} during the periods of investigation in potato.

Sheth *et al.* (2017) revealed that the application of 50 per cent RDN through inorganic fertilizers + 50 per cent RDN through vermicompost in sweet potato had shown significant impact on growth parameters like vine length at 60, 90 DAT and at harvest (78.98 cm, 120.17 cm and 175.87 cm, respectively) and the highest number of leaves at harvest *i.e.* 138.80 per vine. Both of these characters were at par with 50 per cent RDN through inorganic fertilizers + 50 per cent RDN through FYM.

The highest plant height (34.77 cm) and maximum number of leaves (13.8) were recorded with the application of 120 kg Nitrogen per ha in radish Cv. Kashi Sweta (Tripathi *et al*., 2017). The maximum number of leaves (20.87, 15.58 and 14.08) in radish was recorded when N was applied at 90,120 and 150 kg per hectare, respectively (Shrestha and Thapa, 2018).

2.1.2 Effect of nitrogen on nutrient uptake

Tyler *et al*. (1983) revealed that N fertilized plants assimilated total N in a nearly linear pattern by 6 per cent, total N uptake ranged from 142 to 233 kg ha^{-1} indicating 134 kg N ha^{-1} as the optimum rate in case of white rose variety of potato. Tubers removed 178 N kg ha^{-1} of which 78 kg was derived from the applied fertilizer.

Farunes (1990) concluded that the amount of K_2O removed by potato increased with increased levels of nitrogen fertilization. At 100 kg K_2O was removed by potato at this range from 80 to 120 kg ha^{-1} of nitrogen application.

According to Sharma and Sharma (1990) application of N increased not only the uptake of N but also that of P_2O_5 and K_2O by tuber and the increase varied with cultivars. The contributions of N, P_2O_5 and K_2O uptake were 80 and 75 per cent, respectively. Whereas, the contribution of P_2O_5 to P_2O_5 uptake was 2.5 per cent and that of K_2O to K_2O uptake was 2.8 per cent in alluvial soil of Jalandhar. In potato tubers, P_2O_5 and K_2O accumulation increased significantly up to 200 kg ha^{-1}.

2.2 Effect of phosphorus on growth, yield and nutrient uptake of vegetables

2.2.1 Effect of phosphorus on growth and yield

Jain *et al.* (1986) recorded maximum growth and yield of cowpea with application of high doses of phosphorus. Youngdahl (1990) observed favorable effect of phosphorus on reproductive characters of French bean.

Dwivedi *et al.* (1995) revealed that variety Arka Komal significantly gave higher seed yield than contender mainly due to superiority in pods per plant, seeds per pod and shelling percentage. Both varieties responded up to 100 kg P_2O_5 and 50 kg K_2O ha^{-1} for seed yields in French bean.

Bhat and Singh (1997) revealed that application of phosphorus or seed treatment with gibberellic acid for 12 hours were not encouraging. However, two green pickings were optimum for raising good seed crop of okra.

Jarrotia and Sharma (1998) noted maximum of green pod yield with application of phosphorus @ 80 kg ha^{-1} in French bean variety of Contender during both the years of study. Roy and Parthasarathy (1999) observed that application of phosphorus improved the plant height and yield of French bean.

Gupta *et al.* (2000) showed increasing levels of phosphorus caused favourable increase towards yield and yield parameters such as length of pod, number of grains per pod and weight of pods in table pea. The maximum values with regards to these parameters were recorded under application of 75 kg ha^{-1} P_2O_5, which was at par with 50 kg P_2O_5 ha^{-1} in case of green pod yield and length of pod.

Sharma (2000) noticed that the application of 30 kg phosphorus per ha increased the number of branches per plant (8.03). Whereas the maximum plant height (123.2 cm) was observed with application of 90 kg phosphorus per ha in radish Cv. Japanese White.

Swaroop *et al*. (2001) found that green pod yield in cowpea was affected significantly due to phosphorus application. The maximum pod yield was obtained with the application of phosphorus @ 80 kg/ha. Whereas the maximum yield was also recorded with 60 kg K_2O ha^{-1}.

2.2.2 Effect of phosphorus on nutrient uptake

Kasturikrishna and Ahlawat (2000) conducted an experiment at New Delhi and reported that a significant increase in nitrogen and phosphorus content of pea crop due to application of 26.2 kg P_2O_5 ha^{-1} compared to control.

Application of phosphorus up to 40 kg ha^{-1} increased uptake of N, P and K in urd bean over lower levels and control (Rathore *et al.* 2010).

2.3 Effect of potassium on growth, yield and nutrient uptake of vegetables

2.3.1 Effect of potassium on growth and yield

Yang *et al*. (1993) observed that application of high doses of potassic fertilizer in combination with low doses of nitrogenous fertilizer gave the high tuber yield, quality and commodity value of potatoes.

Singh and Singh (1995) conducted an experiment at Varanasi, U.P. on potato cultivar Kufri Badshah. Applied potassium from 0 to 200 kg K_2O ha^{-1} as basal or 2 to 3 splits. Total tuber yield and yield of large and medium sized tubers, increased with increasing potassium rate, while number and yield of small tubers (< 3.75 cm) decreased as potassium rate increased. Tuber yield was highest when potassium was

applied half as basal dose and half at 30 days after planting. Similarly potassium application to potato induced disease resistance, reduces the proportion of culls and hence increases their marketable yield (Sekhon, 1998).

Allison *et al*. (2001) tested the effects of potassic fertilizer on yield of potato. The experiment was initiated on the soils that had exchangeable K values 120 mg l^{-1} but use of K fertilizer resulted in statistically significant increase in fresh weight yield. The average yield in the experiment was 48 t ha^{-1}. Generally, soil exchangeable K was a poor predictor of the probability of a yield response. Potassium fertilizer caused an increase in dry weight yield.

Chettri *et al*. (2002) reported that potassium content in potato plant was positively correlated with tuber yield and application of potassium increased potassium content of potato plant. Similarly harvest index and percentage dry matter increased with the application of potassium up to 100 kg ha^{-1} (Sharma and Sood, 2002).

The application of potassium can increase the proportion of processed grade tubers and tuber yield in potato. The results revealed that the net income and benefit cost ratio were highest for KCl followed by K_2SO_4 and lowest for KNO_3 (Kumar *et al*., 2007).

Bose *et al*. (2008) stated that application of potassium at 120 kg per ha for potato was found to be more effective than 60 kg per ha and noted maximum number of sprouts (3.56), height of the plant (56.53 cm) and number of compound leaves (50.86).

Nikardi (2009) revealed that plant height was not significantly affected by the treatment. However, the sources and application methods of K fertilizer affected the canopy cover, crop cover weeks (CCW), tuber dry weight (DW) and total plant dry weight. Potatoes supplied with K_2SO_4 either in split or split combined with foliar application recorded significantly higher per cent canopy cover, CCW, tuber DW and total plant DW than those supplied with K fertilizer in single application. Among the sources of potassic fertilizers, potatoes supplied with K_2SO_4 had a higher tuber yield compared to those fertilized with KCl, especially under split or split combined with foliar application. To attain the same level of tuber yield as in the split combined with foliar application method, the rate of K_2SO_4 should be increased from 150 to 250 kg K_2O ha^{-1} as single basal application. It is therefore suggested that higher quantity of K_2SO_4 is needed for potato production.

Ewais *et al*. (2010) reported that application of K-fertilizer as 50 per cent of the recommended rate used as soil application and 50 per cent of that added as foliar application along with micronutrients recorded maximum values of plant growth parameters and tuber yield of potato.

Asmaa and Magda (2010) indicated that the vegetative growth parameters in potato *viz.*, plant height, number of leaves and shoots as well as the fresh and dry weight of leaves and shoots were significantly increased by increasing the level of potassium from 40, 80 and up to 120 kg K_2O per ha.

The yield and processing quality attributes of potato was influenced by potassium nutrition *i.e*. tuber size, dry matter content, after-cooking darkening, reducing sugar content, fry colour and storage quality. They also reported that in India reviews of many field experiments conducted by PRII and CPRI on response of potato to potassium application revealed that yield increase between 1.0 t ha^{-1} and 5.2 t ha^{-1}at different sites (Bansal and Trehan, 2011).

Dkhil *et al*. (2011) conducted an experiment to evaluate the response of potato to potassium foliar pulverization in terms of improving vegetative growth, tuber yield and tuber size of potatoes. They observed that increasing potassium nitrate rates resulted in significant increase in plant height (79.10 cm), number of leaves (70 leaves $plant^{-1}$), leaf area (400 cm^2 $plant^{-1}$) and leaf water content (98 %) at 95 DAP. The statistical analysis among yield parameters showed no significant effect of increasing potassium nitrate on tuber yield and tuber number.

Besma *et al*. (2011) studied that increasing potassium nitrate rate in potato resulted in significant increase in plant height (79.10 cm), leaves number (70), leaf area (400 cm^2), leaf relative water content (93 %) and chlorophyll content (0.71 mg / g) at 95 days after planting (DAP).

Zameer *et al*. (2012) studied the comparative effect of sources and rates of potash fertilizer on potato yield on a sandy loam soil. Graded doses of potassium (0, 150 and 225 kg ha^{-1} K_2O) in the form of muriate of potash was applied in triplicate.

Singh and Lal (2012) observed that tubers accounted for 76.6 and 76.4 per cent of total dry matter production at harvest with 150 kg N ha^{-1} and 100 kg K_2O ha^{-1}, respectively in potato. The average tuber weight and its dry matter content increased with increasing potassium levels up to 100 kg K_2O ha^{-1}.

Potassium at 150 kg ha^{-1} gave the best results in most of the parameters recorded (*i.e*. total emergence percentage, plant height, number of tubers $plant^{-1}$, tuber weight per plant and yield ha^{-1}) while, extremely high dose of K showed the poor results as compared to control for some of the parameters such as number of aerial stems $plant^{-1}$, number of leaves $plant^{-1}$, specific gravity of tubers and tuber dry mass did not show any significant change with change in potassium levels in potato crop (Pervez *et al*., 2013).

Moawiya *et al*. (2016) assessed the effect of rates of potassium nitrate levels on yield and quality of potato in Jordan valley of Jordan. The results showed that

significant increase in fresh tuber yield plant^{-1}, tuber weight, and tuber yield ha^{-1} with all the rates of potassium nitrate application. The highest tuber yield was registered at 380 kg ha^{-1}. Potassium nitrate treatments not only increased the yield and yield components (except tuber number plant^{-1}).

An experiment was carried out to assess the effect of potassium fertilizer rates on sweet potato growth and yield components by Dumbuya *et al.* (2017). There were four rates of potassium fertilizer (0, 60, 120 and 180kg K_2O / ha) in the form of muriate of potash applied at 30 and 60 days after planting. The application of 60 kg K_2O per ha produced the longest vines (255 cm and 332.8 cm), highest number of leaves (196.0 and 229.0), more number of branches (5.19 and 7.69) and vine girth (0.382 cm and 0.586 cm) at 30 and 60 days after fertilizer application, respectively.

2.3.2 Effect of potassium on nutrient uptake

Sahota (1986) found that critical levels of ammonium acetate extractable K_2O for the response of K_2O by potatoes are 103 and 113 ppm, respectively in alluvial and hill soils. Potato took up 93 kg ha^{-1} in hills and 148 kg ha^{-1} in plains. The peak uptake being at 30 to 60 days and 75 to 85 days after planting, respectively.

Sud and Nagi (1990) studied the direct and residual effect of K_2O applied to potato and concluded that there was a significant response to residual K_2O than direct application. The K_2O application increased the K_2O uptake in all the three soils of Shimla, Kufri and Galoo. In the absence of K_2O, potato crop removed 58, 64 and 77 per cent of the available K_2O from those three soils, respectively.

Adhikary and Karki (2006) observed that the maximum plant height (33.22 cm), number of shoots (6.96) and biomass production (168.66 g / plant) in potato was obtained with the application of 100 kg potassium (50 kg / ha applied as basal dose and 50 kg / ha as top dressed).

2.4. Interaction of nitrogen and phosphorus on growth, yield and nutrient uptake of vegetables

2.4.1. Interaction of nitrogen and phosphorus on growth and yield

Mosin and kostornoi (1990) reported an increase in yield of oil radish by application of 30 of 60 kg / ha each of N and P. Bhal (1996) reported the effects of N (30, 50, and 70 kg/ha) and P (P_2O_5 at 15 or 30 kg / ha) on the yield of radishes (cultivars Japanese white, Chinese pink and Pusa Himani) during *rabi* 1994 at Rajouri, Jammu and Kashmir. The increasing of P had no significant influence on yield, but yield increased with increasing rates of N, the highest yield (38.4 t/ha) was recorded at the highest N rate (70 kg N/ha).

Sharma (2000) noticed that the application of nitrogen at the rate of 200 kg per ha significantly increased the plant height (133.2 cm) while a greater number of

branches (8.43) was found with 150 kg nitrogen per ha. Application of 30 kg phosphorus per ha increased the number of branches per plant (8.03). Whereas, the maximum plant height (123.2 cm) was observed with application of 90 kg phosphorus per ha in radish cv. Japanese White.

A field experiment was undertaken by Garo *et al.* (2014) to estimate the effect of inorganic (NP) fertilizers on above ground biomass of sweet potato. Two N levels (23 and 46 kg / ha) and two P levels (20 and 40 kg / ha) were considered as inorganic fertilizers along with one unfertilized control treatment. The nitrogen fertilizer level of 46 kg N per ha produced the longest vine (50.65 cm), maximum top weight (25 t / ha) and highest per cent dry top weight (20.30 %). While, the lowest for three growth components produced in control treatment. However, P fertilizer had minimum effects on sweet potato biomass.

The maximum number of main stem (8.25), tallest plants height (95.6 cm), highest above ground biomass (0.28 kg ha^{-1}) and maximum total leaf area (19.35 cm^2) were recorded with the application of 10 t FYM per ha + 111 kg N per ha + 46 kg P_2O_5 per ha in potato crop. (Mohammed *et al*., 2018).

2.4.2. Interaction of nitrogen and phosphorus on nutrient uptake

Singh and Sharma (2002) observed that the effect of N and P as well as net returns over uninoculated roots. Plants supplied with 100 per cent of the recommended dose of N (120 kg / ha) recorded the highest root yield of radish, net returns and uptake of N and P Phosphorus fertilization also exerted significant influence on root yield, net returns and uptake of N and P. The highest yield of radish was recorded, when the preceding root crop was fertilized with the recommended dose of nitrogen and phosphorus (120kg N+120kg P_2O_5 / ha). However, the residual effect of phosphobacterial inoculation of root was not significant on radish.

Kushwah and Banafar (2003) reported that higher potato yield could be obtained with the application of 150 kg N + 80 kg P_2O_5 ha^{-1} and application of Azotobacter and PSB culture were beneficial in increasing dry matter, N and P content and uptake by haulm and tuber yield of potato.

In a study conducted to determine the response of potato to different levels of nitrogen (N) applied in the form of urea (0, 69, 138 and 207 kg / ha) and phosphorus (0, 20, 40 and 60 kg / ha). The results revealed that application of 207 kg N per ha delayed days to flowering and physiological maturity by four and nine days, respectively and application of 60 kg P per ha significantly increased days to flowering by two days, plant height (10.50 cm), underground and aboveground biomass by 32 and 28 per cent, respectively compared to the control (Zelalem *et al.*, 2009).

A study was conducted by Lakra *et al.* (2017) on effect of nitrogen and phosphorus on growth and yield of radish (*Raphanus sativus* L.) Cv. Pusha Chetki under shade net condition. The results showed maximum growth parameters such as plant height (20.53 cm), number of leaves per plant (14.13), shoot length (22.43 cm) and shoot weight (140.33 g) were recorded with the application of nitrogen at 50 kg per ha + Phosphorus at 50 kg per ha.

2.5. Interaction of nitrogen and potassium on growth, yield and nutrient uptake of vegetables

2.5.1. Interaction of nitrogen and potassium on growth and yield

Srinivas and Naik (1990) reported that the highest root yield of 395.9 q / ha was obtained with the highest N (150 kg / ha) and K (80kg / ha) rates. The non-fertilized control yield was 121.85 q / ha. Application of 150 N/ha also increased the LAI, root weight and root length as compared to rest of the doses in radish crop.

Gupta (1992) observed that application of N and K significantly increased the plant height, total number of tubers, proportion of large size tubers and yield of potato. The optimum fertilizer dose was found to be 200.5 kg N and 77.1 kg K_2O ha^{-1}.

Chadachan *et al*. (1993) conducted an experiment to study the economic dose of N and K fertilizers and reported that the potato under rainfed conditions cannot respond to higher doses of fertilizers beyond 200 kg each of N and K_2O ha^{-1}. By increasing the nitrogen dose by 100 per cent and that of K_2O by 50 per cent, the increase in tuber yield was only 15 and 20 per cent, respectively. Thus, the potatoes grown under rainfed conditions should be restricted to only 100 kg each of N and K ha^{-1}.

Nikunja and Dutta (1998) conducted an experiment at Assam Agricultural University, Jorhat to know the response of potato to graded levels of nitrogen and potassium. They reported that the crop responded up to 240 kg N and 180 kg K_2O ha^{-1}. Application of N and K significantly increased the plant height, number of tubers $plant^{-1}$, bulking rate, net profit and net production value. The combination of 240 kg N and 180 kg K_2O ha^{-1} resulted in higher tuber yield (213.8 q ha^{-1}). Based on 2 year's pooled data, the optimum economic dose of N and K_2O were compared to 247 and 160 kg ha^{-1}, respectively with expected yield of 155 and 146q ha^{-1}.

Raghav and Singh (2000) attributed the significant interaction between N and K in the Tarai belt of Uttarakhand. They concluded that plant height was significantly increased by the better utilization of N in the presence of K in potato.

Rai *et al*. (2004) conducted a field experiment to study the effect of potassium and nitrogen on tuber yield, chlorophyll content in leaves, potassium and nitrogen contents in tubers of potato cv. Kufri Bahar. Nitrogen application recorded

significantly higher tuber yield (31.41 %) over control. Application of potassium also enhanced the tuber yield (169.66 to 217.77 kg ha^{-1}). The Maximum doses of nitrogen (120 kg ha^{-1}) and potassium (100 kg ha^{-1}) were proved most effective in increasing tuber yield of potato. The chlorophyll content in leaves (0.235 to 0.425 mg 100 g^{-1}) increased significantly with increasing levels of nitrogen (0-120 kg N ha^{-1}). The combined application of 120 kg N ha^{-1} along with 100 kg K ha^{-1} showed significant response in tuber yield.

Al-Moshileh *et al*. (2005) conducted an experiment to study the effect of various potassium and nitrogen rates on potato. They concluded that K and N is needed by potatoes for economic yield and they gave the recommendation of 450 kg K_2SO_4 ha^{-1} and 300 kg N ha^{-1} for Al-Qassam and similar regions for getting higher potential yield.

Chadha *et al*. (2006) revealed that the uptake value of potato is higher at higher levels of nitrogen and potassium. This was due to better absorption of N and K from the fertilizers during the different growth stages of the crop.

Haque *et al*. (2007) observed that N and K when applied at 180 and 160 kg per ha, respectively significantly increased the plant height (63.70 cm and 64.30 cm) and maximum number of leaves (19.20 and 19.70) in ginger.

Uwah *et al*. (2013) revealed that application of nitrogen at the highest rate significantly increased plant height, produced higher number of leaves and branches $plant^{-1}$, stem girth, number and weight of tubers $plant^{-1}$ and total fresh tuber yield compared with other treatments. Cassava growth, fresh tuber yield and all yield attributes peaked at 80 kg K_2O ha^{-1} rate. At 120 kg N ha^{-1} and 80 kg K ha^{-1} rates increased fresh tuber weight by 48 and 45 per cent and total fresh tuber yield by 36 and 27 per cent respectively, compared to control plots. The application of N between 80 and 120 kg ha^{-1} and K_2O at 80 kg ha^{-1} appeared appropriate for optimum yield under Nigerian condition.

Irfan (2015) revealed that 125 per cent recommended N and K + $ZnSO_4$ (0.5 %) + Borax (0.2 %) at 45 days after planting recorded significantly higher plant height (68 cm), number of shoots (4.2 $plant^{-1}$), number of leaves (88 $plant^{-1}$), total dry matter production (65 g $plant^{-1}$) and late blight incidence and severity recorded (9 %) and tuber weight (279.5 g $plant^{-1}$), number of tubers (4.9 $plant^{-1}$), tuber yield (23.3 t ha^{-1}) at harvest. However, it was on par with 75 per cent recommended N and K + $ZnSO_4$ (0.5 %) + Borax (0.2 %) at 45 DAP in potato crop.

2.5.2. Interaction of nitrogen and potassium on nutrient uptake

VijayaLakshmi *et al*. (2012) conducted an experiment to know the effect of levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and potassium (0, 60, 120 and 180 kg K_2O ha^{-1}) on potato tuber yield and soil available nutrient status. The tuber yield of

potato was significantly increased with nitrogen, potassium and their interactions. The highest tuber yield (223.9 q ha^{-1}) was recorded by combined application of nitrogen at 180 kg ha^{-1} + potassium at 180 kg ha^{-1} (N_3K_3) which was on par with nitrogen at 180 kg ha^{-1} + potassium at 120 kg ha^{-1} (N_3K_2). The total uptake of N and K by potato at harvest was highest with N_3K_3 combination and the per cent increase was 139.4 and 142.8, respectively over N_0K_0. With regard to soil available nutrient status, N_3K_3 recorded highest available N and K_2O contents in soil at all the stages of crop growth, the per cent increase was 72.2 (30 DAP), 114.6 (60 DAP) and 122.3 (at harvest) compared to that of at control (N0K0). Similarly, the available potassium increased by 40.3 (30 DAP), 31.5 (60 DAP) and 41.4 (at harvest) per cent when compared against control (N_0K_0). From the results it was evident that higher levels of nitrogen and potassium had met the requirement of potato crop at different growth stages, which was reflected in terms of yield.

2.6. Interaction of nitrogen, phosphorus and potassium on growth, yield and nutrient uptake of vegetables

2.6.1. Interaction of nitrogen, phosphorus and potassium on growth and yield

Park and fritz (1990) reported that pithiness increased as the amount of NPK fertilizer applied was increased and with higher rates of fertilizer. Besides, it increased as soil moisture content decreased from 90 per cent to 50 per cent of radish crop.

Nandekar *et al*. (1991) conducted an experiment during *rabi* season at Chhindwara. They observed that the plant emergence was not significantly affected by the varying levels of fertilizer application. The most economic dose for potato variety Kufri Badshah in the region was 120 kg, 100 kg and 100 kg of N, P_2O_5 and K_2O ha^{-1}, respectively.

Singh (1991) reported that maximum tuber yield was obtained by the application of 150 kg N, 100 kg P_2O_5 and 100 kg K_2O ha^{-1} + 25 t FYM ha^{-1} at M.P.

Sharma (1992) conducted a field trial at upper Shillong of C.P.R.I., Meghalaya. Potato variety Kufri Jyoti was applied with 0-180 kg N, 0-78 kg P_2O_5 and 0-150 kg K_2O ha^{-1} in all the possible combinations. Tuber yield increased up to 120 kg N, 78 kg P_2O_5 and 50 kg K_2O ha^{-1}.

Singh *et al.* (1992) conducted a field trial at diara area of Karanda, Ghazipur, UP. Potato variety Kufri Sinduri was given with 60 kg N, 30 kg P_2O_5, 20 kg K_2O or double or triples these rates. They concluded that the tuber yield was increased from 19.30 t ha^{-1} with no fertilizer to 37.60 t ha^{-1} with the highest nitrogen, phosphorus and potassium rates.

Lu and Shen (1996) investigated the dressing fertilizer requirements of radish (cv. Wuying) during 1994 on a study soil in China. The results showed that N, P and

K applied alone significantly increased yield. Dressing with N, P_2O_5 and K_2O in combination resulted in interaction. Over application of N reduced the effect of P_2O_5 and K_2O. To obtain high yields, the appropriate amount of dressing fertilizers were 494.7 kg N / ha, 311.85 kg P_2O_5 / ha and 318.4 kg K_2O / ha in combination.

Hussain *et al*. (1997) reported that leaf and root lengths were increased from 31.00 cm to 65.63 cm and 26.65 cm to 38.45 cm respectively when nitrogen was given at a rate of 200 kg / ha. The root diameter, root to shoot ratio, whole plant weight and root weight also increased from 3.00 cm to 4.65 cm, 1.885 cm to 1.97 cm, 110.25 t ha^{-1} to 164.00 t ha^{-1} and 93.25 t ha^{-1} to 147.50 t ha^{-1}, respectively, when N was applied at the rate of 200 kg ha^{-1} in combination with P and K as compared with other treatments in radish crop.

Application of recommended dose of fertilizer (190 kg N, 90 kg P_2O_5 and 90 kg K_2O / ha) along with FYM (25 t / ha) documented maximum plant height, number of tillers and leaf area in turmeric variety Salem (Vishwanath, 2002).

Maximum plant height (43.56 cm), fresh weight of shoot per plant (361.40 g) and dry weight of shoot per plant (23.73 g) were recorded with the application of 100 per cent recommended NPK + 15-tonnes FYM followed by 75 per cent NPK in potato (Banafar *et al*., 2005).

Bilekudari *et al*. (2005) found that higher fertilizer level (130:55:55 kg NPK / ha) significantly increased the plant height (124 cm) and number of branches per plant (9.47) in radish. Powon *et al.* (2006) reported that combined application of 100 kg P and 20 T FYM per hectare registered the maximum plant height in potato as compared to control, which resulted in the minimum plant height.

Raghav *et al*. (2008) recorded the maximum plant height (68.66 cm) and number of haulms per hill (7.55) in potato with the application of 100 per cent recommended dose of NPK (160: 100: 120 kg / ha) + 10 t FYM followed by 100 per cent of recommended dose of NPK alone.

The maximum vine length (103.7 cm) of sweet potato was found with the application of integrated plant nutrient system (IPNS) which consists of 72:52:85 kg NPK per ha + 7 kg S per ha + 1 kg Zn per ha + 5 tonnes cowdung per ha (Ali *et al*., 2009).

The application of 120 kg N, 60 kg P and 180 kg K per ha in radish had a significant effect on leaf number (19.00) as reported by Wilson *et al.* (2009). The maximum number of leaves (18.70, 18.17 and 18.10) and weight of leaves (160.67, 132.83 and 140.82 g) were recorded in onion, when N was applied at 250, 200 and 150 kg per hectare, respectively (Jilani *et al*., 2010).

Kumar *et al.* (2013) recorded the maximum number of branches per plant in potato in the treatment receiving 50 per cent recommended dose of NPK through chemical fertilizers + 50 per cent RDN through poultry manure.

Patel (2013) observed that the growth parameters like plant height, number of compound leaves per plant, fresh weight of shoots per plant and dry weight of shoots per plant were influenced with the increase in the per cent of recommended dose of fertilizers (150 % RDF- 125:100:125 kg NPK / ha) in potato crop.

Sharma *et al*. (2013) noticed that the increased in the number of leaves per plant (14.56) in radish at 60 DAS with the application of 50:50:50 kg N:P:K per ha + 5 t FYM per ha + 1.25 t vermicompost per ha + 0.5 t castor cake per ha. The increase in number of leaves also helps to increase the leaf area (220.73 cm^2).

Jadhav *et al.* (2014) revealed that the highest leaf length (37.59 cm), leaf weight (13.20 g) and total number of leaves per plant (10.60) in radish obtained with 1.2 kg vermicompost + RDF- 50:100:50 kg NPK per ha + 20 kg per ha FYM, which was significantly higher than all other treatments.

An investigation was carried out to find out the effect of nitrogen along with constant doses of phosphorus and potassium on growth and yield of radish. Four different levels *i.e.* 00, 50, 100 and 150 kg per ha of N in the form of urea and constant rates of P (75 kg ha^{-1}) in the form of SSP and K (100 kg ha^{-1}) in the form of MOP were used. The maximum plant height (35.42 cm) was recorded, where nitrogen levels were applied up to 100 kg per ha. While, minimum plant height (32.42 cm) was recorded from plants received with no fertilizers (control). Addition of nitrogen at levels of 100 and 150 kg per ha, along with constant doses of phosphorus and potassium positively influenced the plants to produce more number of leaves per plant (19.17 and 19.75, respectively) and fresh weight of leaves (246.38 g and 247.73 g, respectively) (Baloch *et al.*, 2014).

Dumbuya *et al.* (2016) registered the highest number of leaves (151.3) of sweet potato obtained with 60 kg P_2O_5 per ha than those of 0, 30, 90 and 120 kg P_2O_5 per ha. Mu'azu (2016) suggested that application of NPK each at 200 kg per ha had significantly enhanced most of the growth components of the sweet potato such as vine length, number of branches, crop growth rate and relative growth rate.

The maximum number of leaves per plant (17.30), fresh weight of plant (28.00 g) and dry weight of leaves per plant (7.50 g) were observed with the application of 120:65:100 kg NPK per ha in radish (Kiran *et al*., 2016).

Vikas *et al*. (2017) concluded that application of NPK at 150:50:75 kg ha^{-1} was proved to be most effective to growth parameters (Plant height, number of leaves, number of shoots $plant^{-1}$, fresh weight and dry weight of shoots) and yield parameters (maximum number of stolens, fresh weight and dry weight of tuber, number of tuber

plant^{-1}, grade wise number of tuber, A total number of tuber, grade wise yield of tuber and tuber yield plot^{-1} in potato.

Koodi *et al.* (2017) revealed that the maximum vine length (172.9 cm) and leaf area (185.3 cm^2) at 45 days after planting and total chlorophyll content (1.178 mg / g) at 50 days after planting were observed in 100 per cent RD of NPK (100:60:100 kg / ha) + VC (2.5 t / ha) to sweet potato. Pathak *et al*. (2017) investigated that with the application of recommended FYM @ 20 t per ha + fertilizer @ 80:60:80 NPK kg per ha + plant protection with organic methods + IIHR microbial consortium @ 12.5 kg per ha recorded significantly highest plant height (33.50 cm), number of leaves per plant (10.47) and leaf area (293.46 cm^2) in radish crop.

Beant *et al*. (2018) conducted an experiment to study the effect of nitrogen, phosphorus and potassium on growth and yield of potato (*Solanum tuberosum* L.). Application of different levels of fertilizers increased the growth, yield and yield attributes of potato. The maximum plant height (69.02 cm), number of compound leaves (54.97), number of branches plant^{-1} (12.90), leaf area index (4.36), number of main stems hill^{-1} (4.17), dry weight of haulm (79.20 g hill^{-1}), number of tubers plant^{-1} (13.23), weight of tubers plant^{-1} (385 g), yield of marketable tubers (235.92 q ha^{-1}), total tuber yield (256.29 q ha^{-1}), haulm yield (87.40 q ha^{-1}), biological yield (343.70 q ha^{-1}) and harvest index (76.17 %) were recorded with the combined application of 100 per cent RDF of nitrogen, phosphorus and potasssium.

The maximum plant height (31.74 cm) and number of leaves per plant (10.27) were recorded with the application of recommended FYM at 20 t per ha + fertilizer at 80:60:80 NPK kg per ha + Polypropene with organic methods in radish as reported by Dash *et al*. (2018).

Sharavati *et al*. (2018) noticed that the genotype BSP-29 recorded maximum vine length (140.65 cm), number of auxiliary branches per plant (4.65), number of leaves per vine (212.25), internodal length (4.70 cm), vine girth (4.65 cm), total chlorophyll content (2.20 mg / g @ 45 DAP) and dry weight of vine (53.29 g) at 90 days after planting with the application of 75:50:75 kg NPK per ha in sweet potato.

2.6.2. Interaction of nitrogen, phosphorus and potassium on nutrient uptake

In sandy loam soils of Bangalore with potato variety Kufri Jyoti, the dry matter accumulation and uptake of nutrients increased significantly due to the application of different levels of N, P_2O_5 and K_2O. The uptake of N, P_2O_5 and K_2O ranged from 150 to 238.7, 17.4 to 29.6 and 144.2 to 241.6 kg ha^{-1}, respectively. Tubers accounted for 58.90 to 68.50 per cent N. 60.20 to 67.80 per cent P_2O_5 and 72.10 to 77.60 K_2O per cent of the nutrient removed by the plant (Rajanna *et al*., 1987).

Hikaru *et al*. (2007) reported that N (210 kg / ha), P (150 kg / ha) and K (150 kg / ha) significantly increased the plant height (153.6 cm) and number of leaves (34.0) in turmeric.

Dash and Mohapatra (2008) concluded that application of 125 per cent RDF (120:80:100 kg NPK) in potato recorded significant results on plant height and number of leaves.

2.7 Economics

Jayalakshmi (2003) obtained the higher net returns (`. 82,192 / ha) of medicinal coleus with higher benefit: cost ratio (4.27) in closer spacing (45 cm × 30 cm) with 50 kg N per hectare at 180 days after planting.

Patne (2003) found maximum gross returns (`. 1, 38, 000 / ha), net returns (`. 1, 17, 900 / ha) and benefit: cost ratio (5.86) by applying 40:60:50 kg N, P_2O_5 and K_2O (K as sulphate of potash) per hectare plus FYM at 10 tonnes per hectare in medicinal coleus. Similarly, Ravi (2004) recorded highest net returns of `. 50, 911 per hectare and benefit:cost ratio of 4.27 in medicinal coleus with application of 50 kg N per hectare plus 60 kg P_2O_5 per hectare along with *VasicularArbuscular Mycorrhiza* (VAM) in sandy loam soil at Madurai.

The highest returns per rupee invested of `. 3.68 were obtained from sweet potato cv. Sree Bhadra, when applied with higher doses of nitrogen *i.e.* 100 kg per hectare (Satapathy *et al*., 2007).

Singh *et al*. (2015) revealed that the highest cost of cultivation (93971.40 `. / ha) and maximum gross income (261921.00 `. / ha) in sweet potato were found with the use of FYM @ 10 t per ha + RDF @ 50:25:50 kg per ha + 3 t per ha neem cake. While, the maximum net profit (168238.00 `. / ha) and maximum cost: benefit ratio (1: 3.07) were noted under FYM @ 5 t per ha + RDF @ 50:25:50 kg per ha + 1 t per ha neem cake.

Dash *et al*. (2008) recorded highest fresh rhizome yield (18.70 q / ha) of ginger with B:C ratio (2.44) by the application of recommended dose of fertilizers combined with *Azospirillum* sp. 10 kg per ha and FYM 10 t per ha.

Singh *et al.* (2009) conducted an experiment to investigate the effect of row spacing on growth, yield and quality of onion Cv. N-53. Out of three levels of spacing they found that there was an increase in the B:C ratio (2.08) with a row spacing of 15 cm.

Dawuda *et al.* (2011) recorded that in carrot, the maximum income (`. 7144.9) and profit (`. 4972.1) were recorded at closer spacing (20cm × 5cm). Whereas,

minimum income and profit (`. 5689.1 and `. 3394.3, respectively) were noticed with wider spacing (30cm × 5cm).

Azeze *et al*. (2013) noticed that the highest fresh rhizome yield (142.25 q / ha) and a maximum net profit of `. 6,20,108 per ha with B:C ratio of 4.87 were obtained with the application of 125 kg N + 60 kg $P_2 O_5$ + 60 kg K_2O per hectare in ginger. Kabir *et al.* (2013) reported that highest (2.95) benefit cost ratio was recorded in closer spacing (20cm × 10cm). While, lowest (-0.03) was noticed with 25cm × 15cm spacing in carrot.

Sharma *et al*. (2013) concluded that sowing of radish seed cv. Pusa Chetki with broadcasting method and fertilized with 50 : 50 : 50 kg N : P: K + 5.0 t FYM + 1.25 t vermicompost + 0.5 t castor cake per ha gave maximum net realization (`. 1,63,342 / ha) and highest C:B ratio (6.52) when raised on sandy loam soils of middle Gujarat.

Application of N and K at 200 kg per ha resulted in maximum growth and rhizome yield (100.90 q / ha) with net income of `. 468560 per ha in turmeric variety Roma (Ahirwar *et al*., 2015).

Shruthi (2015) obtained that the maximum benefit cost ratio (1.70) in (45cm × 45 cm + GA_3 250 ppm) treatment combination followed by 45cm × 45 cm + GA_3 200 ppm (1.67). The minimum cost benefit ratio (0.19) in radish was recorded in the treatment combination of 30cm × 30 cm + control S_1G_5.

Shubha (2018) reported that the maximum B:C ratio (2.47) was observed with the application of *Azotobacter* + PSB + KSB + 75 per cent RDF +$MgSO_4$ + Micronutrient mixture (T_{13}) as compared to RDF + FYM (T_1) in potato.

The treatment supplied with *Azospirillum* + PSB + VAM + KSB + 75 % RDF + $MgSO_4$ + Micronutrient mixture (T_{12}) realized the highest benefit: cost ratio (BCR) in chilli (4.33) followed by (T_{13}) *Azospirillum* + PSB + VAM + KSB + 50 per cent RDF + $MgSO_4$ + Micronutrient mixture (4.22). Whereas, the plants supplied with RDF (T_1) registered lowest benefit: cost ratio of 2.84. (Yogaraju, 2017)

Chandini (2019) revealed that highest net returns (`. 647779.12 / ha) and B: C ratio (3.91) were obtained in S_2F_3 (60 x 30 cm + 100:75:100 kg NPK / ha) treatment combination in sweet potato.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The present investigation on "Effect of graded levels of NPK on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki" was carried out in experimental field, Department of Vegetable Science, College of Horticulture, Mudigere during the period from November 2019 to December 2019. The details of the material used and methods adopted during the course of investigation are presented below.

3.1 Geographical location of the experimental site

The experiment was conducted at the College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga, which is situated in hilly region (Zone - 9) of Western Ghats in Karnataka state at $13^0$25' N latitude and 75^0 57' E longitude at an altitude of 982 M above mean sea level.

3.2 Climate

Mudigere is one of the areas, which receives heavy rainfall in Karnataka. The total rainfall received during the year is 3384.5 mm, which was distributed over a period of seven to eight months (May - December) with the peak period of rainfall during July to September. The average annual maximum temperature is 27.99°C and minimum temperature is 18.87°C. Besides average maximum mean relative humidity is 79.34 per cent and minimum mean relative humidity is 61.13 per cent. The meteorological data for the period of experimentation was obtained from the meteorological observatory of Zonal Agricultural and Horticultural Research Station (ZAHRS), Mudigere and the same is presented in Appendix-I.

3.3 Soil characteristics

The soil of the experimental site has the pH of 5.88. The composite soil samples were collected from experimental site up to a depth of 30 cm and analyzed for chemical properties. The results are presented in Appendix - II.

3.4 Source of seed

Seeds of radish cv. Pusa Chetki were produced and maintained in the department, which were used for sowing. Radish cv. Pusa Chetki was developed with the seeds collected from Denmark at Indian Agricultural Research Institute, New Delhi. Roots are pure white in colour and are mild pungent. The roots become ready for harvesting in 40 to 45 days.

3.5 Experimental details

3.5.1 Design and Layout of the experiment

The experiment involved ten treatments and laid out in the open field with Randomized Complete Block Design (RCBD) and is replicated thrice. The treatments in each replication were imposed randomly based on random number table according to definite laws of probability. The plan of layout of the experiment is given in figure.1. General view of experimental plot at vegetative stage is depicted in plate. 1 and plots of individual treatments are shown in plate.2

The experimental details:

Location	: College of Horticulture, Mudigere
Crop	: Radish
Variety	: Pusa Chetki
Statistical design	: Randomized Complete Block Design (RCBD)
Date of sowing	: 11- November -2019
Spacing	: 30 cm X 10 cm
Treatments	: 10
Number of replications	: 03
Gross plot	: 1.5 M × 1.0 M
Planting method	: Ridges and furrows

Treatments details:

T_1 - 50:100:50 kg NPK / ha

T_2 - 100:100:50 kg NPK / ha

T_3 - 150:100:50 kg NPK / ha

T_4 - 200:100:50 kg NPK / ha

T_5 - 50:150:50 kg NPK / ha

T_6 - 50:200:50 kg NPK / ha

T_7 - 50:250:50 kg NPK / ha

T_8 - 50:100:100 kg NPK / ha

T_9 - 50:100:150 kg NPK / ha

T_{10} - 50:100:200 kg NPK / ha

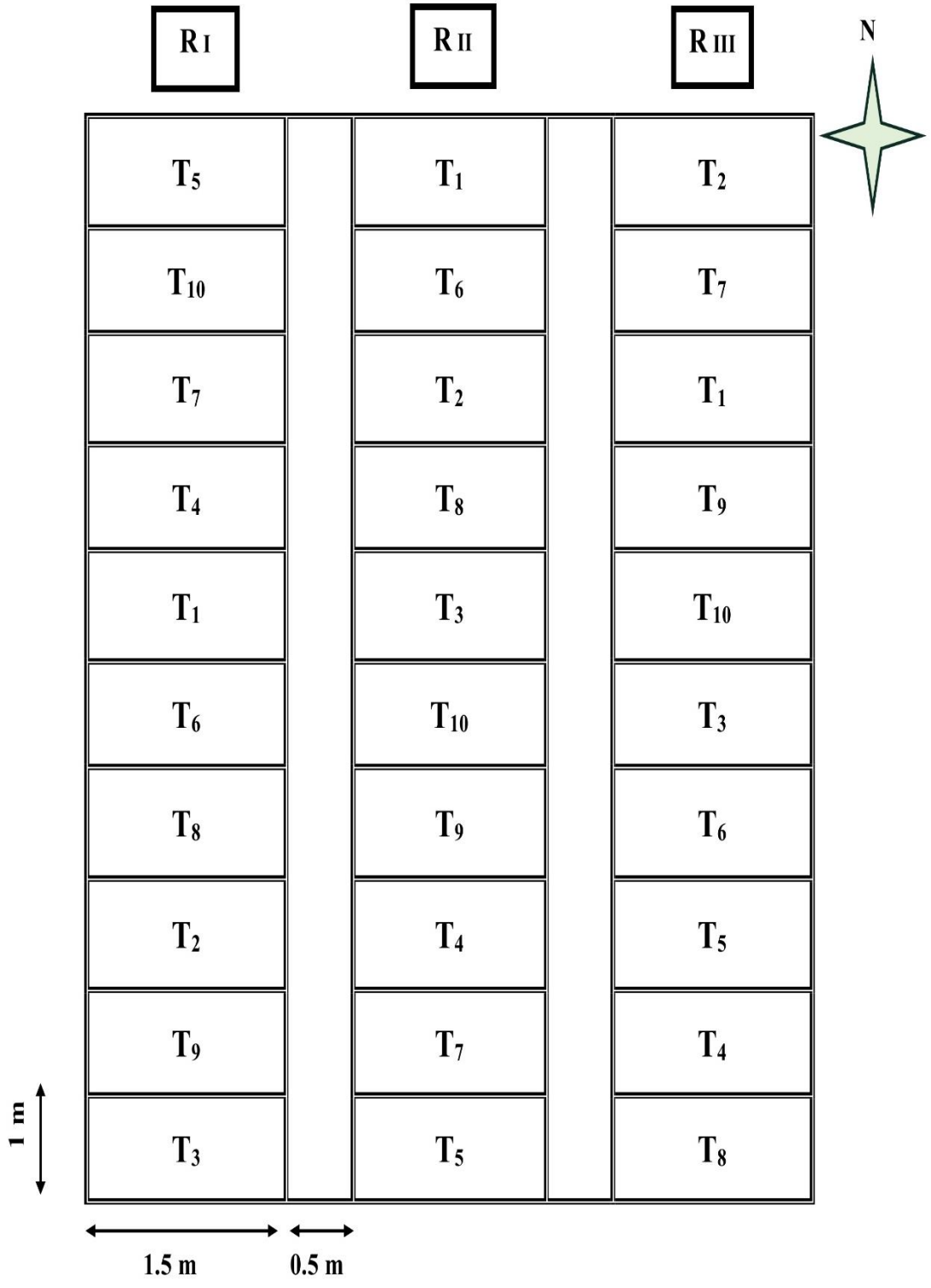
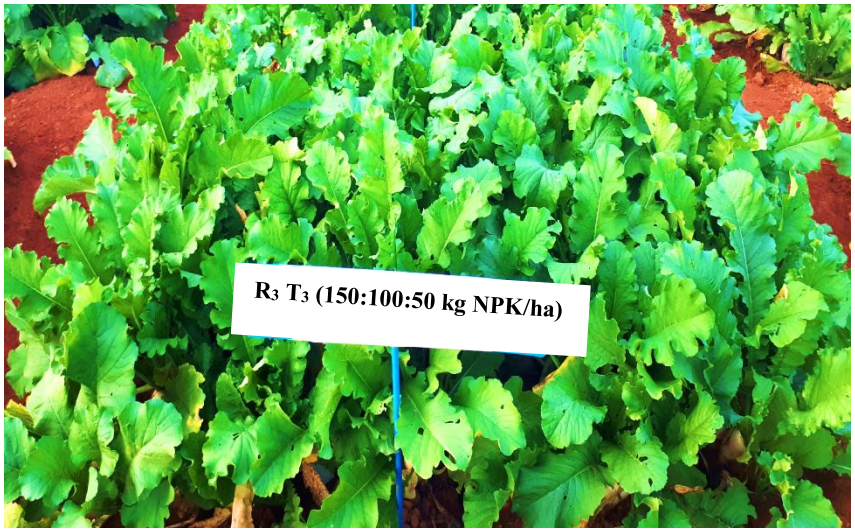


Fig.1. Plan and layout of the experimental plot

Plate 1. General view of the experimental plot



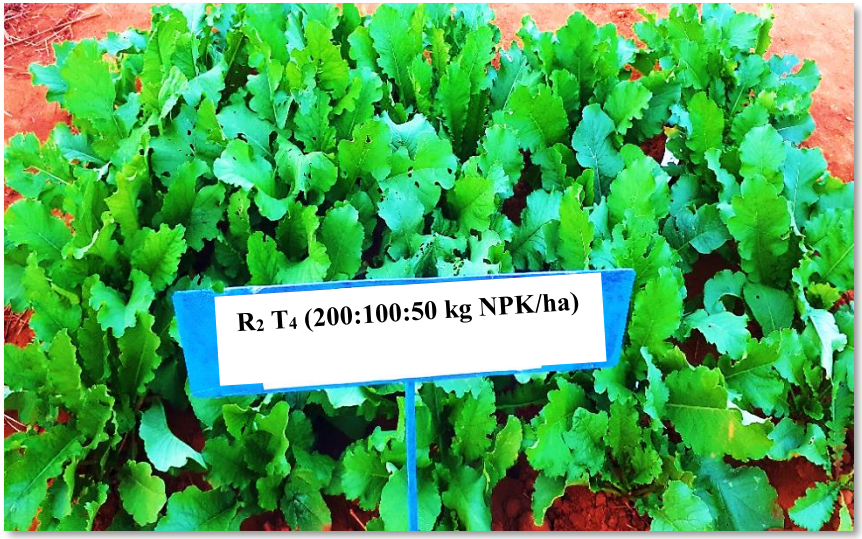
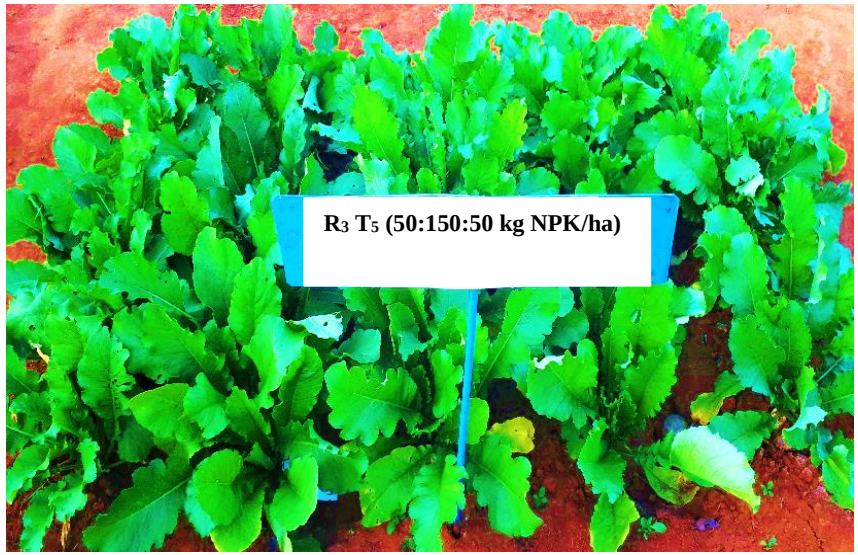
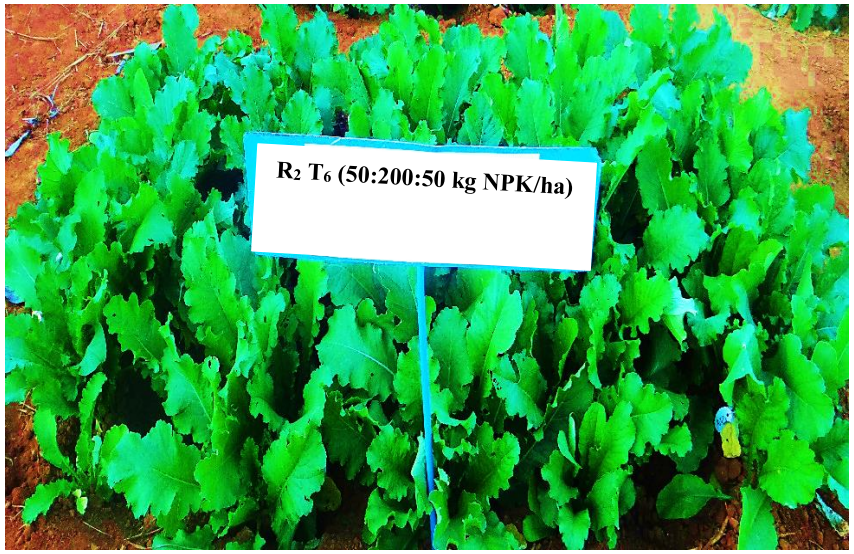
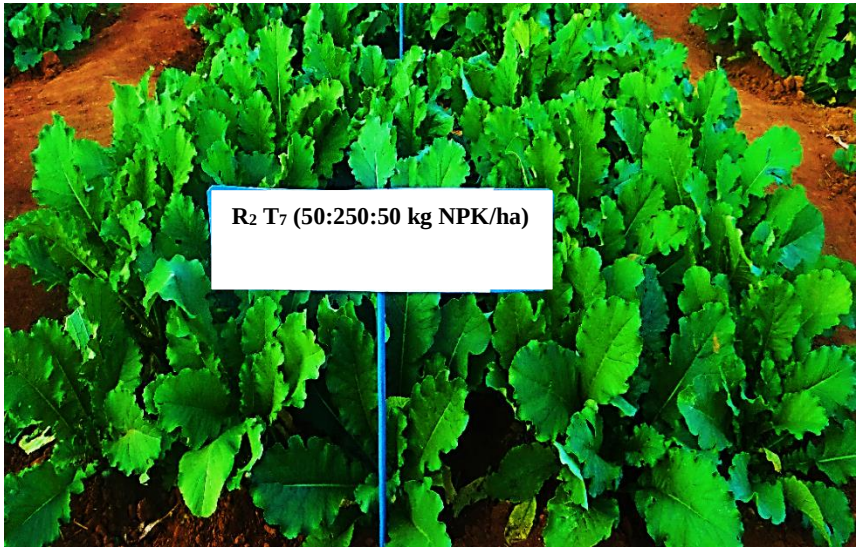
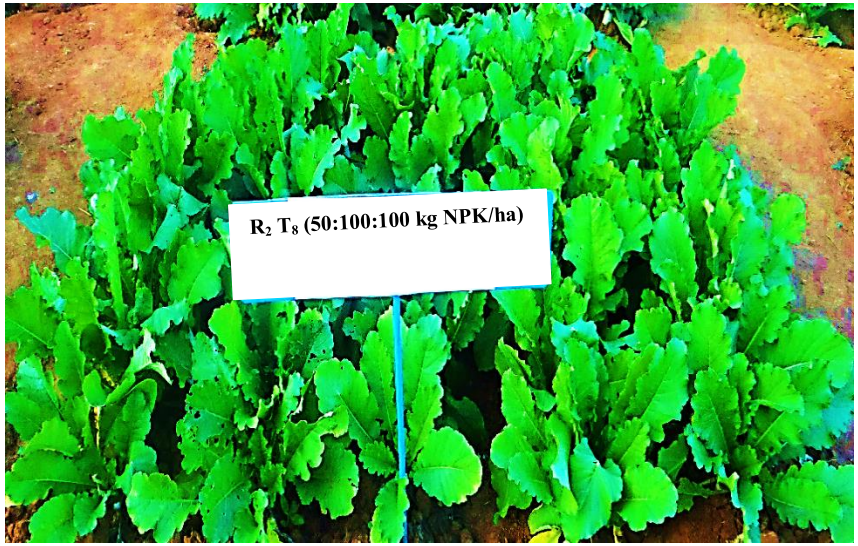


Plate 2. Plots of individual treatments

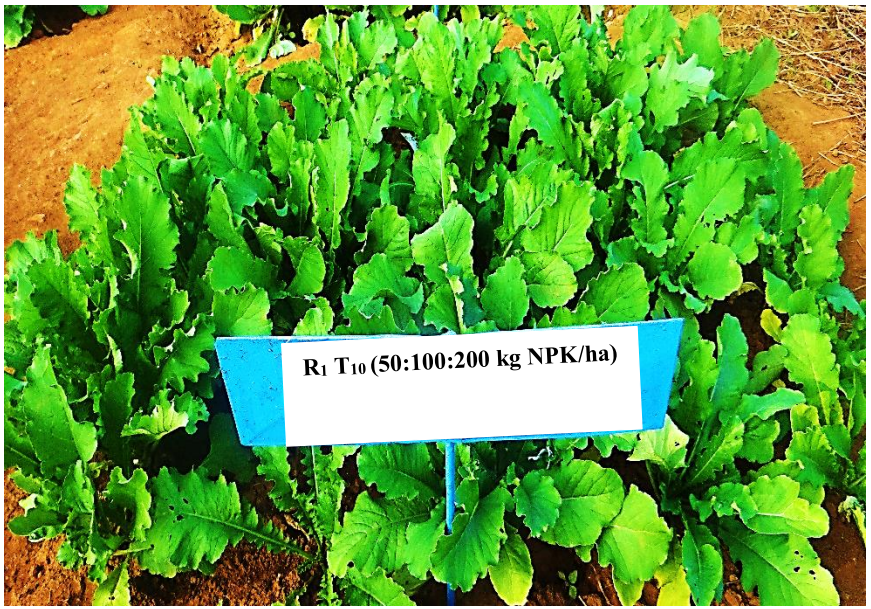

R3 T5 (50:150:50 kg NPK/ha)


R2 T6 (50:200:50 kg NPK/ha)


R2 T7 (50:250:50 kg NPK/ha)


R2 T8 (50:100:100 kg NPK/ha)


R1 T9 (50:100:150 kg NPK/ha)


R1 T10 (50:100:200 kg NPK/ha)

3.6 Cultural practices

3.6.1 Preparation of experimental site

The land was ploughed deeply and weeds, stubbles, stones etc., were completely removed and the soil was brought to fine tilth by repeated harrowing. After levelling of the entire field, required size micro plots were prepared as per the plan of work.

3.6.2 Fumigation of FYM

FYM was sterilized thoroughly with four per cent formalin and covered with black polyethylene sheet to remain air tight for 48 hours. Thereafter, the sheet was removed and the FYM was aerated for 8 days. Later, the sterilized FYM was applied to main field.

3.6.3 Fertilizer application

The crop was fertilized with different levels of nitrogen, phosphorus and potassium for each plot in every replication in the form of urea, single super phosphate and murate of potash respectively. Entire SSP, MOP and 50 per cent urea was applied as a basal dose at the time of sowing and remaining 50 per cent nitrogen applied at 20 days after sowing. The package of practice recommendation of fertilizer (50: 100: 50 kg NPK ha^{-1}) was included in the study for comparison.

3.6.4 Sowing

Sowing was done during the month of November. Seeds were hand dibbled at a depth of about 2 cm in the soil. The seeds were sown on one side of the ridge according to the recommended spacing (30cm × 10 cm). Thinning was done at 10 days after sowing by retaining one seedling per hill to maintain proper spacing and to facilitate the development of roots.

3.6.5 Intercultivation

The crop needs earthing-up at least twice and this operation is sufficient to keep out weeds. In order to keep the soil pores and also free from weeds, regular inter cultivation operations were carried out at frequent intervals. Hand weeding was done as and when the weeds were noticed to keep the plot clean and free from weeds competition.

3.6.6 Irrigation

Protective irrigations were given at 3 to 5 days interval throughout the cropping period of root production.

3.6.7 Plant protection chemicals

To control the pest and diseases, necessary plant protection measures were taken up as per the recommended package of practices for radish. Insects, pests such as, Diamond back moth, Leaf webber, Semilooper, Hairy caterpillar, Mustard sawfly and Aphids were observed during the crop growth period. These pests were managed by spraying of chloropyriphos @ 2 ml / lit, Imidachloprid @ 0.3 ml/lit and Quinalphos @ 2ml/lit.

3.6.8 Harvesting

The roots were harvested at ideal maturity stage based on visual observations. The harvested roots from each treatment and replication were washed separately for recording observations and the remaining roots were stored in the cold storage for marketing.

3.7 Collection of experimental data

3.7.1 Selection of plants

Five plants were selected randomly from each plot and tagged for recording the observations on growth and root yield parameters as mentioned below.

3.7.2 Morphological parameters

Observations on growth parameters such as plant height, number of leaves, leaf length, leaf width, spread of the plant, stem diameter, fresh weight and dry weight of leaves, stem and roots were recorded at 15, 30 and 45 days after sowing.

3.7.2.1 Plant height

Plant height was recorded from base of the plant to the top of the plant and average plant height was then expressed in centimeters.

3.7.2.2 Number of leaves

The numbers of leaves in tagged plants were counted and the average value was worked out.

3.7.2.3 Leaf length

Length of leaves was measured from base to the tip of the leaves and the leaf length was expressed in centimeters.

3.7.2.4 Leaf width

The width of randomly selected five leaves from each tagged plant was recorded by measuring the horizontal distance exactly at the center of the leaves and average was worked out and expressed in centimeters.

3.7.2.5 Spread of the plant

The plant spread was measured in both East-West and North-South directions and the mean was expressed in centimeters.

3.7.2.6 Stem diameter

Stem diameter was recorded with the help of digital vernier calipers. Average stem diameter was worked out from the tagged plants and expressed in centimeters.

3.7.2.7 Fresh weight of leaves

The fresh weight of leaves was taken from each of tagged plant in each replication and the average fresh weight of leaves was then expressed in grams per plant.

3.7.2.8 Dry weight of leaves

The leaves of the tagged plants were collected and dried in oven at 80°C for 72 hours and their average dry weight was then expressed in grams per plant.

3.7.2.9 Fresh weight of stem

The fresh weight of stem was taken from each of tagged plant in each replication and the average fresh weight of stem was then expressed in grams per plant.

3.7.2.10 Dry weight of stem

The stem of the tagged plants were collected and dried in oven at 80°C for 72 hours and their average dry weight was then expressed in grams per plant.

3.7.2.11 Dry weight of root

The roots from five randomly selected plants in each replication were dried in oven at 80°C for 72 hours or a constant weight was achieved and their dry weight was recorded. The average dry weight of root was expressed in grams per plant.

3.7.3 Growth parameters

3.7.3.1 Leaf area

The leaves from five selected plants from each treatment were used for the estimation of leaf area. Leaf area was computed by using Disc method and was expressed as square centimeters per plant.

3.7.3.2 Leaf Area Index (LAI)

The LAI was calculated by dividing the leaf area per plant by the land area occupied by the plant (Sestak *et al.*, 1971).

$$LAI = \frac{\text{Leaf area (cm}^2\text{/plant)}}{\text{Land area (cm}^2\text{/plant)}}$$

3.7.3.3 Absolute Growth Rate (AGR)

The AGR of plant was worked out by dividing the difference in total dry weight of the plant at two consecutive stages by the interval (days) between the two stages and expressed as grams per plant per day (Radford, 1967).

$$AGR = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

$t_2 - t_1$ = time interval between two stages

3.7.3.4 Crop Growth Rate (CGR)

Crop growth rate is defined as the rate of dry matter production per unit ground area per unit time (Watson, 1952) and it was calculated by using the following formula and expressed in g per m^2 per day.

$$CGR = \frac{(W_2-W_1)}{(t_2 - t_1)} X \frac{1}{A}$$

Where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

$t_2 - t_1$ = time interval between two stages

A = Unit land area

3.7.3.5 Net Assimilation Rate (NAR)

The NAR is the rate of increase in dry weight per unit leaf area per unit time. It was calculated by following the formula of Radford (1967) and expressed as g / dm^2 / day.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} X \frac{(\text{Log}_e L_2 - \text{Log}_e L_1)}{(L_2 - L_1)}$$

Where,

L_1 and W_1 = Leaf area (cm^2) and total dry weight of the plant (g) respectively at time t_1.

L_2 and W_2 = Leaf area (cm^2) and total dry weight of the plant (g) respectively at time t_2.

$t_2 - t_1$= time interval between two stages.

3.7.4. Root parameters

3.7.4.1 Root length

The length of the root was measured in five randomly selected plants at 45 DAS from the base of the root to top of the root and average root length was expressed in centimeters.

3.7.4.2 Root girth

The girth of five roots selected randomly at 45 DAS was recorded at the basal portion of the root with the help of thread and scale and the average root girth was expressed in centimeters.

3.7.4.3 Root volume

The volume of root was measured by the water displacement method. A measuring cylinder of one litre capacity was employed for measuring root volume in which known amount of water was added. Five roots were selected randomly from each treatment and individual roots were placed in measuring cylinder. Then amount of water displaced by each root was measured by taking the difference between initial volume and final volume. The volume of the root was expressed in cubic centimeter (cc).

3.7.4.4 Fresh weight of root

The fresh weight of five roots selected randomly after harvest were recorded and the average fresh weight of root was expressed in grams per plant.

3.7.4.5 Root yield per plot

The root yield per net plot was recorded by pooling the root yield of all the plants in each treatment of each replication separately and expressed in kilograms.

3.7.4.6 Root yield per hectare

The weight of root was recorded treatment wise from each net plot and from each replication. Radish crop utilized only 80 per cent of the land and the remaining 20 per cent of the land was used for irrigation channels and bund. Keeping this in mind, the total yield per hectare in tonnes was calculated using the formula,

$$\text{Yield (t / ha)} = \frac{\text{Yield per net plot (kg)}}{\text{Net area of the plot } (m^2)} \text{ X } \frac{10000}{1000}$$

3.7.5 Biochemical parameters

3.7.5.1 Chlorophyll content in leaves

Chlorophyll content of leaf was analyzed by collecting the healthy, fully matured leaves from randomly selected plant at peak growth stage.

Chlorophyll-'a', Chlorophyll-'b' and total chlorophyll content of leaf tissue were determined by using dimethyl sulfoxide (DMSO) method as suggested by Shoaf and Lium (1976). Fresh leaf tissue (100 mg) was cut in to small pieces and incubated in 10 ml of dimethyl sulfoxide in dark for 24 hours. Later the absorbance of the extract was measured at 645 nm and 663 nm using DMSO as blank in spectrophotometer (Model- VISISCAN-167).

The chlorophyll-'a', chlorophyll-'b' and total chlorophyll, contents were calculated by using the formulae given below and expressed in mg per g fresh weight.

$$\text{Chlorophyll-a} = 12.7\ (A_{663}) - 2.69\ (A_{645}) \quad X \quad \frac{V}{1000 \times W \times a}$$

$$\text{Chlorophyll-b} = 22.9\ (A_{645}) - 4.68\ (A_{663}) \quad X \quad \frac{V}{1000 \times W \times a}$$

$$\text{Total chlorophyll} = 20.2\ (A_{645}) + 8.02\ (A_{663}) \quad X \quad \frac{V}{1000 \times W \times a}$$

Where,

A= Absorbance at specific wave lengths (645 nm and 663 nm)

V= Final volume of the extract (10 ml)

W= Fresh weight of the sample (100 mg)

a = Path length of the light (1 cm)

3.7.6 Chemical analysis of Soil

The soil samples from 0-30 cm depth were collected after harvest from each plot for estimation of pH, EC and available nitrogen, phosphorus and potassium as per the procedure described in Appendix-II. The collected soil samples were air dried under shade, powdered and passed through 2 mm sieve.

3.7.6.1 Available nitrogen

The available nitrogen content of soil was determined by alkaline potassium permanganate method as described by Subbaiah and Asija (1956) and was expressed in kg ha^{-1}.

3.7.6.2 Available phosphorus

Available phosphorus was extracted from soil using Brays extractant and concentration of phosphorous present in the extract was determined by stannous chloride reduced molybdo phosphoric blue colour method in HCL system (Jackson, 1973) and was expressed in kg ha^{-1}.

3.7.6.3 Available potassium

The available potassium of soil was determined by using neutral normal ammonium acetate (NN NH_4OAc) and the concentration of potassium present in the extract was determined by flame photometer (Jackson, 1973) and was expressed in kg ha^{-1}.

3.7.7 Chemical analysis of plant sample

3.7.7.1 NPK content of radish

The randomly selected five plants from each plot were oven dried along with roots and used for chemical analysis after grinding haulms and roots separately.

3.7.7.2 Nitrogen

Nitrogen was determined by Kjeldahl's method using digestion mixture consisting of copper sulphate, potassium sulphate and selenium catalytic mixture. Plant samples weighing 1 g were digested in digestion flasks in macro kjheldal unit using sulphuric acid and the digestion mixture. After complete digestion, the digested materials were distilled in alkaline medium and the liberated ammonia was trapped in four per cent boric acid solution containing mixed indicator. The trapped ammonia was titrated against standard sulphuric acid (Jackson, 1973).

3.7.7.3 Digestion of plant samples

One gram plant and root samples were pre-digested with 5 ml nitric acid and digested with di-acid mixture of nitric acid and perchloric acid (9:4). The clean digested material was made up to 50 ml volume with 6 N HCl and was used for the analysis of all mineral elements.

3.7.7.4 Phosphorus

Phosphorus content in the digested plant sample was estimated by vanadomolybdo phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 460 nm wave length as outlined by Jackson (1973).

3.7.7.5 Potassium

Two ml of the di-acid digest was diluted to 25 ml with distilled water and fed to a calibrated flame photometer. By comparing the flame photometer readings of the

sample with the calibration curve of potassium and per cent potassium in the plant sample were calculated (Jackson, 1973).

3.7.8 Uptake of major nutrients by the radish plant

N, P and K uptake was calculated for each treatment separately using the following formula.

$$\text{Nutrient uptake} = \frac{\text{Per cent nutrient concentration}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

3.8 Economics

In order to assess the effects of graded levels of NPK on each treatment, the cost of cultivation was worked out. This included the cost of NPK fertilizers, FYM was taken at the current existing rates. The labour cost, including fertilizer application, irrigation and plant protection, weeding earthing up *etc*., during the cropping period were worked out. The yield obtained under individual treatment during the crop was taken into consideration for working out the economics (Appendix- a and b). Based on the total cost of cultivation and gross return obtained, the net return and benefit cost ratio (BCR) were worked out and was computed per hectare.

3.8.1 Cost of cultivation

The cost of all inputs prevailing at the time of their use and the labour cost were used to work out the cost of cultivation and expressed in ` per ha.

3.8.2 Gross return

The gross income was worked out based on the prevailing market of the produce and expressed in ` per ha.

3.8.3 Net return

The net income per hectare was calculated on the basis of gross income and cost of cultivation per ha and expressed in ` per ha.

$$\text{Gross return} - \text{Cost of cultivation} = \text{Net return}$$

3.8.4 Benefit: Cost ratio

$$\text{Benefit: Cost ratio} = \frac{\text{Net return (` / ha)}}{\text{Total cost of cultivation (` / ha)}}$$

3.9 Statistical analysis

Observations were recorded from five randomly selected plants of each treatment and replication. The data comprising the calculated average values of each observation treatment wise and replication wise were subjected to computerized statistical analysis using a method suggested by Panse and Sukhatme (1967). The level of significance used in F and t test was at p=0.05 and critical difference (CD) values were worked out wherever F test was significant.

EXPERMENTAL RESULTS

IV EXPERIMENTAL RESULTS

A field experiment was conducted at College of Horticulture, Mudigere during the year 2019-20 in *rabi* season on "Effect of graded levels of NPK on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki". The results obtained in the present investigation are presented in this chapter.

4.1 Morphological parameters

4.1.1 Plant height

The data on plant height as influenced by graded levels of nitrogen, phosphorus and potassium recorded at 15, 30, and 45 days after sowing (DAS) presented in Table 1. Plant height of radish varied significantly among different nutrition levels at all stages of plant growth.

The plant height differed significantly with respect to different nutrition levels. At 15 days after sowing, significantly highest (12.43 cm) plant height was found at T_4 (200:100:50 kg NPK / ha) level and it was followed by T_3 (150:100:50 kg NPK / ha) level (11.35 cm). Whereas, lowest plant height (9.17 cm) was recorded in T_1 (50:100:50 kg NPK / ha). Plant height at 30 days after sowing varied significantly among different nutrition levels. The results showed that significantly highest plant height (32.61 cm) was recorded in T_4 (200:100:50 kg NPK / ha) and it was followed by T_3 (150:100:50 kg NPK / ha) level (31.95 cm), while lowest plant height (27.93 cm) was recorded in T_1 (50:100:50 kg NPK / ha). At 45 days after sowing, significantly highest (42.71 cm) plant height was found at T_4 (200:100:50 kg NPK / ha) level followed by T_3 (150:100:50 kg NPK / ha) level (39.27 cm). Whereas, lowest plant height (33.13 cm) was recorded in T_1 (50:100:50 kg NPK / ha).

4.1.2 Number of leaves per plant

The perusal of data indicated that the number of leaves per plant varied significantly at all stages of plant growth at 15, 30, 45 days after sowing (DAS) as influenced by graded levels of nitrogen, phosphorus and potassium are presented in Table 2.

The number of leaves per plant differed significantly with respect to levels of nutrition. The significantly maximum number of leaves per plant was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (8.93, 12.20, 14.47 at 15, 30 and 45 DAS, respectively), which was followed by application of T_3 (150:100:50 kg NPK / ha) nutrition level (8.27, 11.60, 13.27 at 15, 30 and 45 DAS, respectively), While, minimum number of leaves per plant was recorded at T_1 (50:100:50 kg NPK / ha) nutrition level (7.07, 9.40, 9.87 at 15, 30, and 45 DAS, respectively).

Table 1. Effect of graded levels of nitrogen, phosphorus and potassium on plant height at different growth stages in radish cv. Pusa Chetki

Treatments	Plant height (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	9.17	27.93	33.13
T_2 - 100:100:50 kg NPK / ha	10.07	29.04	36.30
T_3 - 150:100:50 kg NPK / ha	11.35	31.95	39.27
T_4 - 200:100:50 kg NPK / ha	12.43	32.61	42.71
T_5 - 50:150:50 kg NPK / ha	9.83	28.47	34.38
T_6 - 50:200:50 kg NPK / ha	10.42	30.00	36.88
T_7 - 50:250:50 kg NPK / ha	9.52	28.25	34.43
T_8 - 50:100:100 kg NPK / ha	9.82	28.50	35.80
T_9 - 50:100:150 kg NPK / ha	9.70	28.53	35.00
T_{10} - 50:100:200 kg NPK / ha	9.75	28.30	35.03
S.Em±	**0.17**	**0.27**	**0.78**
C.D @ 5%	**0.50**	**0.81**	**2.31**

DAS: Days After Sowing

Table 2: Effect of graded levels of nitrogen, phosphorus and potassium on number of leaves per plant at different growth stages in radish cv. Pusa Chetki

Treatments	Number of Leaves per plant		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	7.07	9.40	9.87
T_2 - 100:100:50 kg NPK / ha	7.87	11.07	11.93
T_3 - 150:100:50 kg NPK / ha	8.27	11.60	13.27
T_4 - 200:100:50 kg NPK / ha	8.93	12.20	14.47
T_5 - 50:150:50 kg NPK / ha	7.27	10.87	11.47
T_6 - 50:200:50 kg NPK / ha	8.07	11.33	12.47
T_7 - 50:250:50 kg NPK / ha	7.33	10.13	11.07
T_8 - 50:100:100 kg NPK / ha	7.53	9.73	11.20
T_9 - 50:100:150 kg NPK / ha	7.27	10.07	11.30
T_{10} - 50:100:200 kg NPK / ha	7.53	10.60	11.13
S.Em±	**0.11**	**0.22**	**0.18**
C.D @ 5%	**0.34**	**0.66**	**0.54**

DAS: Days After Sowing

4.1.3 Leaf length

The data on the leaf length as influenced by graded levels of nitrogen, phosphorus and potassium at different growth stages 15, 30 and 45 days after sowing (DAS) are presented in Table 3. Leaf length of radish varied significantly among all stages of plant growth.

The leaf length differed significantly with respect to different nutrition levels. At 15 days after sowing, significantly highest (10.62 cm) leaf length was found at T_4 (200:100:50 kg NPK / ha) level and it was statistically on par with T_3 (150:100:50 kg NPK / ha) level (10.29 cm). Whereas, lowest leaf length (8.53 cm) was recorded in T_1 (50:100:50 kg NPK / ha). Leaf length at 30 days after planting varied significantly among different nutrition levels. The results showed that significantly highest leaf length (27.90 cm) was indicated in T_4 (200:100:50 kg NPK / ha) and it was followed by T_3 (150:100:50 kg NPK / ha) level (27.25 cm). While, lowest leaf length (21.69 cm) was recorded in T_1 (50:100:50 kg NPK / ha). At 45 days after sowing, significantly highest (32.57 cm) leaf length was noticed at T_4 (200:100:50 kg NPK / ha) level and it was statistically on par with T_3 (150:100:50 kg NPK / ha) level (31.00 cm). Whereas, lowest leaf length (25.24 cm) was registered in T_1 (50:100:50 kg NPK / ha).

4.1.4 Leaf width

The data on the leaf width at different growth stages 15, 30, 45 days after sowing (DAS) as influenced by graded levels of nitrogen, phosphorus and potassium are presented in Table 4. Leaf width varied significantly at all stages of the plant growth with respect to nutrition.

The maximum leaf width was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (4.04, 10.89 and 11.86cm at 15, 30 and 45 DAS, respectively), which was on par with application of T_3 (150:100:50 kg NPK / ha) nutrition level (3.93, 10.31 and 11.38cm at 15, 30 and 45 DAS, respectively). While, minimum leaf width was recorded at T_1 (50:100:50 kg NPK / ha) nutrition level (3.32, 8.04 and 9.94cm at 15, 30 and 45 DAS, respectively).

4.1.5 Spread of the plant (North-South)

The data on plant spread (North-South) as influenced by graded levels of nitrogen, phosphorus and potassium at different growth stages recorded at 15, 30, and 45 days after sowing (DAS) are presented in Table 5. The spread of the plant in radish significantly differed among different nutrition levels treatments at all stages of plant growth.

Table 3: Effect of graded levels of nitrogen, phosphorus and potassium on leaf length at different growth stages in radish cv. Pusa Chetki

Treatments	Leaf length (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	8.53	21.69	25.24
T_2 - 100:100:50 kg NPK / ha	9.95	25.58	28.97
T_3 - 150:100:50 kg NPK / ha	10.29	27.25	31.00
T_4 - 200:100:50 kg NPK / ha	10.62	27.90	32.57
T_5 - 50:150:50 kg NPK / ha	9.11	25.03	27.44
T_6 - 50:200:50 kg NPK / ha	10.05	26.44	29.83
T_7 - 50:250:50 kg NPK / ha	9.85	24.90	26.43
T_8 - 50:100:100 kg NPK / ha	9.49	23.33	28.55
T_9 - 50:100:150 kg NPK / ha	9.23	24.80	26.26
T_{10} - 50:100:200 kg NPK / ha	9.89	24.94	26.86
S.Em±	**0.15**	**0.84**	**0.90**
C.D @ 5%	**0.46**	**2.49**	**2.67**

DAS: Days After Sowing

Table 4: Effect of graded levels of nitrogen, phosphorus and potassium on leaf width at different growth stages in radish cv. Pusa Chetki

Treatments	Leaf width (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	3.32	8.04	9.94
T_2 - 100:100:50 kg NPK / ha	3.66	9.57	10.89
T_3 - 150:100:50 kg NPK / ha	3.93	10.31	11.38
T_4 - 200:100:50 kg NPK / ha	4.04	10.89	11.86
T_5 - 50:150:50 kg NPK / ha	3.38	8.71	10.34
T_6 - 50:200:50 kg NPK / ha	3.75	9.74	11.11
T_7 - 50:250:50 kg NPK / ha	3.55	8.85	10.62
T_8 - 50:100:100 kg NPK / ha	3.49	8.61	10.31
T_9 - 50:100:150 kg NPK / ha	3.60	8.82	10.58
T_{10} - 50:100:200 kg NPK / ha	3.53	9.07	10.45
S.Em±	**0.05**	**0.28**	**0.14**
C.D @ 5%	**0.14**	**0.83**	**0.41**

DAS: Days After Sowing

Table 5: Effect of graded levels of nitrogen, phosphorus and potassium on spread of the plant (North-South) at different growth stages in radish cv. Pusa Chetki

Treatments	Spread of the plant (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	16.77	26.33	29.50
T_2 - 100:100:50 kg NPK / ha	18.61	28.52	33.98
T_3 - 150:100:50 kg NPK / ha	19.59	29.85	36.61
T_4 - 200:100:50 kg NPK / ha	20.83	31.25	40.81
T_5 - 50:150:50 kg NPK / ha	18.40	28.67	32.64
T_6 - 50:200:50 kg NPK / ha	19.11	28.77	35.17
T_7 - 50:250:50 kg NPK / ha	17.79	27.70	32.93
T_8 - 50:100:100 kg NPK / ha	17.75	26.95	30.77
T_9 - 50:100:150 kg NPK / ha	17.47	27.29	32.61
T_{10} - 50:100:200 kg NPK / ha	17.49	27.61	31.50
S.Em±	**0.29**	**0.36**	**1.23**
C.D @ 5%	**0.87**	**1.08**	**3.65**

DAS: Days After Sowing

The application of 200:100:50 kg NPK / ha at 15 DAS, recorded significantly maximum (20.83 cm) plant spread in T_4, which was followed by T_3 (19.59 cm). While, minimum (16.77 cm) was observed in T_1 (50:100:50 kg NPK / ha). At 30 DAS, the maximum (31.25 cm) plant spread was significantly found in T_4 (200:100:50 kg NPK / ha) and it was followed by T_3 (29.85 cm) with application of (150:100:50 kg NPK / ha). Whereas, least (26.33 cm) was found in T_1 (50:100:50 kg NPK / ha). At 45 DAS, the maximum (40.81 cm) plant spread was significantly shown in T_4 with application of (200:100:50 kg NPK / ha), which was followed by (36.61 cm) with application of T_3 (150:100:50 kg NPK / ha), while lowest (29.50 cm) plant spread was recorded in T_1 with application of 50:100:50 kg NPK / ha.

4.1.6 Spread of the plant (East-West)

The data pertaining to plant spread (East-West) as influenced by graded levels of nitrogen, phosphorus and potassium at different growth stages 15, 30 and 45 days after sowing (DAS) are presented in Table 6.

Spread of the plant varied significantly at all the stages of plant growth due to different treatments. At 15 DAS, (200:100:50 kg NPK / ha) T_4 was recorded significantly higher plant spread (E-W) (18.00 cm) over rest of the treatments and it was followed by T_3 (16.61 cm) with application form of (150:100:50 kg NPK / ha), while least plant spread (14.61 cm) was observed in control (T_1). At 30 DAS, the maximum (30.13 cm) plant spread was significantly found in T_4 (200:100:50 kg NPK / ha) over rest of the treatments and it was followed by T_3 (28.24 cm) with application of (150:100:50 kg NPK / ha). Whereas, minimum (24.93 cm) plant spread was recorded in T_1. At 45 DAS, the maximum (43.93 cm) plant spread significantly shown in T_4 with application form of 200:100:50 kg NPK / ha, which was followed by T_3 (37.68 cm) with application of 150:100:50 kg NPK / ha. While, lowest (32.56 cm) plant spread was recorded in T_1 with application of 50:100:50 kg NPK / ha.

4.1.7 Stem diameter

The data on stem diameter as influenced by graded levels of nitrogen, phosphorus and potassium at different growth stages recorded in 15, 30 and 45 days after sowing (DAS) are presented in Table 7. The stem diameter of radish varied significantly among different treatments.

Table 6: Effect of graded levels of nitrogen, phosphorus and potassium on spread of the plant (East-West) at different growth stages in radish cv. Pusa Chetki

Treatments	Spread of the plant (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	14.61	24.93	32.56
T_2 - 100:100:50 kg NPK / ha	15.47	27.47	35.75
T_3 - 150:100:50 kg NPK / ha	16.61	28.24	37.68
T_4 - 200:100:50 kg NPK / ha	18.00	30.13	43.93
T_5 - 50:150:50 kg NPK / ha	15.15	26.27	34.16
T_6 - 50:200:50 kg NPK / ha	15.83	27.64	36.51
T_7 - 50:250:50 kg NPK / ha	15.18	26.42	34.21
T_8 - 50:100:100 kg NPK / ha	15.11	26.32	33.55
T_9 - 50:100:150 kg NPK / ha	15.23	27.12	35.57
T_{10} - 50:100:200 kg NPK / ha	15.02	25.94	35.17
S.Em±	**0.19**	**0.41**	**1.16**
C.D @ 5%	**0.57**	**1.23**	**3.44**

DAS: Days After Sowing

Table 7: Effect of graded levels of nitrogen, phosphorus and potassium on diameter of the stem at different growth stages in radish cv. Pusa Chetki

Treatments	Stem diameter (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	0.76	0.79	1.20
T_2 - 100:100:50 kg NPK / ha	0.87	0.97	1.35
T_3 - 150:100:50 kg NPK / ha	0.93	1.04	1.43
T_4 - 200:100:50 kg NPK / ha	0.96	1.09	1.53
T_5 - 50:150:50 kg NPK / ha	0.85	0.91	1.29
T_6 - 50:200:50 kg NPK / ha	0.90	1.00	1.39
T_7 - 50:250:50 kg NPK / ha	0.83	0.91	1.26
T_8 - 50:100:100 kg NPK / ha	0.77	0.88	1.31
T_9 - 50:100:150 kg NPK / ha	0.82	0.87	1.28
T_{10} - 50:100:200 kg NPK / ha	0.80	0.83	1.29
S.Em±	**0.01**	**0.02**	**0.03**
C.D @ 5%	**0.02**	**0.06**	**0.08**

DAS: Days After Sowing

The diameter of stem differed significantly with respect to different treatments. At 15 days after sowing, stem diameter was significantly found to be higher (0.96 cm) in T_4 with application of (200:100:50 kg NPK / ha) which was followed by T_3 (0.93 cm). While, minimum (0.76 cm) stem diameter was recorded at control (T_1). The stem diameter at 30 days after sowing varied significantly among different treatments. The results revealed that significantly maximum (1.09 cm) stem diameter was recorded in T_4, which was followed by T_3 (1.04 cm) and it was statistically on par with each other. Whereas, minimum (0.79 cm) stem diameter was recorded in control (T_1). At 45 days after sowing (DAS), the significantly maximum (1.53 cm) stem diameter was recorded in T_4 with the application of 200:100:50 kg NPK / ha which was followed by T_3 (1.43 cm) and it was significantly differ with each other. Whereas, least (1.20 cm) stem diameter was found in T_1.

4.1.8 Fresh weight of leaves

The data presented on fresh weight of leaves as influenced by graded levels of nitrogen, phosphorus and potassium at different stages showed significant differences among the different treatments (Table 8).

The fresh weight of leaves differed significantly with respect to different nutrition levels. At 15 days after sowing, significantly maximum (13.42 g) fresh weight of leaves was found at T_4 (200:100:50 kg NPK / ha) nutrition level and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (11.43 g). Whereas, minimum fresh weight of leaves (6.67 g) was recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. Fresh weight of leaves at 30 days after sowing varied significantly among different nutrition levels. The results revealed that significantly maximum fresh weight of leaves (65.32 g) was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (58.31 g). While, minimum fresh weight of leaves (35.66 g) was recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. The maximum fresh weight of leaves at 45 days after sowing was noticed in T_4 (200:100:50 kg NPK / ha) nutrition level (70.94 g) and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (64.50 g). While, minimum fresh weight of leaves (40.21 g) was recorded T_1 (50:100:50 kg NPK / ha) nutrition level.

4.1.9 Dry weight of leaves

The data with respect to the effect of graded levels of nitrogen, phosphorus and potassium on dry weight of leaves are presented in Table 9. The dry weight of leaves was found to be significantly influenced by nutrition levels at all stages of plant growth.

Table 8: Effect of graded levels of nitrogen, phosphorus and potassium on fresh weight of leaves at different growth stages in radish cv. Pusa Chetki

Treatments	Fresh weight of leaves (g)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	6.67	35.66	40.21
T_2 - 100:100:50 kg NPK / ha	9.44	51.24	56.11
T_3 - 150:100:50 kg NPK / ha	11.43	58.31	64.50
T_4 - 200:100:50 kg NPK / ha	13.42	65.32	70.94
T_5 - 50:150:50 kg NPK / ha	8.93	41.20	50.82
T_6 - 50:200:50 kg NPK / ha	10.30	54.80	60.71
T_7 - 50:250:50 kg NPK / ha	8.66	39.71	43.88
T_8 - 50:100:100 kg NPK / ha	7.50	38.63	44.98
T_9 - 50:100:150 kg NPK / ha	8.94	43.70	47.79
T_{10} - 50:100:200 kg NPK / ha	8.76	39.52	47.07
S.Em±	**0.52**	**4.24**	**1.94**
C.D @ 5%	**1.55**	**12.60**	**5.76**

DAS: Days After Sowing

Table 9: Effect of graded levels of nitrogen, phosphorus and potassium on dry weight of leaves at different growth stages in radish cv. Pusa Chetki

Treatments	Dry weight of leaves (g)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	0.49	1.92	2.99
T_2 - 100:100:50 kg NPK / ha	0.70	2.78	5.81
T_3 - 150:100:50 kg NPK / ha	0.78	3.40	6.76
T_4 - 200:100:50 kg NPK / ha	0.84	3.89	7.27
T_5 - 50:150:50 kg NPK / ha	0.63	2.37	5.11
T_6 - 50:200:50 kg NPK / ha	0.72	3.00	6.30
T_7 - 50:250:50 kg NPK / ha	0.66	2.32	5.18
T_8 - 50:100:100 kg NPK / ha	0.62	2.49	4.52
T_9 - 50:100:150 kg NPK / ha	0.59	2.37	4.07
T_{10} - 50:100:200 kg NPK / ha	0.60	2.11	3.71
S.Em±	**0.03**	**0.23**	**0.24**
C.D @ 5%	**0.08**	**0.69**	**0.72**

DAS: Days After Sowing

The dry weight of leaves differed significantly with respect to levels of nutrition. The significantly maximum dry weight of leaves was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (0.84, 3.89 and 7.27 g at 15, 30 and 45 DAS, respectively), which was followed by application of 150:100:50 kg NPK / ha (T_3) nutrition level (0.78, 3.40 and 6.76 g at 15, 30, and 45 DAS, respectively). While, minimum dry weight of leaves was recorded at T_1 (50:100:50 kg NPK / ha) nutrition level (0.49, 1.92 and 2.99 at 15, 30, and 45 DAS, respectively).

4.1.10 Fresh weight of stem

The data presented on fresh weight of stem as influenced by graded levels of nitrogen, phosphorus and potassium on different growth stages (15, 30 and 45 DAS) are presented in Table 10. The fresh weight of stem was found to be significantly influenced by nutrition levels at all stages of plant growth.

The fresh weight of stem differed significantly with respect to nutrition levels. The maximum fresh weight of stem was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (4.77, 22.92, and 31.76 g at 15, 30 and 45 DAS, respectively), which was followed by application of T_3 (150:100:50 kg NPK / ha) nutrition level (4.30, 21.07, and 30.18 g at 15, 30 and 45 DAS, respectively). While, minimum fresh weight of stem was recorded at T_1 (50:100:50 kg NPK / ha) nutrition level (3.30, 14.27 and 20.06 g at 15, 30, and 45 DAS, respectively).

4.1.11 Dry weight of stem

The data on dry weight of stem as influenced by graded levels of nitrogen, phosphorus and potassium levels recorded significant differences at different stages of growth are presented in Table 11.

The dry weight of stem differed significantly with respect to different nutrition levels. At 15 days after sowing, significantly maximum (0.34 g) dry weight of stem was found at T_4 (200:100:50 kg NPK / ha) nutrition level followed by T_3 (150:100:50 kg NPK / ha) nutrition level (0.31 g). Whereas, minimum dry weight of stem (0.16 g) was recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. Dry weight of stem at 30 days after sowing varied significantly among different nutrition levels. The results revealed that significantly maximum dry weight of stem was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level (1.36 g) and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (1.21 g). While, minimum dry weight of stem (0.62 g) was noted in T_1 (50:100:50 kg NPK / ha) nutrition level. Significantly maximum (1.63 g) dry weight of stem at 45 days after sowing was recorded in T_4 (200:100:50 kg NPK / ha) and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (1.46 g). While, minimum dry weight of stem (0.72 g) was recorded in T_1 (50:100:50 kg NPK / ha).

Table 10: Effect of graded levels of nitrogen, phosphorus and potassium on fresh weight of stem at different growth stages in radish cv. Pusa Chetki

Treatments	Fresh weight of stem (g)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	3.30	14.27	20.06
T_2 - 100:100:50 kg NPK / ha	3.92	18.97	26.20
T_3 - 150:100:50 kg NPK / ha	4.30	21.07	30.18
T_4 - 200:100:50 kg NPK / ha	4.77	22.92	31.76
T_5 - 50:150:50 kg NPK / ha	3.62	15.67	21.83
T_6 - 50:200:50 kg NPK / ha	4.06	20.28	28.13
T_7 - 50:250:50 kg NPK / ha	3.65	17.68	23.90
T_8 - 50:100:100 kg NPK / ha	3.57	17.29	23.28
T_9 - 50:100:150 kg NPK / ha	3.58	17.35	23.35
T_{10} - 50:100:200 kg NPK / ha	3.69	16.79	24.08
S.Em±	**0.12**	**0.53**	**0.62**
C.D @ 5%	**0.35**	**1.59**	**1.85**

DAS: Days After Sowing

Table 11: Effect of graded levels of nitrogen, phosphorus and potassium on dry weight of stem at different growth stages in radish cv. Pusa Chetki

Treatments	Dry weight of stem (g)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	0.16	0.62	0.72
T_2 - 100:100:50 kg NPK / ha	0.24	0.99	1.16
T_3 - 150:100:50 kg NPK / ha	0.31	1.21	1.46
T_4 - 200:100:50 kg NPK / ha	0.34	1.36	1.63
T_5 - 50:150:50 kg NPK / ha	0.21	0.83	1.07
T_6 - 50:200:50 kg NPK / ha	0.26	1.15	1.30
T_7 - 50:250:50 kg NPK / ha	0.22	0.89	0.95
T_8 - 50:100:100 kg NPK / ha	0.21	0.85	0.95
T_9 - 50:100:150 kg NPK / ha	0.19	0.80	1.00
T_{10} - 50:100:200 kg NPK / ha	0.18	0.68	0.85
S.Em±	**0.01**	**0.10**	**0.10**
C.D @ 5%	**0.04**	**0.31**	**0.30**

DAS: Days After Sowing

4.1.12 Dry weight of root

The data with respect to the effect of graded levels of nitrogen, phosphorus and potassium on dry weight of root are presented in Table 12. The dry weight of root was found to be significantly influenced by nutrition levels at different growth stages.

The dry weight of root differed significantly with respect to levels of nutrition. Dry weight of root at 15 days after sowing was significantly found to be maximum (2.27 g) in T_4 with the application of (200:100:50 kg NPK / ha) nutrition level followed by T_3 (150:100:50 kg NPK / ha) nutrition level (2.10 g). Whereas, T_1 (50:100:50 kg NPK / ha) nutrition level recorded lowest dry weight of root (1.70 g). The dry weight of root at 30 days after sowing varied significantly among different nutrition levels. The results revealed that significantly maximum dry weight of root was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level (4.62 g) and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (4.38 g), which was statistically on par with each other. While, minimum dry weight of root (2.22 g) was noted in T_1 (50:100:50 kg NPK / ha) nutrition level. The significantly maximum (9.89 g) dry weight of root at 45 days after sowing was recorded in T_4 (200:100:50 kg NPK / ha) and it was followed by T_3 (150:100:50 kg NPK / ha) nutrition level (8.73 g). While, minimum dry weight of root (4.92 g) was recorded in T_1 (50:100:50 kg NPK / ha).

4.1.13 Total dry matter of the plant

The data on total dry matter of the plant as influenced by graded levels of nitrogen, phosphorus and potassium recorded at 15, 30 and 45 DAS are presented in Table 13. Total dry matter of the plant varied significantly at all stages of plant growth.

The total dry weight of the plant differed significantly with respect to levels of nutrition. Significantly maximum total dry weight of the plant was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (3.45, 9.87 and 18.79 g at 15, 30 and 45 DAS, respectively), which was followed by application of 150:100:50 kg NPK / ha (T_3) nutrition level (3.19, 8.99 and 16.95 g at 15, 30 and 45 DAS, respectively). While, minimum dry weight of the plant was recorded at T_1 (50:100:50 kg NPK / ha) nutrition level (2.35, 4.76 and 8.63 at 15, 30 and 45 DAS, respectively).

4.2 Growth parameters

4.2.1 Leaf area

The data pertaining to leaf area presented in Figure 2. The leaf area showed significant difference at all stages of plant growth with respect to nitrogen, phosphorus and potassium.

Table 12. Effect of graded levels of nitrogen, phosphorus and potassium on dry weight of the root at different growth stages in radish cv. Pusa Chetki

Treatments	Dry weight of root (g)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	1.70	2.22	4.92
T_2 - 100:100:50 kg NPK / ha	1.94	3.51	6.89
T_3 - 150:100:50 kg NPK / ha	2.10	4.38	8.73
T_4 - 200:100:50 kg NPK / ha	2.27	4.62	9.89
T_5 - 50:150:50 kg NPK / ha	1.86	2.80	6.14
T_6 - 50:200:50 kg NPK / ha	2.03	3.76	7.65
T_7 - 50:250:50 kg NPK / ha	1.89	2.71	5.86
T_8 - 50:100:100 kg NPK / ha	1.86	2.88	6.08
T_9 - 50:100:150 kg NPK / ha	1.83	2.79	5.62
T_{10} - 50:100:200 kg NPK / ha	1.84	3.01	6.56
S.Em±	**0.03**	**0.21**	**0.41**
C.D @ 5%	**0.07**	**0.62**	**1.21**

DAS: Days After Sowing

Table 13. Effect of graded levels of nitrogen, phosphorus and potassium on total dry matter of the plant at different growth stages in radish cv. Pusa Chetki

Treatments	Total dry matter of the plant (g)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 - 50:100:50 kg NPK / ha (Control)	2.35	4.76	8.63
T_2 - 100:100:50 kg NPK / ha	2.88	7.28	13.86
T_3 - 150:100:50 kg NPK / ha	3.19	8.99	16.95
T_4 - 200:100:50 kg NPK / ha	3.45	9.87	18.79
T_5 - 50:150:50 kg NPK / ha	2.70	6.00	12.32
T_6 - 50:200:50 kg NPK / ha	3.01	7.91	15.25
T_7 - 50:250:50 kg NPK / ha	2.77	5.92	11.99
T_8 - 50:100:100 kg NPK / ha	2.69	6.22	11.55
T_9 - 50:100:150 kg NPK / ha	2.61	5.96	10.69
T_{10} - 50:100:200 kg NPK / ha	2.62	5.80	11.12
S.Em±	**0.03**	**0.17**	**0.43**
C.D @ 5%	**0.09**	**0.50**	**1.27**

DAS: Days After Sowing

The Leaf area per plant differed significantly with respect to levels of nutrition. Significantly maximum leaf area per plant was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (210.33, 285.67 and 350.67 cm^2 at 15, 30 and 45 DAS, respectively), which was followed by application of T_3 (150:100:50 kg NPK / ha) nutrition level (199.77, 274.50 and 304.50 cm^2 at 15, 30 and 45 DAS, respectively). While, minimum leaf area per plant was observed at T_1 (50:100:50 kg NPK / ha) nutrition level (63.00, 83.33 and 97.67 cm^2 at 15, 30 and 45 DAS, respectively).

4.2.2 Leaf Area Index (LAI)

The data on leaf area index as influenced by graded levels of nitrogen, phosphorus and potassium recorded at 15, 30 and 45 days after sowing (DAS) are presented in Figure 3.

Significant difference was observed for leaf area index due to different treatments at all stages of the plant growth. Among the nutrient levels treatments T_4 (200:100:50 kg NPK / ha) recorded significantly maximum (0.70) leaf area index. While, the minimum (0.21) leaf area index was recorded at T_1 (control) at 15 DAS. At 30 DAS, T_4 (200:100:50 kg NPK / ha) recorded significantly maximum (0.95) leaf area index and it was on par with T_3 (0.91), while, the lowest (0.28) leaf area index was observed in control (T_1). However at 45 DAS, T_4 (200:100:50 kg NPK / ha) recorded significantly maximum (1.16) leaf area index, which was followed by T_3 (1.01) with application of 150:100:50 kg NPK / ha, but the least leaf area index (0.32) was noticed in control (T_1).

4.2.3 Absolute Growth Rate (AGR)

The data pertaining to absolute growth rate are presented in Figure 4. Absolute growth rate as influenced by graded levels of nitrogen, phosphorus and potassium was recorded at 15 - 30 DAS and 30 - 45 DAS. The AGR varied significantly at all stages of plant growth.

The absolute growth rate differed significantly with respect to levels of nutrition. Also, significantly maximum absolute growth rate was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level (0.42 and 0.59 g / plant / day at 15-30 and 30-45 DAS, respectively) followed by application of T_3 (150:100:50 kg NPK / ha) nutrition level (0.38 and 0.53 g / plant / day at 15-30 and 30-45 DAS, respectively). While, minimum absolute growth rate was recorded at T_1 (50:100:50 kg NPK / ha) nutrition level (0.16 and 0.25 g / plant / day at 15-30 and 30-45 DAS, respectively).

4.2.4 Crop Growth Rate (CGR)

The data pertaining to crop growth rate are presented in Figure 5. The crop growth rate as influenced by graded levels of nitrogen, phosphorus and potassium was

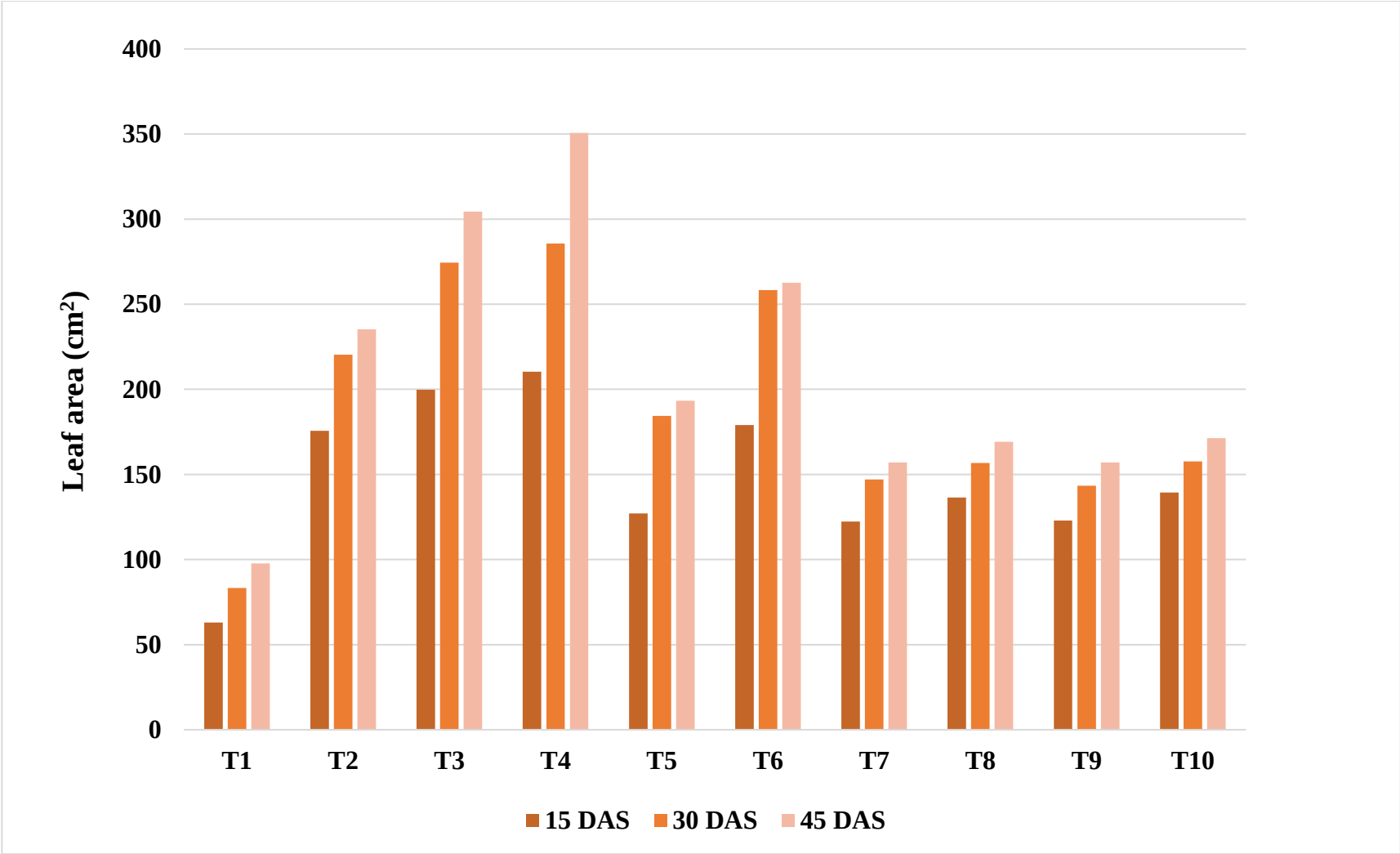


Fig. 2. Effect of graded levels of nitrogen, phosphorus and potassium on leaf area at different growth stages in radish

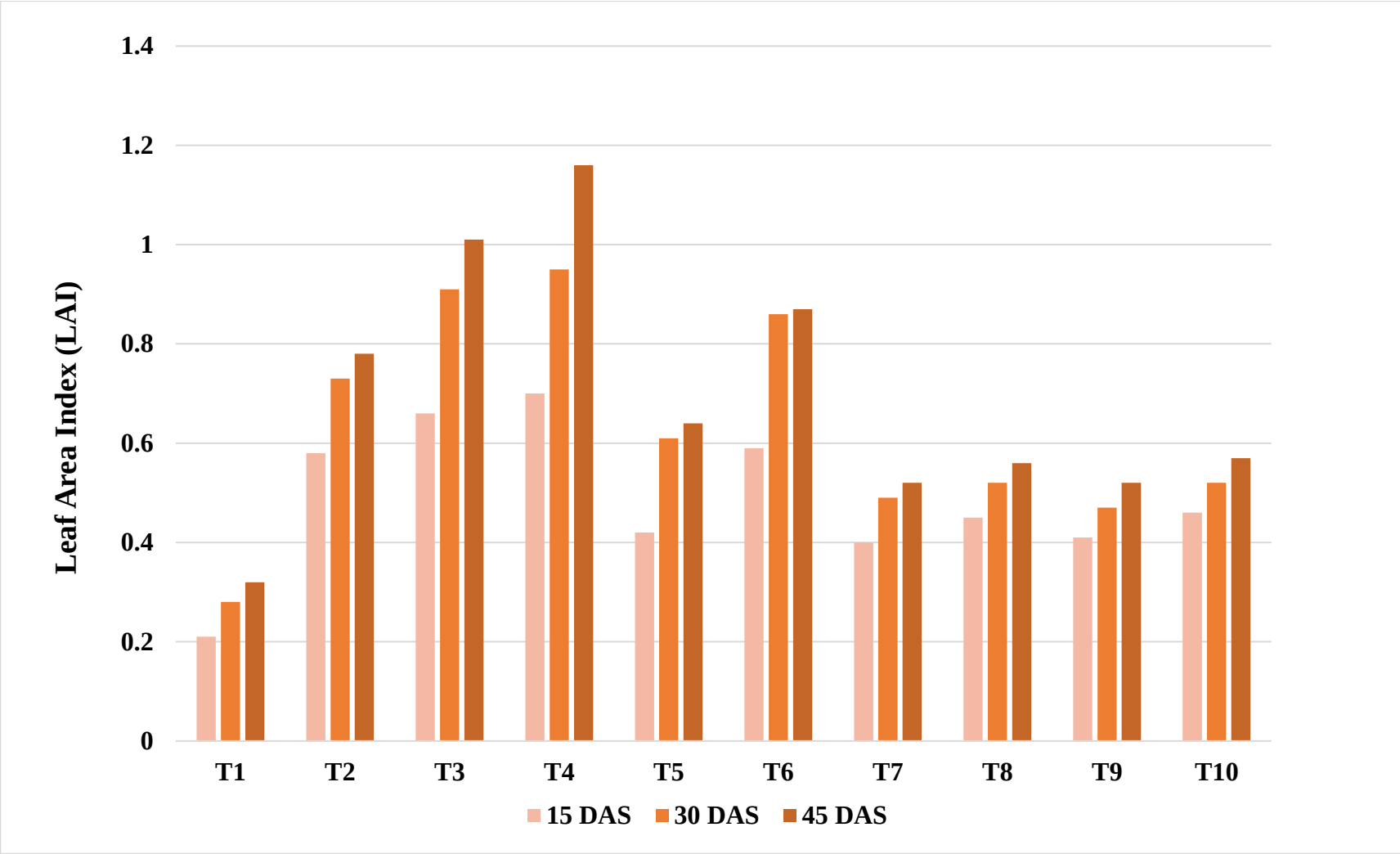


Fig 3. Effect of graded levels of nitrogen, phosphorus and potassium on Leaf area index at different growth stages in radish

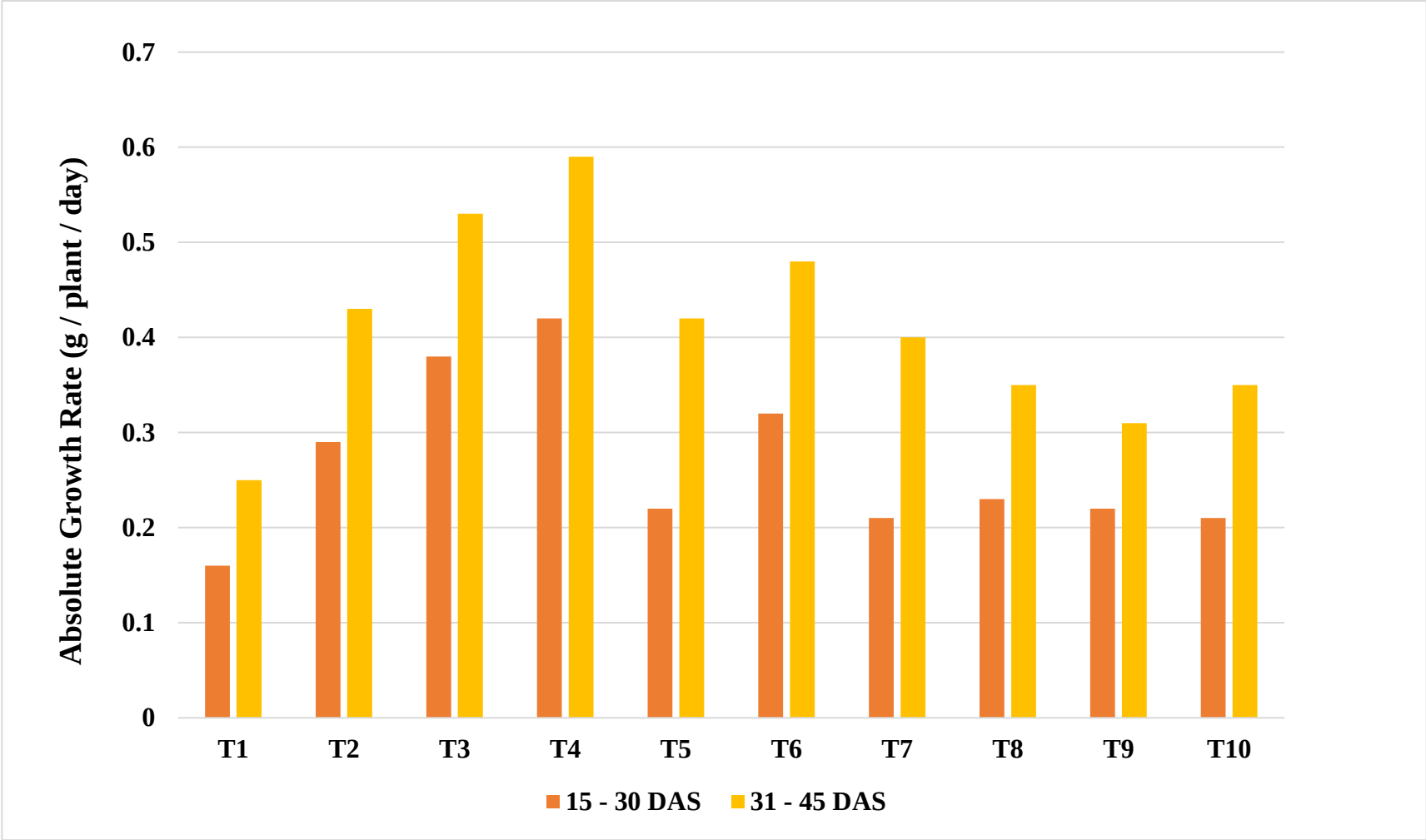


Fig 4. Effect of graded levels of nitrogen, phosphorus and potassium on Absolute Growth Rate at different growth stages in radish

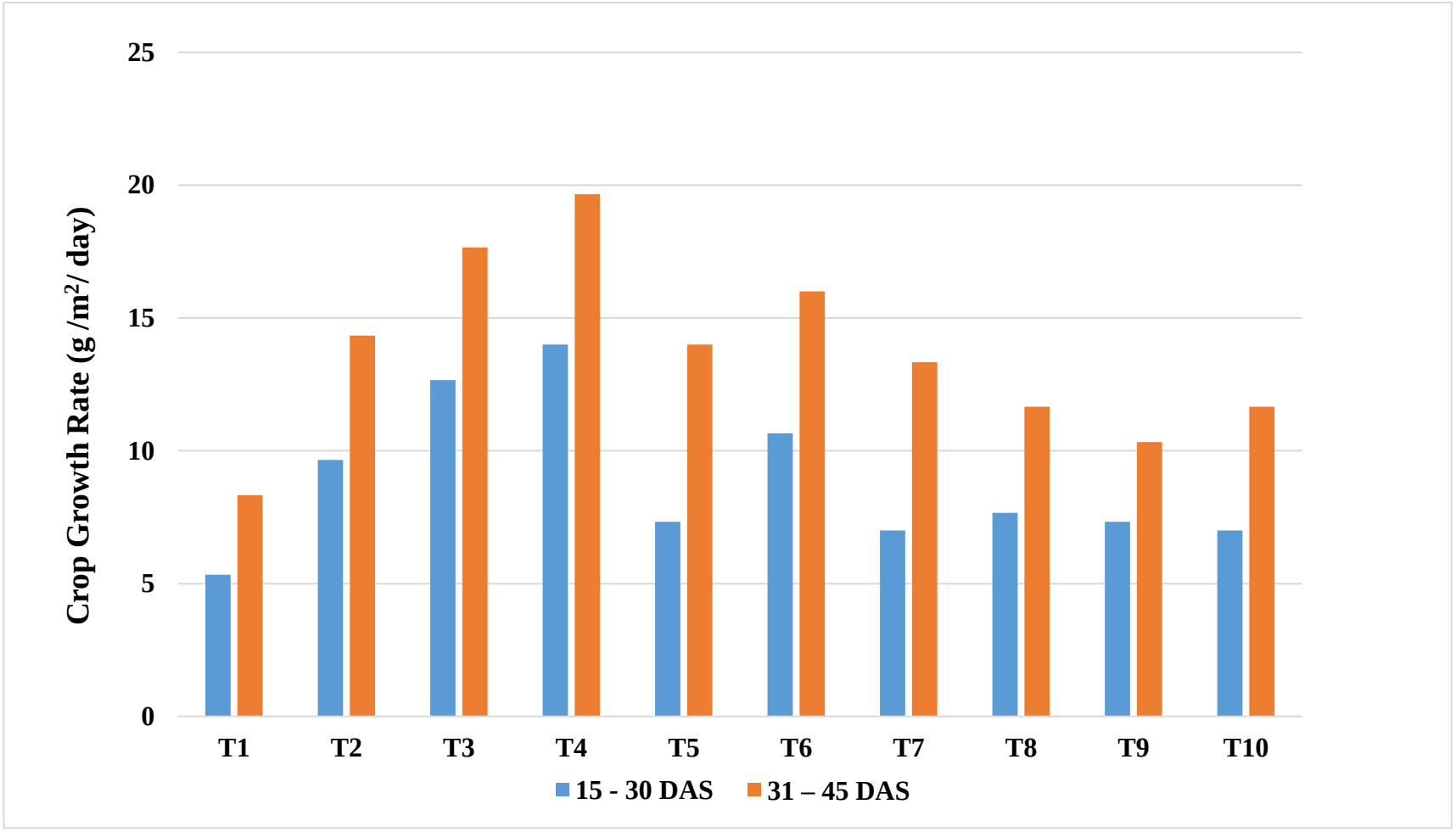


Fig 5. Effect of graded levels of nitrogen, phosphorus and potassium on crop growth rate at different growth stages in radish

recorded at 15 - 30 DAS and 30 - 45 DAS. CGR varied significantly at all stages of plant growth.

The crop growth rate was differed significantly at all the stages of the plant growth. At 15-30 DAS, significantly maximum crop growth rate (14.00 g per m^2 per day) was observed at T_4 (200:100:50 kg NPK / ha) followed by T_3 (150:100:50 kg NPK / ha) (12.66 g per m^2 per day). While, least was noticed at T_1 (5.33 g per m^2 per day). At 30-45 DAS, significantly maximum crop growth rate (19.66 g per m^2 per day) was recorded at T_4 (200:100:50 kg NPK / ha) followed by T_3 (150:100:50 kg NPK / ha) (17.66 g per m^2 per day). While, the minimum crop growth rate (8.33 g per m^2 per day) was recorded in control (T_1).

4.2.5 Net Assimilation Rate (NAR)

The data on net assimilation rate as influenced by graded levels of nitrogen, phosphorus and potassium recorded at 15-30 DAS and 30-45 DAS are presented in Figure 6. The NAR varied significantly at all stages of plant growth.

The net assimilation rate was shown to increase significantly up to T_4 (200:100:50 kg NPK / ha) nutrition level compared to other levels of nutrition. At 15-30 DAS, significantly maximum net assimilation rate (0.0088 g / dm^2 / day) was recorded at T_4 (200:100:50 kg NPK/ha) nutrition level followed by T_3 (150:100:50 kg NPK/ha) nutrition level (0.0075 g / dm^2 /day). While, the least under T_1 (50:100:50 kg NPK/ha) nutrition level (0.0057 g /dm^2 /day). At 30-45 DAS, significantly maximum net assimilation rate (0.0291 g / dm^2 / day) was noted in T_4 (200:100:50 kg NPK/ha) nutrition level which was on par with T_3 (150:100:50 kg NPK/ha) nutrition level (0.0258 g / dm^2 / day). While, the least under T_1 (50:100:50 kg NPK / ha) nutrition level (0.0081 g / dm^2 /day).

4.3 Root parameters

4.3.1 Root length

The data pertaining on root length as influenced by graded levels of nitrogen, phosphorus and potassium on yield recorded at 45 days after sowing (harvesting time) are presented in Table 14 and plate 3.

The significant influence of nutrition on root length was also established and application of 200:100:50 kg NPK per ha resulted in the production of longer root (23.60 cm). While, the plants with the application of 50:100:50 kg NPK per ha recorded shorter root of 15.98 centimeters.

4.3.2 Root girth

The data on root girth as influenced by graded levels of nitrogen, phosphorus and potassium on yield recorded at 45 days after sowing (harvesting time) are

presented in Table 14. The root girth of radish varied significantly among different treatments.

The root girth also differed significantly with nutrition levels. It was found to be significantly maximum *i.e.* 13.13 centimeter in T_4 (200:100:50 kg NPK / ha) followed by T_3 (11.83 cm). Whereas, minimum root girth was recorded in T_1 (7.22 cm).

4.3.3 Root volume

The data on the volume of root as influenced by graded levels of nitrogen, phosphorus and potassium on yield recorded at 45 days after sowing are presented in Table 14. The root volume varied significantly with different treatments.

The root volume differed significantly in response to nutrition levels. Root volume was found to be significantly maximum, *i.e.* 257.00 cubic centimeter with the application of T_4 (200:100:50 kg NPK / ha) nutrition level followed by T_3 (150:100:50 kg NPK / ha) nutrition level *i.e.* 229.33 cubic centimeter. However, the T_1 (50:100:50 kg NPK / ha) nutrition level recorded the least root volume (115.00 cc).

4.3.4 Fresh weight of root

The data presented on fresh weight of root as influenced by graded levels of nitrogen, phosphorus and potassium on yield at 45 days after sowing showed significant differences among the different treatments (Table 15).

The fresh weight of root differed significantly with respect to different nutrition levels. The fresh weight of root was found to be significantly maximum (271.33 g) in T_4 with the application of (200:100:50 kg NPK / ha) nutrition level followed by T_3 (150:100:50 kg NPK / ha) nutrition level (235.33 g). Whereas, the T_1 (50:100:50 kg NPK / ha) nutrition level recorded lowest fresh weight of root (110.67 g).

4.3.5 Root yield per plot

The data pertaining to root yield per plot as influenced by graded levels of nitrogen, phosphorus and potassium are presented in Table 15, which showed significant difference among the treatments.

Significantly maximum (5.00 kg / plot) root yield per plot was noted at T_4 (200:100:50 kg NPK / ha) and it was followed by T_3 (150:100:50 kg NPK / ha) *i.e.* 4.43 kg / plot. Whereas, minimum root yield per plot (2.47 kg / plot) was recorded in T_1 (50:100:50 kg NPK / ha).

4.3.6 Root yield per hectare

The data with respect to root yield per hectare as influenced by graded levels of nitrogen, phosphorus and potassium is presented in Table 15, which showed significant differences among the treatments.

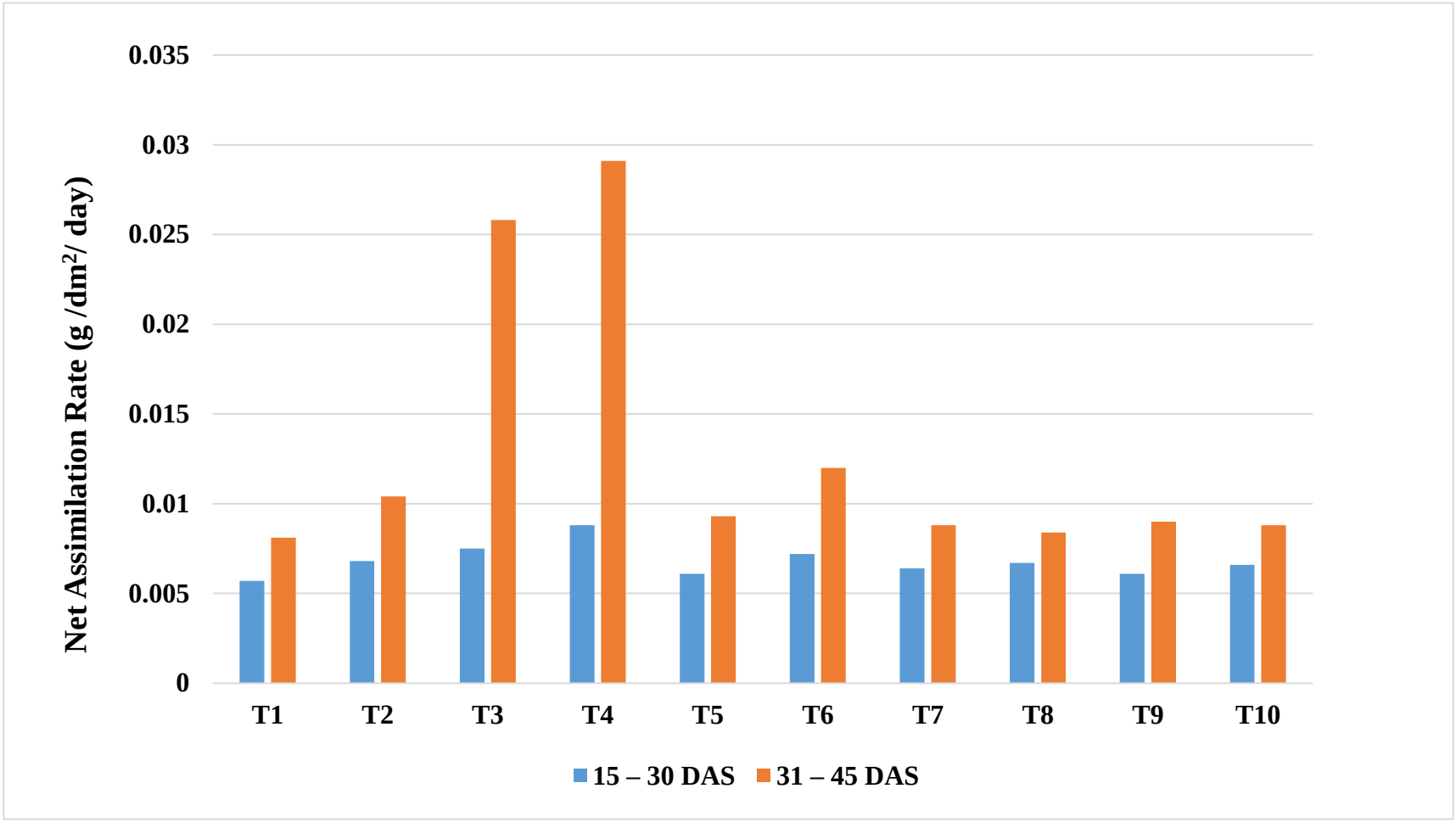
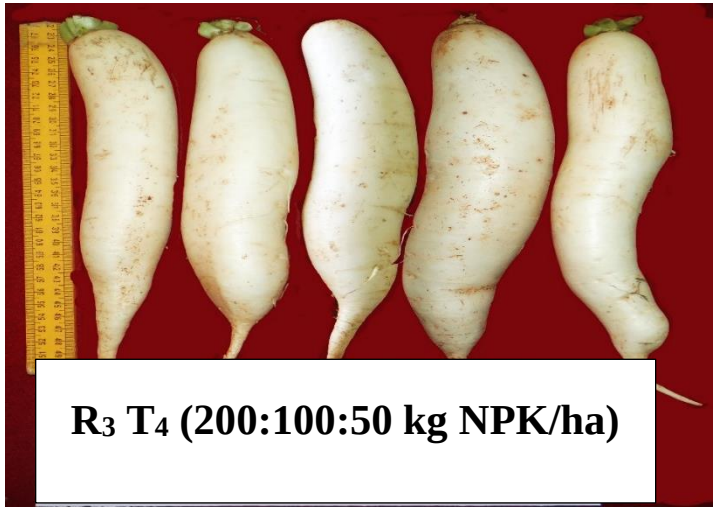
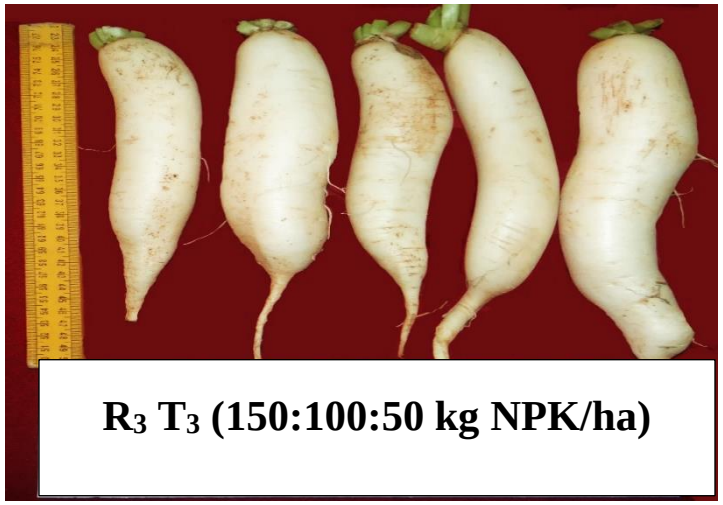


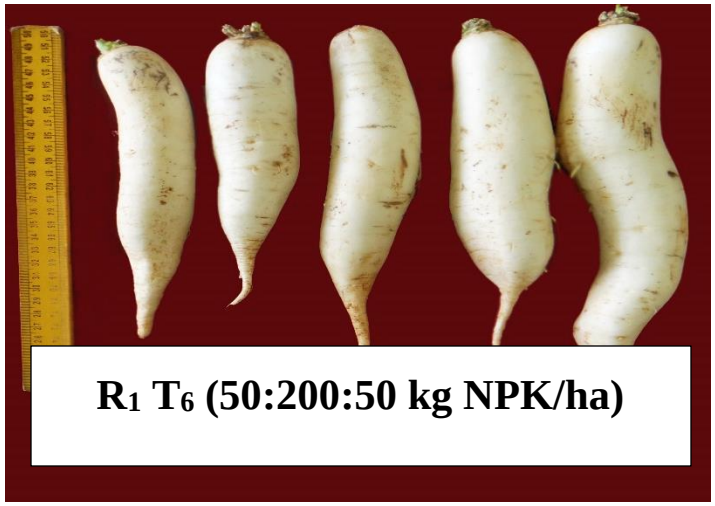
Fig 6. Effect of graded levels of nitrogen, phosphorus and potassium on net assimilation rate at different growth stages in radish



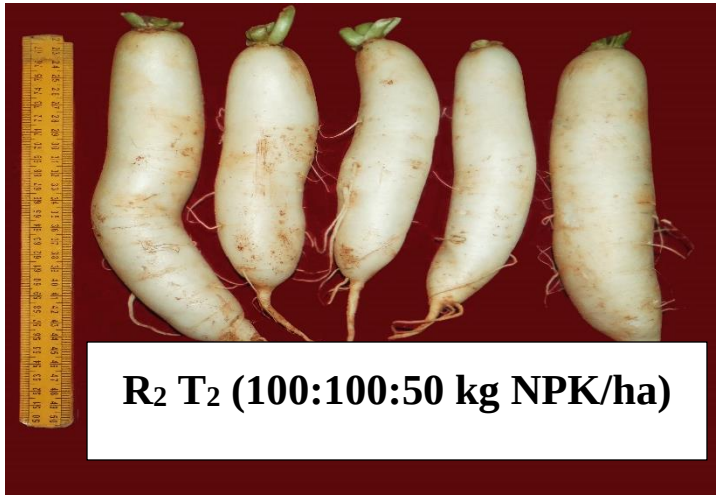
R_3 T_4 (200:100:50 kg NPK/ha)



R_3 T_3 (150:100:50 kg NPK/ha)



R_1 T_6 (50:200:50 kg NPK/ha)



R_2 T_2 (100:100:50 kg NPK/ha)

Plate 3. Roots of best treatments

Table 14. Effect of graded levels of nitrogen, phosphorus and potassium on root length, root girth and root volume at harvest in radish

Treatments	Root length (cm)	Root girth (cm)	Root volume (cc)
T_1 - 50:100:50 kg NPK / ha (Control)	15.98	7.22	115.00
T_2 - 100:100:50 kg NPK / ha	19.47	10.14	200.67
T_3 - 150:100:50 kg NPK / ha	21.57	11.83	229.33
T_4 - 200:100:50 kg NPK / ha	23.60	13.13	257.00
T_5 - 50:150:50 kg NPK / ha	19.21	9.58	177.00
T_6 - 50:200:50 kg NPK / ha	20.90	11.18	216.67
T_7 - 50:250:50 kg NPK / ha	18.17	8.95	161.33
T_8 - 50:100:100 kg NPK / ha	17.93	9.22	152.60
T_9 - 50:100:150 kg NPK / ha	17.94	8.17	152.67
T_{10} - 50:100:200 kg NPK / ha	18.37	8.73	176.00
S.Em±	**0.56**	**0.25**	**12.82**
C.D @ 5%	**1.66**	**0.74**	**38.10**

DAS: Days After Sowing

Table 15. Fresh weight of root, root yield per plot and per hectare as influenced by graded levels of nitrogen, phosphorus and potassium in radish

Treatments	Fresh weight of root (g)	Root yield/plot (kg)	Root yield/ha (t)
T_1 - 50:100:50 kg NPK / ha (Control)	110.67	2.47	16.44
T_2 - 100:100:50 kg NPK / ha	179.67	3.67	24.44
T_3 - 150:100:50 kg NPK / ha	235.33	4.43	29.55
T_4 - 200:100:50 kg NPK / ha	271.33	5.00	33.33
T_5 - 50:150:50 kg NPK / ha	174.67	3.47	23.11
T_6 - 50:200:50 kg NPK / ha	205.00	3.97	26.44
T_7 - 50:250:50 kg NPK / ha	160.33	3.63	24.20
T_8 - 50:100:100 kg NPK / ha	143.67	3.10	20.66
T_9 - 50:100:150 kg NPK / ha	136.00	2.77	18.44
T_{10} - 50:100:200 kg NPK / ha	173.67	3.17	21.11
S.Em±	**10.16**	**0.11**	**0.74**
C.D @ 5%	**30.17**	**0.33**	**2.21**

The significant influence of nutrition levels on root yield per hectare was recorded and application of higher doses of nutrients T_4 - 200:100:50 kg NPK per ha resulted in maximum yield per hectare (33.33 t / ha) followed by T_3 - 150:100:50 kg NPK per ha (29.55 t /ha).While, minimum was recorded in T_1 - 50:100:50 kg NPK per ha (16.44 t / ha).

4.4 Biochemical parameter

4.4.1 Chlorophyll content in leaves

The data pertaining to chlorophyll 'a', chlorophyll 'b' and total chlorophyll content in leaves at peak growth stage are presented in Table 16. The chlorophyll content in leaves was found to be significantly influenced by graded levels of nitrogen, phosphorus and potassium.

Chlorophyll 'a' in leaves was significantly influenced by graded levels of nitrogen, phosphorus and potassium. Significantly maximum chlorophyll 'a' content in leaves (0.92 mg/g fresh weight) was recorded at (200:100:50 kg NPK / ha) T_4 followed by (150:100:50 kg NPK / ha) T_3 (0.83 mg/g fresh weight). While, minimum (0.43 mg/g fresh weight) was recorded in control (T_1).

Chlorophyll 'b' content in leaves was significantly influenced by graded levels of nitrogen, phosphorus and potassium. Significantly maximum chlorophyll 'b' content in leaves (0.82 mg / g fresh weight) was recorded at (200:100:50 kg NPK / ha) T_4 followed by (150:100:50 kg NPK / ha) T_3 (0.78 mg / g fresh weight) and it was statistically on par with each other. While, minimum (0.31 mg / g fresh weight) was recorded in control (T_1).

Significantly maximum total chlorophyll content in leaves (1.75 mg / g fresh weight) was recorded at (200:100:50 kg NPK / ha) T_4 followed by (150:100:50 kg NPK / ha) T_3 (1.60 mg / g fresh weight). While, minimum (0.74 mg / g fresh weight) was recorded in control (T_1).

4.5 Soil analysis

4.5.1 pH

The data on pH of soil was affected by graded levels of nitrogen, phosphorus and potassium are presented in Table 17.

Significantly the highest pH of the soil among different nutrition levels, T_4 (200:100:50 kg NPK / ha) nutrition level has recorded highest pH value *i.e.* 6.27, which was statistically on par with T_3 nutrition level (6.25).While, minimum was recorded in T_1 (5.80).

4.5.2 Electrical Conductivity

The data pertaining to electrical conductivity of soil after harvest is presented in Table 17.

The electrical conductivity differed significantly due to nutrients level. The electrical conductivity of soil was found to be significantly maximum (0.33 dsm^{-1}) at T_4 (200:100:50 kg NPK / ha) and minimum electrical conductivity of soil (0.23 dsm^{-1}) was recorded in T_1.

4.5.3 Available NPK

The data on available NPK status of soil was affected by graded levels of nitrogen, phosphorus and potassium are presented in Table 17. Available N, P and K status of soil was significantly influenced by nutrition levels.

Among different nutrition levels, soil available NPK content were recorded significantly maximum (324.03 N, 36.31 P_2O_5, 182.53 K_2O kg / ha) in T_1 (50:100:50 kg NPK / ha) nutrition level which was followed by T_{10} (50:100:200 kg NPK / ha) for N, P and K (322.00, 34.40 and 181.83 kg /hectare, respectively). Whereas, minimum available N, P, K status of soil (301.07 N, 28.13 P_2O_5, 171.67 K_2O kg per hectare) was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level.

4.6 Plant analysis

The data with respect to N, P and K content in leaf as affected by nutrition levels are presented in Figure 7.

4.6.1 Nitrogen content in leaf

Nitrogen content in leaf differed significantly due to nutrients level. The significantly maximum N content in leaf (3.65 %,) was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum was recorded in T_1 - 50:100:50 kg NPK / ha (2.54 %) nutrition level.

4.6.2 Phosphorous content in leaf

Phosphorus content in leaf differed significantly due to nutrients level. Significant maximum P content in leaf (0.61%) was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum was recorded in T_1 - 50:100:50 kg NPK / ha (0.30 %,) nutrition level.

4.6.3 Potassium content in leaf

Potassium content in leaf differed significantly due to nutrients level. The significant maximum K content in leaf (4.25 %) was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. Whereas, minimum K content in leaf (2.52 %) was recorded in T_1- 50:100:50 kg NPK / ha

Table 16. Effect of graded levels of nitrogen, phosphorus and potassium on chlorophyll content of leaves in radish

Treatments	Chlorophyll content in leaves (mg/g fr. wt)		
	Chlorophyll (a)	**Chlorophyll (b)**	**Total Chlorophyll**
T_1 - 50:100:50 kg NPK / ha (Control)	0.43	0.31	0.74
T_2 - 100:100:50 kg NPK / ha	0.63	0.51	1.14
T_3 - 150:100:50 kg NPK / ha	0.83	0.78	1.60
T_4 - 200:100:50 kg NPK / ha	0.92	0.82	1.75
T_5 - 50:150:50 kg NPK / ha	0.55	0.30	0.85
T_6 - 50:200:50 kg NPK / ha	0.73	0.57	1.30
T_7 - 50:250:50 kg NPK / ha	0.54	0.48	1.02
T_8 - 50:100:100 kg NPK / ha	0.57	0.44	1.01
T_9 - 50:100:150 kg NPK / ha	0.50	0.33	0.83
T_{10} - 50:100:200 kg NPK / ha	0.54	0.36	0.90
S.Em±	**0.09**	**0.09**	**0.11**
C.D @ 5%	**0.27**	**0.26**	**0.34**

Table 17: Effect of graded levels of nitrogen, phosphorus and potassium on chemical properties and available nutrient status of soil after harvest of radish

Treatments	pH	EC (dsm^{-1})	N (kg /ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
T_1 - 50:100:50 kg NPK / ha (Control)	5.80	0.23	324.03	36.31	182.53
T_2 - 100:100:50 kg NPK / ha	6.21	0.30	309.47	30.53	174.83
T_3 - 150:100:50 kg NPK / ha	6.25	0.32	305.30	29.13	172.70
T_4 - 200:100:50 kg NPK / ha	6.27	0.33	301.07	28.13	171.67
T_5 - 50:150:50 kg NPK / ha	6.15	0.29	314.10	32.23	177.87
T_6 - 50:200:50 kg NPK / ha	6.23	0.31	307.33	29.27	174.13
T_7 - 50:250:50 kg NPK / ha	6.11	0.27	317.73	31.33	176.97
T_8 - 50:100:100 kg NPK / ha	6.10	0.26	311.87	30.57	177.97
T_9 - 50:100:150 kg NPK / ha	6.18	0.25	319.80	33.17	180.13
T_{10} - 50:100:200 kg NPK / ha	6.15	0.24	322.00	34.40	181.83
S.Em±	**0.07**	**0.015**	**3.83**	**0.60**	**1.51**
C.D @ 5%	**0.20**	**0.046**	**11.39**	**1.78**	**4.49**

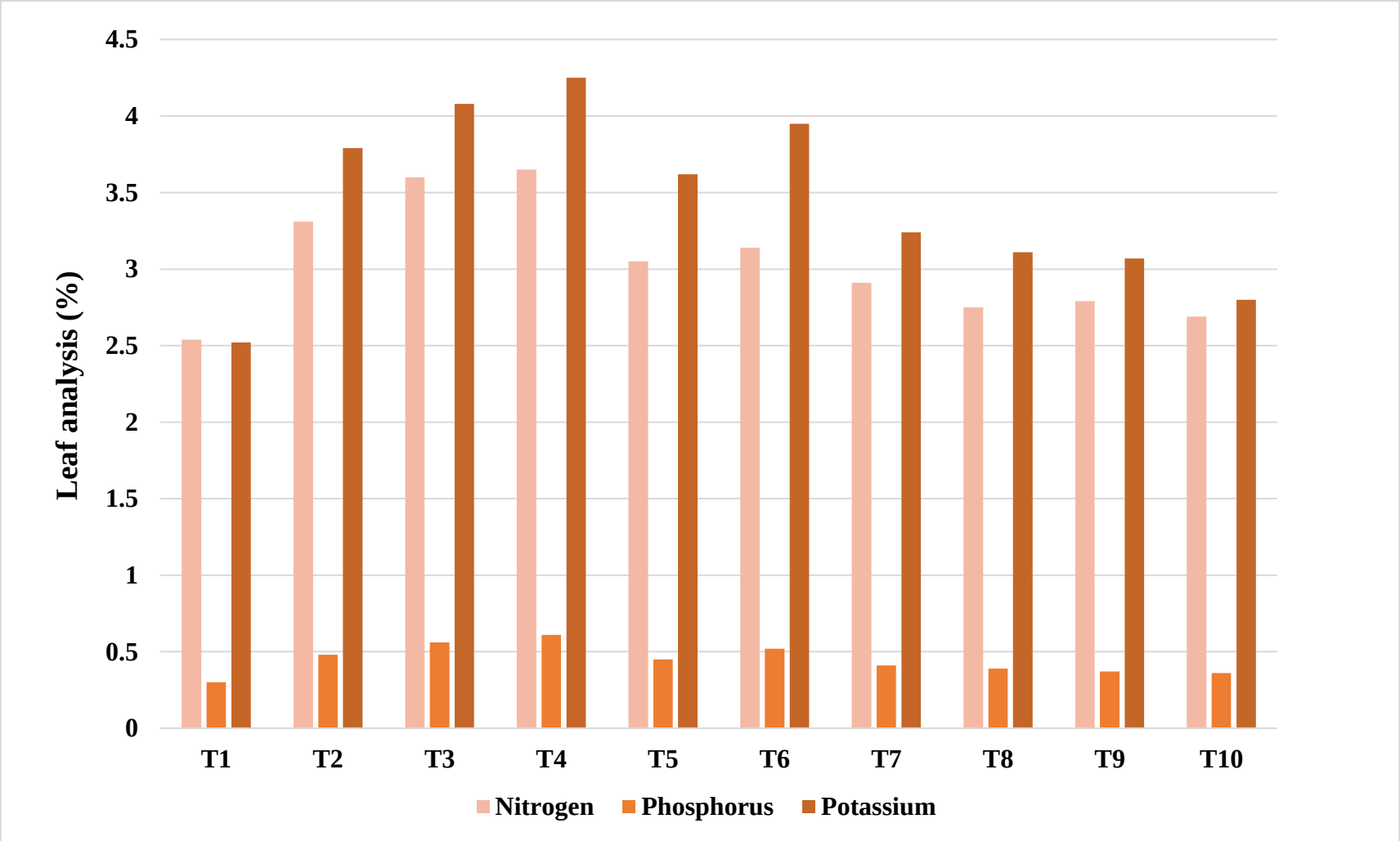


Fig 7. Effect of graded levels of nitrogen, phosphorus and potassium on primary nutrient content of leaves in radish

4.7 Nutrient uptake

The data pertaining to uptake of nutrients *viz*., nitrogen, phosphorous and potassium of radish as influenced by graded levels of nitrogen, phosphorus and potassium are presented in Figure 8.

4.7.1 Nitrogen uptake

The total nitrogen uptake by radish significantly influenced by graded levels of nitrogen, phosphorus and potassium.

Significantly, higher total nitrogen uptake by radish was recorded (103.45 kg ha^{-1}) with application of 200 kg N ha^{-1} in T_4 followed by 150 kg N ha^{-1} (102.32 kg ha-1) in T_3, and application of 50 kg N ha-1 recorded significantly lower total N uptake (81.75 kg ha-1) in T_1.

4.7.2 Phosphorous uptake

Significantly, higher phosphorous uptake by radish was recorded (18.57 kg ha^{-1}) with application of 100 kg P ha^{-1} in T_4, which was on par with 100 kg P ha^{-1} (17.07 kg ha^{-1}) in T_3, and application of 100 kg P ha^{-1} recorded significantly lower total phosphorous uptake (13.00 kg ha^{-1}) in T_1.

4.7.3 Potassium uptake

Significantly, higher potassium uptake by radish was recorded (140.33 kg ha^{-1}) with application of 50 kg K ha^{-1} in T_4, which was on par with 50 kg K ha^{-1} (133.27 kg ha^{-1}) in T_3. Significantly lower potassium uptake was recorded in 50 kg K ha^{-1} (105.23 kg ha^{-1}) T_1.

4.8 Economics

The data on effect of graded levels of nitrogen, phosphorus and potassium on cost economics of radish cultivation is presented in Table 18. The significantly maximum total cost of cultivation (`. 102337.60) was found in $T_7$ (50:250:50 kg NPK / ha), which was followed by $T_6$ (50:200:50 kg NPK per ha) (`. 100150.60). While, minimum was found in T_1 (50:100:50 kg NPK per ha) (`. 95775.60). Whereas, the maximum net returns (`. 402222.00) and benefit cost ratio (4.11) was recorded at T_4 (200:100:50 kg NPK / ha) followed by T_3 (150:100:50 kg NPK per ha) (`. 346173.00 and 3.56, respectively). The minimum net returns (`. 150824.00) and benefit cost ratio (1.57) was recorded in T_1 (50:100:50 kg NPK / ha).

Table 18. Cost economics of radish cultivation

Treatments	Treatment cost (₹. / ha) A	General cost of cultivation (₹. / ha) B	Total cost of cultivation (₹. / ha) (A+B)	Total root yield (t / ha)	Total returns (₹. / ha)	Net returns (₹. / ha)	B:C ratio
T_1 - 50:100:50 kg NPK / ha (Control)	6475.60	89300.00	95775.60	16.44	246600	150824.00	1.57
T_2 - 100:100:50 kg NPK / ha	7126.00	89300.00	96426.00	24.44	366600	270174.00	2.80
T_3 - 150:100:50 kg NPK / ha	7777.00	89300.00	97077.00	29.55	443250	346173.00	3.56
T_4 - 200:100:50 kg NPK / ha	8428.00	89300.00	97728.00	33.33	499950	402222.00	4.11
T_5 - 50:150:50 kg NPK / ha	8662.60	89300.00	97962.60	23.11	346650	248687.00	2.53
T_6 - 50:200:50 kg NPK / ha	10850.60	89300.00	100150.60	26.44	396600	296449.40	2.96
T_7 - 50:250:50 kg NPK / ha	13037.60	89300.00	102337.60	24.20	363000	260662.40	2.54
T_8 - 50:100:100 kg NPK / ha	7924.60	89300.00	97224.60	20.66	309900	212675.40	2.18
T_9 - 50:100:150 kg NPK / ha	9373.60	89300.00	98673.60	18.44	276600	177926.40	1.80
T_{10} - 50:100:200 kg NPK / ha	10822.60	89300.00	100122.60	21.11	316650	216527.40	2.16

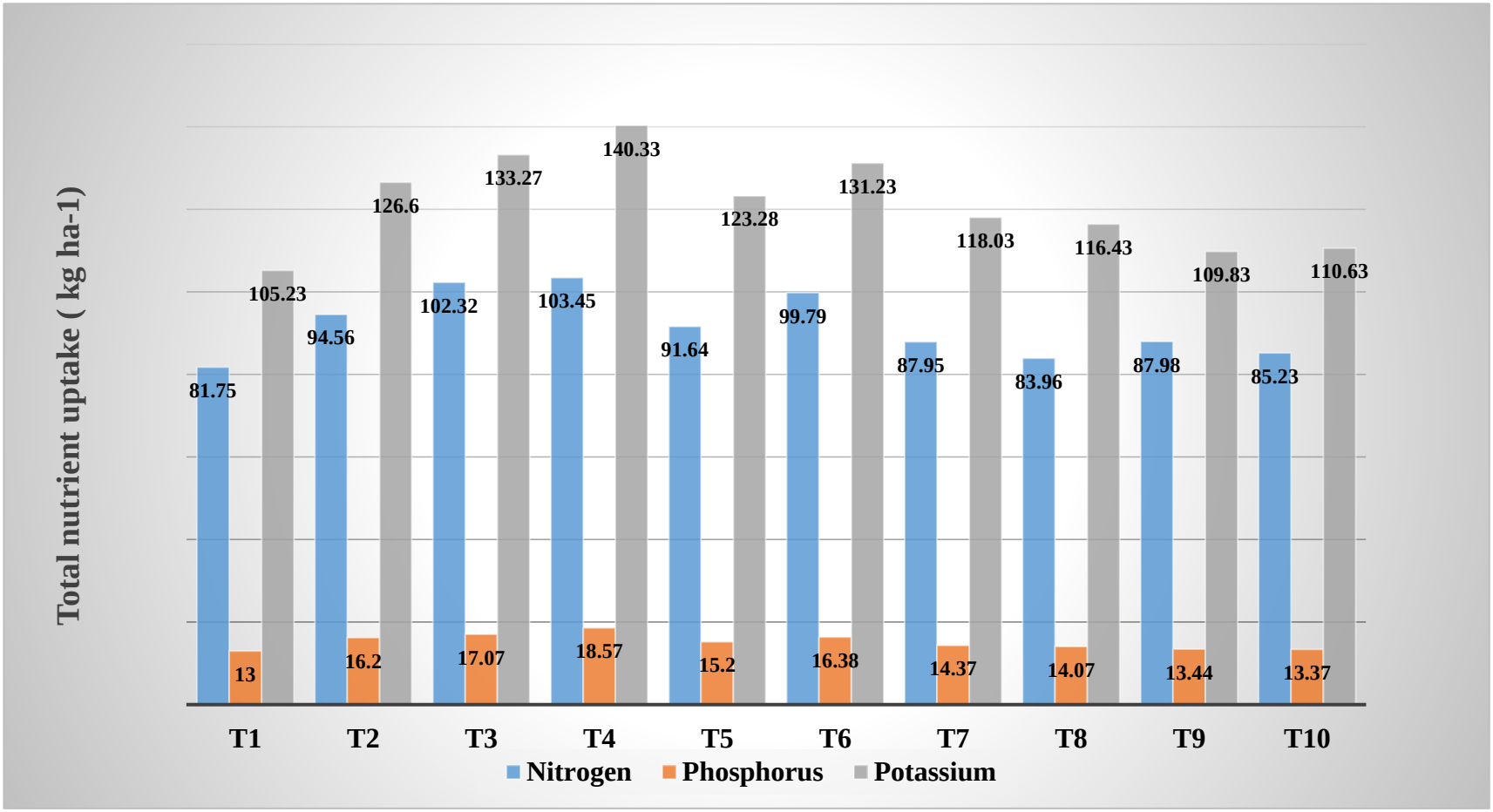


Fig 8. Effect of graded levels of nitrogen, phosphorus and potassium on total nutrient uptake by radish at harvest

DISCUSSION

V DISCUSSION

With increase in population, the demand for radish is also increasing and hence the production has to be augmented to meet this increasing demand. Radish is an important root vegetable crop, which can be grown throughout the year in one or other part of the country as a mono or mixed crop.

The productivity of cv. Pusa Chetki of radish is low mainly because of low availability of nutrients for growth and development. The investigation was carried out to study the effect of graded levels of nitrogen, phosphorus and potassium on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki as affected by different nutrient levels at College of Horticulture, Mudigere during the year 2019-20 in *rabi* season. The results of the studies are discussed herewith the support of available literature.

5.1 Effect of graded levels of nitrogen, phosphorus and potassium on growth and yield of radish

5.1.1 Morphological parameters

In the present investigation, significant differences were found with respect to plant height in different nutrition levels. The results showed that significantly maximum plant height (42.71 cm) was recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum plant height (33.13 cm) was recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. This clearly supports the fact that higher application of nitrogen has a vital role in betterment of plant physiological process such as cell division, cell elongation along with timely metabolic processes and also favoured the greater assimilation of photosynthates. These results are in conformity with the findings of Tripathi *et al*. (2017), Sharma (2000), Baloch *et al.* (2014), Pathak *et al*. (2017), Dash *et al*. (2018) and Bilekudari *et al*. (2005) in radish. Dkhil *et al*. (2011), Besma *et al*. (2011), Banafar *et al*. (2005), Patel (2013), Vikas *et al*. (2017), Raghav *et al*. (2008), Gupta (1992) and Nikunja and Dutta (1998) in potato. Haque *et al*. (2007), Hikaru *et al*. (2007) and (Vishwanath, 2002) in turmeric.

Nutrient levels had exerted significant effect on number of leaves per plant during all the growth stages. The result indicated that significantly highest (14.47) number of leaves were observed in T_4 with nutrient level of 200:100:50 kg NPK / ha followed by T_3 (150:100:50 kg NPK / ha) nutrition level (13.27). While, minimum number of leaves per plant (9.87) was found in T_1 (50:100:50 kg NPK / ha) nutrition level. This could be attributed to the enhanced availability of nutrients at the appropriate time, which might have resulted in increased photosynthetic rate and accumulation of metabolites in plants. Lakra *et al.* (2017), Dash *et al*. (2018),Wilson *et al.* (2009), Sharma *et al*. (2013), Jadhav *et al.* (2014), Baloch *et al.* (2014), Pathak *et al*. (2017) and Shrestha and Thapa, (2018) in radish. Dumbuya *et al.* (2016) in

sweet potato. Dkhil *et al*. (2011), Besma *et al*. (2011), Vikas *et al*. (2017) in potato. Hikaru *et al*. (2007) and Haque *et al*. (2007) in turmeric.

The leaf length and leaf width varied significantly among different nutrition levels. The results indicated that significantly maximum leaf length and leaf width (32.57 cm and 11.86 cm, respectively) were recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum leaf length and leaf width (25.24 cm and 9.94 cm, respectively) were recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. The increase in leaf length and leaf width may be due to increased availability of higher dose of nutrients. Similar results have been reported by Parthasarathi *et al*. (1999), Thapa *et al*. (2003) and Jadhav *et al.* (2014) in radish.

At all the stages of plant growth significant variation was observed for plant spread (N-S and E-W) due to nutrition level. The significantly highest plant spread (N-S and E-W) (40.81, 43.93 cm, respectively) was recorded at T_4 (200:100:50 kg NPK / ha) nutrition level, followed by T_3 (36.61, 37.68 cm, respectively) with application of (150:100:50 kg NPK / ha) T_3. Whereas, lowest plant spread (N-S and E-W) (29.50, 32.56 cm, respectively) was registered in T_1 (50:100:50 kg NPK / ha) nutrition level. It might be due to better utilization of nutrients for proper growth and development of plant.

The stem diameter at 45 days after sowing registered significantly maximum (1.53 cm) in T_4 with the application of 200:100:50 kg NPK / ha nutrition level While, minimum stem diameter (1.20 cm) was documented in T_1 (50:100:50 kg NPK / ha) nutrition level. This could be attributed to the enhanced availability of nutrients at the appropriate time, which might have increased stem diameter. Similar, results were obtained by Dumbuya *et al*. (2017) and Sharavati *et al*. (2018) in sweet potato.

In the present study, fresh and dry weight of leaves, stem, root and total dry matter of the plant varied significantly among different levels of nutrition. The significantly maximum fresh and dry weight of leaves, stem and root (70.94 & 7.27, 31.76 & 1.63, 271.33 and 9.89, respectively) were recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. But minimum fresh and dry weight of leaves, stem and root (40.21 & 2.99, 20.06 & 0.72, 110.67 and 4.92, respectively) were recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. The significantly maximum total dry matter of the plant (18.79 g) was noticed in T_4 (200:100:50 kg NPK / ha) nutrition level. However, minimum total dry matter of the plant (8.63 g) was recorded in T_1 (50:100:50 kg NPK / ha) nutrition level. The increase in fresh and dry weight of leaves, stem and root and total dry matter of the plant could be due to higher uptake and accumulation of greater amount of photosynthates leading to increase in number of leaves, plant size and fresh bio mass, which in turn yields higher dry matter content. Similar results have been quoted by (Baloch *et al.*, 2014), Kiran *et al*. (2016)

in radish, Banafar *et al*. (2005), Patel (2013) and Asmaa and Magda (2010) in potato, Jilani *et al*. (2010) in onion.

5.1.2 Growth parameters

Leaf area and leaf area index are an important parameters that forms a basic platform for photosynthetic activity and as well storing photosynthates for further biological activity. In the present study, significantly maximum leaf area and leaf area index (350.67 cm^2 and 1.16, respectively) were recorded with the application of T_4 (200:100:50 kg NPK / ha) nutrition level. While, the minimum leaf area and leaf area index (97.67 cm^2 and 0.32, respectively) were noticed in T_1 (50:100:50 kg NPK / ha) nutrition level. The size of the leaf plays an important role in photosynthetic activity as it intercepts more of solar energy with the increase in leaf area. Leaf area and number of leaves per plant decides the efficiency of photosynthetic activity, which contributes towards better growth and yield. Increased leaf area and leaf area index could be attributed to the better availability of nutrients for growth and development of plant, which, in turn, enhances the photosynthesis of leaves. These results are in agreement with the results of Sharma *et al.* (2013), Pathak *et al*. (2017), Srinivas and Naik (1990) in radish. Najm *et al*. (2010) and Besma *et al.* (2011), Dkhil *et al*. (2011) and Mohammed *et al*., (2018) in potato. Koodi *et al.* (2017) in sweet potato. (Vishwanath, 2002) and Meenakshi *et al*. (2001) in turmeric.

Significantly maximum AGR (0.59 g / plant / day at 30-45 DAS), CGR (19.66 g / m^2/ day at 30- 45 DAS), and NAR (0.0291 g / dm^2 / day at 30-45 DAS), were indicated in T_4 (200:100:50 kg NPK / ha) nutrition level. This might be due to increase in the dry weight, because of higher number of leaves, plant biomass and leaf surface area induced by the application of optimum dose of NPK fertilizers. Similar results were obtained by Dumbuya *et al*. (2016) in sweet potato.

5.1.3 Biochemical parameters

Chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll content in leaves were significantly influenced by nutrition levels. Significantly maximum total chlorophyll content in leaves (1.75 mg/g fr. wt) was recorded in T_4 with application of (200:100:50 kg NPK / ha) followed by (1.60 mg/g fr. wt) (150:100:50 kg NPK / ha) (T_3). While, minimum (0.74 mg/g fr. wt) was revealed in control (T_1). The increase in chlorophyll content could be attributed to increased N content in the leaves, which is a constituent of chlorophyll pigment. The increase in N content of the leaves is due to the better uptake of nitrogen. Similar results have been quoted by Kanbi and Bhatnagar (2005), Besma *et al*. (2011), Singh and Lal (2012) and Rai *et al*. (2004) in potato and Koodi *et al*. (2017) and Sharavati *et al*. (2018) in sweet potato.

5.1.4 Yield parameters

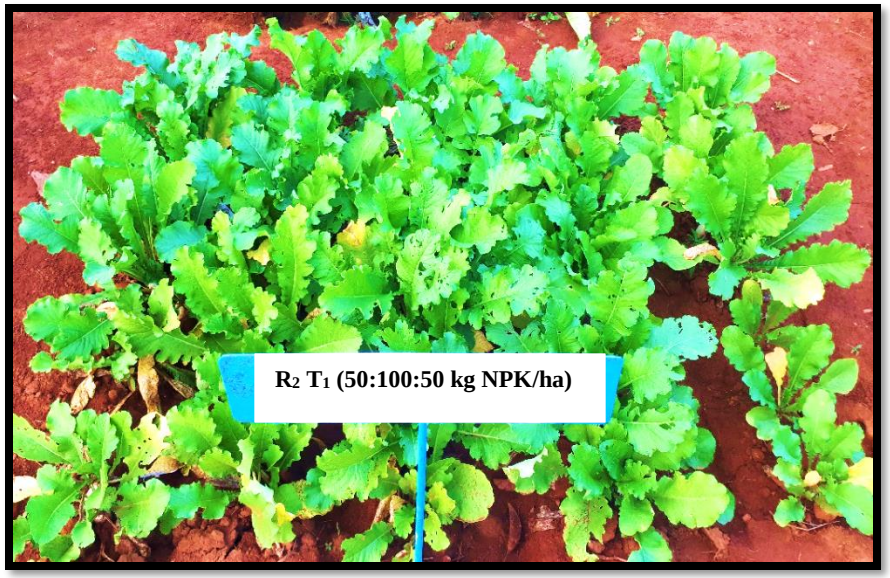
The root length and root girth were varied significantly among different nutrition levels. The significantly maximum root length and root girth (23.60, 13.13 cm, respectively) were recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum root length and root girth (15.98, 7.22 cm, respectively) were recorded in T_1 (50:100:50 kg NPK / ha) nutrition level (Plate 4.). The significant effect of potassium on root characters might be due to the fact that easily available potassium plays an important role in starch formation and metabolism. Thereby increased the length and girth of root. These findings are in close conformity with those reported by Kumar *et al.* (1994), Ijaz *et al.* (1997), Parthasarathi *et al*. (1999) Kamalakannan and Manivannan (2003) and Hussain *et al*. (1997) in radish.

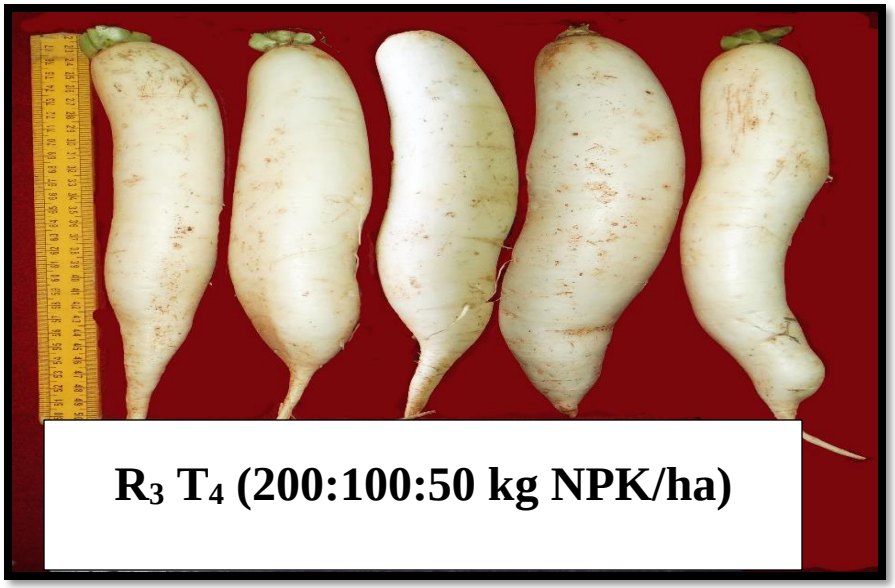
The root volume was significantly influenced by different nutrition levels. The root volume increased with the application of T_4 (200:100:50 kg NPK / ha) nutrition level. The T_4 (200:100:50 kg NPK / ha) nutrition level was recorded significantly maximum root volume (257.00 cc). However, the minimum root volume (115.00 cc) was noticed in the T_1 (50:100:50 kg NPK / ha) nutrition level. The increase in the root volume might be due to the optimum levels of NPK dose, which helped in better assimilation of carbohydrates and buildup of new cells and consequently there was increased size of the root in turn more root volume as the root volume is mainly depends on the size or weight of the root. These findings are in close association with the report of Sharma *et al*. (2013) in radish.

In the present investigation, significantly higher root yield per plot and per hectare were recorded with the application of T_4 (200:100:50 kg NPK / ha) nutrition level. Among the different nutrition treatments, T_4 recorded the significantly maximum root yield per plot and per hectare (5.00 kg / plot and 33.33 t / ha, respectively) followed by T_3 (4.43 kg / plot and 29.55 t / ha, respectively). While the lowest root yield per plot and per hectare (2.47 kg / plot and 16.44 t / ha, respectively) were observed in T_1 (50:100:50 kg NPK / ha) nutrition level. Potassium is thought to be essential for the formation translocation of carbohydrates and needed in large quantities by most of the root crops (Thompson and Kelly, 1957). Potassium imparts resistance to plant against insects, pests, diseases and drought condition, which might have been resulted in heavy growth of the crop. The favorable effects of potassium application on growth and yield attributes were responsible for higher root yield. Similar results have been quoted by Srinivas and Naik (1990), Parthasarathi *et al*. (1999), Ndang and Akali (1999), Bokhtiar *et al,* (2001) in radish.

5.1.5 Soil analysis

Soil pH, EC and available nutrients like Nitrogen (N), Phosphorus (P) and Potassium (K) contents of soil were influenced significantly by different nutrition





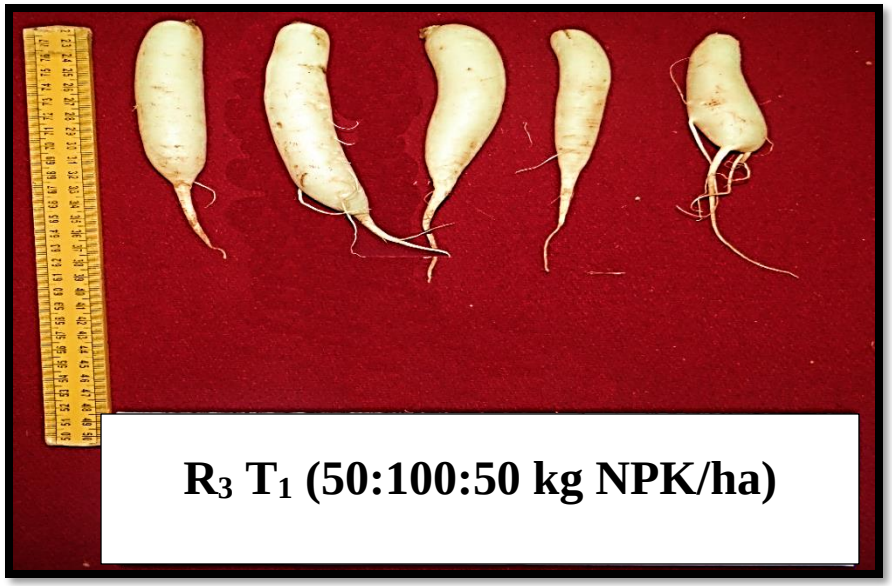


Plate 4. Best treatment with control

levels. The increased pH (6.27) and EC (0.33 dsm^{-1}) were noticed in T_4 (200:100:50 kg NPK / ha) and the increased N (324.03 kg / ha), P (36.31 kg / ha) and K (182.53 kg / ha) were found in T_1 (50:100:50 kg NPK / ha). This was mainly due to more root elongation by increased cell division, easy assimilation and N at higher dose might cause more uptake of major nutrients by crop. Similar results were observed by Shaktawat and Shekhawat, (2010) in barley.

As compared to initial status of soil and also increased fertilizer levels in the crop, available nutrients in the soil was increased. This might be due to increase in available nitrogen, which may be due to the direct addition of nitrogen through inorganic sources. Slow release of phosphorous form added single super phosphate and increase in available K might be attributed the direct addition of potassium to the available pool of the soil.

5.1.6 Plant analysis

In the present investigation, the nitrogen (3.65 %), phosphorus (0.61 %) and potassium content (4.25 %) in the leaves were reported significantly maximum with the application T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum N (2.54 %), P (0.30 %) and K (2.52 %) were recorded with the application of T_1 (50:100:50 kg NPK / ha) nutrition level. The probable reason for recording higher nutrient content in leaves of radish may be due to that plants supplied with optimum dose of NPK and absorbed greater quantities of nutrients thus facilitating the production of more number of sink points. These results are in agreement with Bodkhe and Mahorkar (2010) in radish.

5.2 Effect of graded levels of nitrogen, phosphorus and potassium on the nutrient uptake of radish

In the present study, significantly higher uptake of nitrogen, phosphorous and potassium were recorded with application of 200:100:50 kg NPK / ha in T_4 (103.45 kg ha^{-1}, 18.57 kg ha^{-1} and 140.33 kg ha^{-1}, respectively) and found to be on par with application of 150:100:50 kg NPK / ha in T_3 (102.32 kg ha-1, 17.07 kg ha^{-1} and 133.27 kg ha^{-1}, respectively.). While, least was found with application of 50:100:50 kg NPK / ha in T_1 (81.75 kg ha-1, 13.00 kg ha^{-1} and 105.23 kg ha^{-1}, respectively). This was mainly due to more root elongation by increased cell division, easy assimilation and N at higher dose might cause more uptake of major nutrients by crop. Similar results were reported by Sharma and Sood (2002), Chopra *et al*. (2010) and Lakshmi *et al*. (2012) in potato.

5.3 Effect of graded levels of nitrogen, phosphorus and potassium on economics of radish

Economics is the ultimate criteria for acceptance or rejection and wider adoption of any technology. Among the different indicators of economic efficiency in any production system, net returns has greater impact on the practical utility and acceptance of the technology by the farmers. Assessment of treatments in terms of economic traits revealed that the gross returns, net returns and benefit cost (B: C) ratio differed due to graded levels of nitrogen, phosphorus and potassium application.

Benefit cost ratio is an important and ultimate factor, which decides the optimum levels of input to be used for maximization of production and returns of any crop. In the present study, the benefit cost ratio was worked out for different nutrition levels in radish. The significantly maximum net returns and benefit cost ratio (402222 and 4.11, respectively) were recorded at T_4 (200:100:50 kg NPK / ha) followed by T_3- 150:100:50 kg NPK per ha (346173 and 3.56, respectively). The minimum net returns and cost benefit ratio (150824 and 1.57, respectively) were recorded in the T_1 (control).

Conclusion

Among the different nutrition levels, T_4 200:100:50 kg NPK / ha was found to be optimum with respect to morphological traits, growth parameters, growth and yield in radish. The highest B.C ratio (4.11) was also recorded in the same treatment. These results confirmed that nutrition levels improve the growth and yield of radish under hill zone of Karnataka.

Future line of work

In continuation of the present investigation, the following future line of work is suggested for further research.

1. Residual effect of nutrients on succeeding crop needs to be studied.
2. Possibility of green manure intercropping approach in radish need to be explored.
3. Need to study the different methods of application of nitrogen, phosphorus and potassium.
4. Split application of nitrogen and potassium under high rainfall area need to be carried out.

SUMMARY

VI SUMMARY

The present investigation on “Effect of graded levels of nitrogen, phosphorus and potassium on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki” was carried out at Department of Vegetable Science, College of Horticulture, Mudigere during the period from November 2019 to Feb - 2020

The experiment consists of different levels of nutrition were tried in various combinations and assessed for growth and yield characters. The results obtained from the study are summarized here under.

Significantly, higher plant height (42.71 cm), number of leaves per plant (14.47), leaf length (32.57 cm) and width (11.86 cm), spread of the plant [(N-S 40.81 cm) and (E-W 43.93 cm)] and stem diameter (1.53 cm) were noticed with the application of T_4 (200:100:50 kg NPK / ha) nutrition level. While, minimum values were recorded in T_1 (50:100:50 kg NPK / ha) nutrition level.

Fresh weight of leaves, stem and root as influenced by nutrition levels differed significantly. Significantly more fresh weight of leaves, stem and root (70.94, 31.76 and 271.33 g, respectively) were recorded in T_4 (200:100:50 kg NPK / ha) nutrition level. Whereas, minimum values were recorded in T_1 (50:100:50 kg NPK / ha) nutrition level.

Significantly, highest dry matter accumulation in leaves (7.27 g / plant), stem (1.63 g / plant) and root (9.89 g / plant) were observed in T_4 (200:100:50 kg NPK / ha) nutrition level.

Significantly, maximum (18.79 g) total dry matter of the plant was noticed in T_4 (200:100:50 kg NPK / ha) nutrition level. While, significantly minimum (8.63 g) total dry matter of the plant was found in T_1 (50:100:50 kg NPK / ha) nutrition level.

Significantly higher leaf area (350.67 cm^2), leaf area index (1.16), absolute growth rate (0.59 g / plant / day @ 30-45 DAS), crop growth rate (19.66 g / m^2 / day @ 30-45 DAS) and net assimilation rate (0.0291 g / dm^2 / day @ 30-45 DAS) were found to be highest in T_4 (200:100:50 kg NPK / ha) nutrition level. Whereas, minimum values were recorded in T_1 (control).

The biochemical parameter studies indicated significant differences due to different treatments. Chlorophyll ‘a’ (0.92 mg / g fr. wt), chlorophyll ‘b’ (0.82 mg / g fr. wt) and total chlorophyll content (1.75 mg / g fr. wt) were significantly higher with the application of T_4 (200:100:50 kg NPK / ha) as compared to T_1 (50:100:50 kg NPK / ha) nutrition level.

Yield and root parameters varied significantly by graded levels of nitrogen, phosphorus and potassium. Among different nutrient applications, 200:100:50 kg NPK / ha was significantly differed with respect to yield and root attributes in radish.

The significantly higher root length (23.60 cm), root girth (13.13 cm), root volume (257.00 cc), root yield per plot (5.00 kg) and root yield per ha (33.33 t) were recorded in T_4 (200:100:50 kg NPK / ha). While, minimum values were recorded in T_1 (control).

Soil analysis as influenced by nutrition levels differed significantly. Soil available NPK content (324.03 N, 36.31 P_2O_5, 182.53 K_2O kg per hectare) were recorded significantly maximum in T_1 (50:100:50 kg NPK / ha) nutrition level and the highest values of EC (0.33 dsm^{-1}) and the maximum pH (6.27) were recorded in T_4 (200:100:50 kg NPK / ha).

Different levels of nutrition significantly influenced the leaf nutrient content. The significantly more nitrogen (3.65 %), phosphorus (0.61 %) and potassium content (4.25 %) in the leaves were reported more with the application of T_4 (200:100:50 kg NPK / ha) nutrition level.

Significantly, higher uptake of nitrogen, phosphorous and potassium were noticed with application of 200:100:50 kg NPK / ha (103.45 kg ha^{-1}, 18.57 kg ha^{-1} and 140.33 kg ha^{-1}, respectively). While, least was found with application of 50:100:50 kg NPK / ha (81.75 kg ha^{-1}, 13.00 kg ha^{-1} and 105.23 kg ha^{-1}, respectively).

Among all the treatments, highest net returns (`. 402222.00 / ha) and B: C ratio (4.11) were obtained in the treatment consists of 200:100:50 kg NPK / ha.

Based on B:C ratio worked out under cost economics, sowing of radish with application of NPK at 200:100:50 kg per ha was found to be best with respect to growth and yield attributes under hill zone of Karnataka.

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*Originals not seen.

APPENDICES

VIII APPENDICES

APPENDIX- I

Monthly mean meteorological data recorded during the experimental year 2019–20 recorded at the ZAHRS, Mudigere.

Months	Rainfall (mm)	Temperature (^{0}C)		Relative Humidity (%)	
		Maximum	Minimum	Maximum	Minimum
May	83.3	30.06	18.54	82.19	60.5
June	273.7	27.03	18.26	80.53	61.13
July	740.2	25.16	19.70	75.38	63.67
August	1402.7	24.62	19.74	73.61	63.70
September	525.3	25.26	19.83	79.83	60.53
October	329.3	26.25	19.58	80.19	60.96
November	26.3	29	18.933	80.26	60.133
December	1.4	28.64	19	80.12	60.25
January	0	29	18.06	80	60.12
February	0	30.27	17.344	80.413	60.827
March	2.3	32.70	18.61	80.25	60.64
Total	**3384.5**	**307.99**	**207.59**	**872.77**	**672.46**
Mean	**307.68**	**27.99**	**18.87**	**79.34**	**61.13**

APPENDIX-II

Physical and Chemical properties of soil at the experimental site before sowing

Sl. No.	Particulars	Values	Method employed
Physical properties			
1.	Coarse sand (%)	42.50	International pipette method (Piper, 1966)
2.	Fine sand (%)	22.75	
3.	Silt (%)	17.50	
4.	Clay (%)	13.60	
Chemical properties			
1.	Soil pH	5.88	pH meter (Jackson, 1967)
2.	Electrical Conductivity (dsm-1)	0.13	Conductivity bridge (Jackson, 1967)
3.	Available nitrogen (kg / ha)	274.00	Alkaline permanganate method (Subbaiah and Asija, 1956)
4.	Available phosphorus (kg / ha)	23.00	Bray's method(Jackson,1967)
5.	Available potassium (kg / ha)	183.00	Neutral Normal Ammonium Acetate method by (Jackson, 1967)

APPENDIX - III – a

General cost of cultivation (Rs. / ha) (Excluding the cost of the treatment inputs)

Sl. No.	Particulars	Unit (man days)	Price per unit (Rs.)	Cost / ha (Rs.)
I	**Variables**			
(A)	**Labour charges**			
1	Cost of seed	10 kg	500	5,000
2	Preparation of ridges and furrows	10	300	3,000
3	Sowing of the seeds	12	300	3,600
4	Application of manures, fertilizers and lime	10	300	3,000
5	Irrigation	22	300	6,600
6	Weeding	20	300	6,000
7	Spraying of chemicals	12	300	3,600
8	Earthing up	9	300	2,700
9	Harvesting and selling of roots	12	300	3,600
10	Miscellaneous			1,200
(B)	**Service charges of land preparation**	By tractor for 8.0 Hrs	800	6,400
(C)	**Cost of material inputs**			
1	FYM	20 t	900	18,000
2	Lime	3 t	4	12,000
3	Irrigation cost (In terms of electricity)	7.0 Hrs	800	5,600
II	**Fixed costs**			
1	Land rent + Rental value	-	-	9,000
	Grand total			**89,300**

General cost of cultivation = **Rs. 89,300**

APPENDIX - III – b

Treatment wise cost per hectare

Treatments details	Quantity required	Per unit cost (Rs.)	Total cost (Rs./ha)
	Urea:SSP:MOP (kg)	Urea:SSP:MOP (Rs.)	
T_1 - 50:100:50 kg NPK / ha (Control)	108.6:625:83.3	651.6:4375:1449	6475.60
T_2 - 100:100:50 kg NPK / ha	217:625:83.3	1302:4375:1449	7126.00
T_3 - 150:100:50 kg NPK / ha	325.5:625:83.3	1953:4375:1449	7777.00
T_4 - 200:100:50 kg NPK / ha	434:625:83.3	2604:4375:1449	8428.00
T_5 - 50:150:50 kg NPK / ha	108.6:937.5:83.3	651.6:6562:1449	8662.60
T_6 - 50:200:50 kg NPK / ha	108.6:1250:83.3	651.6:8750:1449	10850.60
T_7 - 50:250:50 kg NPK / ha	108.6:1562:83.3	651.6:10937:1449	13037.60
T_8 - 50:100:100 kg NPK / ha	108.6:625:166.6	651.6:4375:2898	7924.60
T_9 - 50:100:150 kg NPK / ha	108.6:625:249.9	651.6:4375:4347	9373.60
T_{10} - 50:100:200 kg NPK / ha	108.6:625:333.2	651.6:4375:5796	10822.60

APPENDIX-IV

List of symbols and abbreviations

Symbols	Abbreviations
%	Per cent
^{0}C	Degree Celsius
dm^{2}	Deci meter square
Cm	Centimeter
cm^{2}	Centimeter square
M	Meter
m^{2}	Meter square
$t\ ha^{-1}$	Tones per hectare
et al.	and other
G	Gram
i.e.	That is
$kg\ ha^{-1}$	Kilogram per hectare
MT	Metric tones
Mg	Milligram
Ml	Milliliter
L	Liter
Mm	Millimeter
LAI	Leaf area index
AGR	Absolute growth rate
CGR	Crop growth rate
NAR	Net assimilation rate
C. D	Critical difference
S.Em ±	Standard Error of Mean
S. D	Standard deviation
viz.	Namely
DAS	Days after sowing
dsm^{-1}	Decisiemens per meter