

**EFFECT OF PLANT GEOMETRY AND GROWTH
REGULATORS ON GROWTH, ROOT AND SEED
YIELD OF RADISH (*Raphanus sativus* L.) cv. PUSA
CHETKI**

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MAY, 2015**

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Thesis submitted to the
**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL
SCIENCES, SHIVAMOGGA**

*In partial fulfillment of the requirements for the
Degree of*

MASTER OF SCIENCE (Horticulture)

in

VEGETABLE SCIENCE

By

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MAY, 2015



Affectionately dedicated to

My Chairperson Dr. V. Srinivasa

My forever loving parents

Mr. Thammaiah & Mrs. Savithri

My loving brother Manju

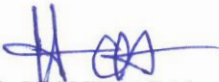
and my best friend Manavi

**DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF HORTICULTURE, MUDIGERE
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SCIENCES, SHIVAMOGGA**


CERTIFICATE

This is to certify that the thesis entitled “**EFFECT OF PLANT GEOMETRY AND GROWTH REGULATORS ON GROWTH, ROOT AND SEED YIELD OF RADISH (*Raphanus sativus* L.) cv. PUSA CHETKI**” submitted in partial fulfillment of the requirement for the award of degree of **MASTER OF SCIENCE (Horticulture)** in **VEGETABLE SCIENCE** to the University of Agricultural and Horticultural Sciences, Shivamogga is a record of *bona-fide* research work carried out by **Ms. SHRUTHI, H.T.** ID No. **MH2TAC035** under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or any other similar titles.

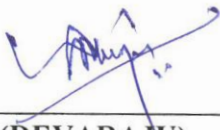
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ACKNOWLEDGEMENT

Words cannot begin to express the love and gratitude that is in my heart, but this is my humble attempt...

*Firstly, I would like to express my heartfelt gratitude to all seen and unseen helping hands reaching out to me during my endeavour to reach a milestone. It is sense of pride to have worked under the guidance of **Dr. V. Srinivasa**, Professor and Head, Department of Vegetable Science, College of Horticulture, Mudigere and Chairperson of my advisory committee. A man of versatile personality, motivator of all, perfect planner, a good interpreter. I am most thankful to him for his excellent guidance, encouragement, keen interest throughout the course of this investigation. I am incapable of quantifying feeling of my gratitude. I also wish him a good health and mind always, as the world has very few such great persons and requires them more and more.*

*It gives me great pleasure to express my heartfelt thanks to members of my advisory committee **Dr. M. Ganapathi**, Assistant Professor of Crop Physiology, College of Horticulture, Mudigere. **Mr. Devaraju**, Assistant Professor, Department of Vegetable Science, College of Horticulture, Mudigere and **Dr. T. N. Usha**, Assistant Professor, Department of Seed Science and Technology, College of Horticulture, Mudigere for their constructive criticism, inspiration, guidance and moral support are highly appreciated and remembered.*

*I am gratefully indebted to my parents **Mr. Thammaiah** and **Mrs. Savithri** for their ultimate blessings, abundant love and affection,*

moral encouragement, constant support, and personal sacrifice during the academic carrier, my gratitude is too deep for words.

*I am overwhelmed with sincere feelings of indebtedness to my brother **Manju** and all my family members whose wishes motivated me to work towards this Cherished goal.*

Things would go vigorous without the moral and dedicated support of my friends, Manavi, Ibaad, Heena, Revati, Mamatha, Beeresh, Heena Kausar, Puji, Rajesh, Praveen, Sachin, Irfan, Ravi, Ramesh and also my junior friends Praveen Yadhalli, Ashok, Manoj, Heena, Lavanya, Aparna, Sachin, Hanumanth, Halesh, Maruthi and Mohan.

I avail this opportunity to express my heartfelt thanks to Ms. Prajna, Ms. Chandana, Ms. Kumari, Mr. Mahesh, Mr. Harish, Mr. Suresh Chougala, Mr. Rakesh, Mr. Darshan, Mr. Girish and Mrs. Prema for their kind help during my research programme.

Finally I sincerely wish to thank all those seen and unseen helping hands in completing the M.Sc. Programme.

Mudigere
May, 2015

Shruthi H.T.
(Shruthi, H.T.)

EFFECT OF PLANT GEOMETRY AND GROWTH REGULATORS ON GROWTH, ROOT AND SEED YIELD OF RADISH

(*Raphanus sativus* L.) cv. Pusa Chetki

SHRUTHI, H.T. (MH2TAC035)

ABSTRACT

The study was conducted to find out the optimum spacing and growth regulators levels in radish cv. Pusa Chetki in open field condition at department of Vegetable Science, College of Horticulture, Mudigere, during 2014-15. The experiment consists of two levels of spacing (45×45 cm and 30×30 cm) and two levels of growth regulators (GA_3 and NAA) each at two concentration (200 ppm and 250 ppm) with control in all possible combinations were assessed for vegetative, root and seed characters. Among the different spacings, S_2 (45×45 cm) and among the different growth regulators levels, G_2 (GA_3 250 ppm) recorded maximum plant height, number of leaves per plant, leaf length, leaf width, spread of plant, number of branches per plant, stem diameter, fresh weight of leaves, stem and root, leaf area, chlorophyll content, absolute growth rate, dry matter accumulation in different plant parts like leaves, stem and roots, root length and root girth, number of siliqua per plant, number of seeds per pod, pod weight, length of pod and the same treatment also recorded maximum seed quality parameters. The maximum root and seed yield were obtained under closer spacing (30×30 cm) and GA_3 250 ppm. Interactions of spacing and growth regulators levels were found significant with respect to morphological, root and seed quality parameters. The treatment combination S_2G_2 (45×45 cm + GA_3 250 ppm) recorded significantly higher values with respect to plant height (85.53 cm), root length (36.80 cm), number of siliqua per plant (264.00), germination percentage (93.33 %) and the same treatment combination also recorded maximum benefit cost ratio (1.70) compared to other treatment combinations.

May, 2015

Department of Vegetable Science



Dr. V. Srinivasa

Major advisor

ಅಂತರ ಮತ್ತು ಸಸ್ಯ ಪ್ರಚೋದಕಗಳ ಬಳಕೆಯಿಂದ ಮೂಲಂಗಿ (ರಫನಸ್ ಸಟ್ಸಿವಸ್ ಲಿ.) ತಳಿ
ಪೂಸ ಚೇತಕಿಯ ಬೆಳವಣಿಗೆ, ಬೇರು ಮತ್ತು ಬೀಜದ ಇಳುವರಿಯ ಮೇಲಾಗುವ ಪರಿಣಾಮ

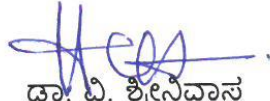
ಶ್ರುತಿ, ಹೆಚ್. ಟಿ (ಎಂಹೆಚ್‌೨ಟಿಎಸಿಂ ೩೫)

ಸಾರಾಂಶ

ಮೂಲಂಗಿಯ ತಳಿಯಾದ ಪೂಸ ಚೇತಕಿಗೆ ಅತ್ಯಂತ ಸೂಕ್ತವಾದ ಅಂತರ ಮತ್ತು ಸಸ್ಯ ಪ್ರಚೋದಕಗಳನ್ನು ಕಂಡು ಹಿಡಿಯಲು ೨೦೧೪ - ೧೫ ರ ಅವಧಿಯಲ್ಲಿ ಮೂಡಿಗರೆ ತೋಟಗಾರಿಕಾ ಮಹಾವಿದ್ಯಾಲಯ, ತರಕಾರಿ ವಿಭಾಗದ ಮುಖ್ಯ ಕ್ಷೇತ್ರದಲ್ಲಿ ಅಧ್ಯಯನ ನಡೆಸಲಾಯಿತು. ಪ್ರಯೋಗವು ಎರಡು ಅಂತರ ಮಟ್ಟವನ್ನು (೩೦ × ೩೦ ಸೆಂ. ಮೀ. ಮತ್ತು ೪೫ × ೪೫ ಸೆಂ. ಮೀ.) ಮತ್ತು ಎರಡು ಸಸ್ಯ ಪ್ರಚೋದಕಗಳನ್ನು (ಜಿಐ೩ ಮತ್ತು ಎನ್‌ಐಐ) ತಲಾ ಎರಡು ಪ್ರಮಾಣದಲ್ಲಿ (೨೦೦ ಪಿಪಿಎಮ್ ಮತ್ತು ೨೫೦ ಪಿಪಿಎಮ್) ಮತ್ತು ಸಸ್ಯ ಪ್ರಚೋದಕ ರಹಿತ ಚಿಕಿತ್ಸೆಯನ್ನು ಒಳಗೊಂಡಿದೆ. ಈ ಮೇಲೆ ತಿಳಿಸಿದ ಸಂಭಾವ್ಯ ಸಂಯೋಜನೆಗಳನ್ನು ಒಳಗೊಂಡಿರುತ್ತದೆ. ಈ ಎಲ್ಲಾ ಸಂಭಾವ್ಯ ಸಂಯೋಜನೆಗಳಿಂದ ಮೂಲಂಗಿಯ ಬೆಳವಣಿಗೆ, ಬೇರು ಮತ್ತು ಬೀಜದ ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟದ ನಿಯತಾಂಕಗಳನ್ನು ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ವಿವಿಧ ಅಂತರಗಳ ಪೈಕಿ ಎಸ್ - ೨ (೪೫ × ೪೫ ಸೆಂ. ಮೀ.) ಮತ್ತು ವಿವಿಧ ಸಸ್ಯ ಪ್ರಚೋದಕಗಳ ಪೈಕಿ ಜಿಬೈರಿಲಿಕ್ ಆಮ್ಲ (ಜಿಐ ೩ - ೨೫೦ ಪಿಪಿಎಮ್) ಸಿಂಪರಣೆ ಮಾಡಿದ ಸಸಿಗಳಲ್ಲಿ ಗರಿಷ್ಠ ಗಿಡದ ಎತ್ತರ, ಎಲೆಗಳ ಸಂಖ್ಯೆ, ಎಲೆಯ ಉದ್ದ, ಎಲೆಯ ಅಗಲ, ಗಿಡದ ವಿಸ್ತರಣೆ, ಕವಲುಗಳ ಸಂಖ್ಯೆ, ಕಾಂಡದ ವ್ಯಾಸ, ನಿರ್ದಿಷ್ಟ ಎಲೆಗಳ, ಕಾಂಡ ಮತ್ತು ಬೇರಿನ ತೂಕ, ಎಲೆಗಳ ವಿಸ್ತೀರ್ಣ, ಪತ್ರಹರಿತ್ತಿನ ಅಂಶ, ಸಂಪೂರ್ಣ ಬೆಳವಣಿಗೆ ದರ, ಎಲೆ, ಕಾಂಡ ಮತ್ತು ಬೇರುಗಳಂತಹ ವಿಭಿನ್ನ ಸಸ್ಯ ಭಾಗಗಳಲ್ಲಿ ಒಣ ಪದಾರ್ಥ ಶೇಖರಣೆ, ಬೇರಿನ ಉದ್ದ, ಬೇರಿನ ಸುತ್ತಳತೆ, ಮೂಲಂಗಿ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಬೀಜಗಳ ಸಂಖ್ಯೆ, ಮೂಲಂಗಿ ಕಾಯಿಯ ತೂಕ, ಕಾಯಿಯ ಉದ್ದ ಮತ್ತು ಗರಿಷ್ಠ ಬೀಜದ ಗುಣಮಟ್ಟದ ನಿಯತಾಂಕಗಳನ್ನು ಅದೇ ಚಿಕಿತ್ಸೆಗಳಲ್ಲಿ ಗುರುತಿಸಲಾಯಿತು. ಎಸ್ - ೧ (೩೦ × ೩೦ ಸೆಂ. ಮೀ.) ಮತ್ತು ಜಿಐ೩ (೨೫೦ ಪಿಪಿಎಮ್) ಚಿಕಿತ್ಸೆಯಲ್ಲಿ ಅಧಿಕ ಬೇರು ಮತ್ತು ಬೀಜದ ಇಳುವರಿಯನ್ನು ಪಡೆಯಲಾಯಿತು. ಅಂತರ ಮತ್ತು ಸಸ್ಯ ಪ್ರಚೋದಕ ಮಟ್ಟದ ಪರಸ್ಪರ ವಹಿವಾಟುಗಳಲ್ಲಿ ಮೂಲಂಗಿಯ ಬೆಳವಣಿಗೆ ಮತ್ತು ಬೀಜದ ಗುಣಮಟ್ಟದ ನಿಯತಾಂಕಗಳಿಗೆ ಸಂಬಂಧಿಸಿದಂತೆ ಗಮನಾರ್ಹ ವ್ಯತ್ಯಾಸ ಕಂಡುಬಂದಿದೆ. ಎಸ್ - ೨ ಜಿ - ೨ (೪೫ × ೪೫ ಸೆಂ. ಮೀ. + ಜಿಐ೩ ೨೫೦ ಪಿಪಿಎಮ್) ಚಿಕಿತ್ಸೆಯ ಸಂಯೋಜನೆಯಲ್ಲಿ ಗಿಡದ ಎತ್ತರ (೮೫. ೫೩ ಸೆಂ. ಮೀ.), ಬೇರಿನ ಉದ್ದ (೩೬. ೮೦ ಸೆಂ. ಮೀ), ಮೂಲಂಗಿ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ (೨೬೪), ಬೀಜ ಮೊಳಕೆಯೊಡೆಯುವ ಪ್ರಮಾಣ (ಶೇ. ೯೩. ೩೩) ಗಮನಾರ್ಹವಾಗಿ ಹೆಚ್ಚಿನ ಮೌಲ್ಯಗಳನ್ನು ದಾಖಲಿಸಲಾಗಿದೆ. ಅದೇ ಚಿಕಿತ್ಸೆ ಸಂಯೋಜನೆಯಲ್ಲಿ ಇತರ ಚಿಕಿತ್ಸಾ ಸಂಯೋಜನೆಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಗರಿಷ್ಠ ಪ್ರಯೋಜನ ವೆಚ್ಚದ ಪ್ರಮಾಣವನ್ನು (೧.೭೦) ಕೂಡ ದಾಖಲಿಸಲಾಗಿದೆ.

ಮೇ, ೨೦೧೫

ತರಕಾರಿ ವಿಜ್ಞಾನ ವಿಭಾಗ


ಡಾ. ಪಿ. ಶ್ರೀನಿವಾಸ
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

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INTRODUCTION

I. INTRODUCTION

Radish (*Raphanus sativus* L.) is one of the most important root vegetable 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 multicentre origin of this crop. Wild species available in Mediterranean region are considered probable progenitors of European radish. Japanese type would have originated from wild species that remain in coastal region of Japan.

Radish belongs to the family *Brassicaceae* with diploid chromosome number $2n = 18$. It is a quick growing herbaceous annual. The enlarged edible roots are fusiform botanically which may differ in colour from white to red. The Asiatic varieties which are primarily for tropical climate, produce edible roots in the first season and seeds in second season as biennial crop. The leaves are rosette covered with stiff bristles. The fleshy roots of radish is modified root (fusiform) developed from both the primary root and the hypocotyl. Roots vary greatly in shape, size and length (Singh and Vishal, 2012). Radish is highly cross-pollinated due to sporophytic system of self- incompatibility. Honey bees are chief source of pollinators. The inflorescence is a typical terminal raceme and arises on main stem. The flowers are regular, cruciform, bisexual completely hypogynous which are white, rose or lilac in colour. Androecium is six in number in two whorls and gynoecium two celled. The fruit of radish is true pod of 2.5 to 7.5 cm length, which has pithy interior and does not dehisce after drying (Arya *et al.*, 1981).

Radish is very rich in vitamin A, B and C with little of carbohydrates, iron and protein. 100 g of edible roots contain 93.7 per cent water, 4.2 per cent carbohydrates, 1.1 per cent protein, 0.1 per cent fat, 0.7 per cent fiber, 30 IU vitamin A, 24 mg vitamin C, 37 mg calcium, 31 mg phosphorous, 260 mg potassium, 15 mg magnesium, 37 mg sulphur and chlorine. Radish also contains glucose as the major sugar and smaller quantities of fructose and sucrose (Singh and Vishal, 2012).

Radish is eaten either as raw as salad or cooked in various ways. It has cooling effect and increases appetite. Radish preparations are useful in liver and gall bladder troubles. The seeds are said to be peptic, expectorant, diuretic and carminative. Radish is considered to be useful for patient suffering from piles, liver trouble, enlarged spleen and jaundice (Brar and Nandpuri, 1972). It is relished for its pungent flavour and is considered as an appetizer. Radish has refreshing and depurative properties. In homeopathy, radish roots and leaves are used for diarrhea. Leaves, roots, flowers and pods are active against gram positive bacteria. The radish seeds are a potential source of non drying fatty oil suitable for soup making, illuminating the edible purposes (Singh, 1989).

Radish is mainly cultivated in Maharashtra, Assam, Utter Pradesh, Madhya Pradesh, Himachal Pradesh, Haryana, Jammu and Kashmir. In India, radish is being cultivated in an area of 1,70,300 ha with the production of 24, 10,750 MT and productivity of 14.15 t / ha (Anon, 2013). In Karnataka, it is cultivated in an area of 5,700 ha with the production of 63,600 MT and productivity of 11.15 t / ha. Radish is mainly grown in all districts of Karnataka and the major districts are Bengaluru, Chikkaballapura, Chitradurga, Davanagere, Kolar, Ramanagara and Shivamogga (Anon, 2013).

Radish is predominantly a cool season crop but Asiatic types can tolerate high temperature than temperate types. The roots develop best flavour and texture at cooler temperature range of 10 - 15°C. A long day as well as high temperature will result in premature bolting. It can be cultivated in all type of soil but well drained, fertile, rich in organic matter, sandy loamy and light friable soils are found to be best for radish cultivation.

Among the several inputs for agriculture, quality seed occupies an important position next only to water. Hence, production of healthy seed is a sheat anchor for successful agriculture. Good quality seed is essential prerequisite for successful production of any crop. There is a great demand for quality seed in radish. Lot of emphasis has been given by government of India to improve the quality of

seed and planting materials which has not only opened new vistas in increasing production and productivity but also provided ample opportunities for export of quality seed.

Planting geometry is one of the major management aspect, which is limiting factor in the seed production of radish. Optimum spacing would help in efficient harvesting of solar energy with least competition for growth factors. Though spacing requirement of commercial vegetable radish has been studied, the information on influence of spacing on seed yield and seed quality of radish seed production is lacking.

The plant growth regulators are new generation agro - chemicals and are expected to play an important role in overcoming the hurdles in manifestation of biological yield even in root crops. In recent years, plant growth regulators are used in overcoming the factors which limits the growth and yield to obtain maximum benefit from seed production. When added in small amounts, modify the architect and growth of plant usually by stimulating or inhibiting the natural growth. The plant growth regulators serve as highly influential agents by which growth is regulated, both in time during ontogeny and in space at any point of time. It is also observed that exogenous application of growth regulators increases the seed yield. These growth hormones regulate the physiological processes and balance the source and sink, thereby increase the productivity and quality of many crop species (Nickele, 1978).

GA₃ application brings about metabolic changes that affect both quality and quantity of the desired product. It stimulates synthesis of hydrolic enzymes which are secreted and act on starchy endosperm in turn affecting seed germination and establishment of seedlings. NAA improves the net photosynthesis rate by increasing CO₂ fixation and reducing the photorespiration. It also helps in mobilization of reserve food materials for seed filling, ultimately increases seed test weight.

There is a need to standardize various agronomic techniques to improve growth and seed yield in radish. Among the various cultural practices, optimum spacing along

with application of growth regulators play an important role in enhancing the root and seed yield.

Keeping all these points in view, the present investigation was carried out at college of Horticulture, Mudigere, to determine the optimum spacing with optimum concentration of growth regulators to get maximum root and seed yield with the following objectives.

1. To study the effect of different levels of spacing on growth, root and seed yield of radish.
2. To assess the effect of various growth regulators on growth, root and seed yield of radish.
3. To find out the interaction of spacing and growth regulators on growth, root and seed yield of radish.
4. To workout the cost of cultivation for radish seed production.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Radish (*Raphanus sativus* L.) is one of the important vegetable crop in India. The productivity of the crop depends on the genetic potentiality and adoption of various judicious cultural practices. Among cultural practices, spacing and growth regulators play an important role in increasing productivity of vegetable crops. A brief review of work pertaining to the present investigation on the “Effect of plant geometry and growth regulators on growth, root and seed yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki” are presented in this chapter. Wherever the literature pertaining to the radish is meager, the related works on other vegetable crops have been reviewed and presented here under.

2.1 Effect of spacing on growth, root and seed yield of radish

2.1.1 Effect of spacing on growth parameters

Malik and Kanwar (1969) observed higher plant height (106.7 cm) at a row spacing of 45 cm, whereas higher numbers of branches (28.9 / plant) were noticed with a wider row spacing of 75 cm in carrot.

Parashar *et al.* (1975) recorded significantly higher number of leaves (36.3 / plant), fresh weight of leaves (336.5 g / plant) and dry weight of leaves (52.6 g / plant) with the lower plant population (60,000 plants / ha) over higher plant population (> 80,000 plants / ha) in sugarbeet.

Gray (1981) reported that, there was no significant difference between the flowering period of the primary umbels and plant height at different plant densities when plant population increased from 1,00,000 to 8,00,000 plants per hectare in carrot.

Sharma and Singh (1981) while studying the effect of spacing, observed significantly higher plant height (139 cm) at 60 × 15 cm spacing over other spacings (i.e. 60 × 30, 60 × 45 and 60 × 60 cm) in carrot cv. Pusa Kesar.

Under Oachghat (Solan, H.P.) conditions Saini *et al.* (1982) observed that the plant height increases significantly with closer spacing of 30 × 30 cm in 'Japanese White' variety of radish as compared to wider spacing of 90 × 60 cm.

Malik *et al.* (1983) reported that maximum plant height of 92.5 cm at 45 × 20 cm spacing when compared to two other spacings (45 × 30 cm and 45 × 40 cm) in carrot cv. Hissar Sel – 1. In radish cv. Japanese White, Singh and Singh (1985) observed taller plants (104.35 cm) under 30 × 30 cm spacing, whereas maximum number of branches (13.95 / plant) were noticed with 90 × 60 cm spacing.

Rastogi *et al.* (1987) noticed that the plants with closer spacing (60 × 30 cm and 60 × 45 cm) were significantly taller than those sown at wider spacing (60 × 60 cm). The maximum number of branches (14.5 / plant) were noticed at 60 × 45 cm and minimum (11.30 / plant) at the spacing of 60 × 30 cm in radish cv. Japanese White.

Maurya *et al.* (1990) observed that wider spacing of 60 × 75 cm had produced significantly maximum number of leaves per plant in radish under Varanasi conditions.

According to Singh *et al.* (1990) radish seeds produced by spacing of 60 × 60 cm recorded more number of branches (38.5) per plant and flowered early (37.5 days) but higher plant height (138.6 cm) was observed at 75 × 30 cm spacing in radish cv. Japanese White.

Chattergee and Som (1991) reported significantly more number of branches per inflorescence stalk (6.85) at 40 × 20 cm spacing over lower spacings (40 × 10 cm and 40 × 15 cm) in radish cv. Improved Chinese Pink.

Saharan and Baswana (1991) recorded maximum plant height, more number of branches per plant under wider spacing (60 × 75 cm) compared to closer spacing in Pusa Chetki variety of radish.

Significantly more number of leaves per plant (26.13), number of primary branches per plant (11.87), secondary branches and tertiary branches per plant

(67.72) were recorded at 60 × 60 cm spacing over lower spacing (60 × 30 cm and 60 × 45 cm). But maximum plant height (156.7 cm) was noticed at 60 × 30 cm spacing in radish cv. Pusa Rashmi (Sharma and Lal, 1991).

Joshi and Patil (1992) reported that in closer spacing of 45 × 45 cm produced significantly maximum plant height of radish (28.9 cm) as compared to wider spacing of 60 × 60 cm and 75 × 75 cm.

Srivastava *et al.* (1992) recorded maximum plant height (149.3 cm) and more number of primary branches (4.96) at 60 × 60 cm spacing compared to 60 × 30 cm (145.3 cm and 4.76, respectively) and 60 × 45 cm (145.2 cm and 5.51 respectively) in radish cv. Pusa Chetki.

Similarly, Jamawal and Thakur (1993) reported that medium wider spacings (60 × 45 cm, 60 × 60 cm) produces significantly taller plants (153.3 cm) than with narrow spaced plants (60 × 30 cm) and maximum number of branches (18.32) at 60 × 60 cm spacing in radish cv. Pusa Himani.

Kanwar (1993) recorded significantly superior plant height (108.0 cm) at 45 × 45 cm spacing, whereas significantly higher number of primary branches (13.9) was obtained at wider spacing of 60 × 60 cm in radish cv. Pusa Chetki.

Ahmad and Tanki (1997) reported maximum plant height (113 cm) at 60 × 45 cm spacing over 60 × 30 cm (110 cm) and 60 × 60 cm (110 cm) spacing in carrot. Significantly taller plant (161.5 cm) were observed at 45 × 30 cm spacing, whereas significantly more number of branches (10.79) per plant were noticed at 45 × 60 cm spacing in turnip (Yadav and Singh, 1997).

Samnotra *et al.* (1998) obtained significantly superior plant height (127.3cm) and more number of branches per plant (14.33) at 40 cm row spacing over its lower row spacing in radish cv. Japanese White.

Malik *et al.* (1999) recorded significantly higher plant height (146 cm) at 60 × 45 cm spacing and maximum number of branches (8.3 / plant) and early 50 per cent flowering (52.4 days) at 60 × 45 cm spacing in radish cv. Pusa Chetki.

Sarker *et al.* (2002) noted that the maximum plant height was highest (37.06 cm) at a closer spacing of 60 × 45 cm as compared to the wider spacing of 60 × 60 cm and maximum number of loose leaves per plant (17.86) was obtained from 90 DAT with the wider spacing of 60 × 60 cm as compared to the closer spacing of 60 × 45 cm (16.93) in cabbage.

Warade *et al.* (2003) recorded that leaves per plant were maximum with the wider spacing of 60 × 60 cm as compared to closer spacing 60 × 15 cm in 'Pusa Chetki' variety of radish under Akola conditions.

Pervez *et al.* (2004) conducted an experiment in radish with different plant spacings of 5, 10 and 15 cm and with a row spacing of 37.5 cm, it was observed that maximum plant height (47.2 cm) was reported with the spacing of 10 cm under Pakistan conditions, the number of leaves per plant were maximum with the spacing of 37.5 × 15 cm (18.7) followed by 37.5 × 10 cm (16.3) in radish.

In a trail conducted under Faizabad conditions on cabbage recorded that the maximum plant height (26.62 cm) with the plant spacing of 45 × 30 cm. The gradual decrease in the plant height was noted with the wider plant spacings of 45 × 45 cm (25.55 cm) and 45 × 30 cm (23.99 cm) but the maximum number of leaves (19.64) were recorded with the wider plant spacing of 45 × 60 cm as compared to the closer plant spacing of 45 × 45 cm (18.62) and 45 × 30 cm (17.68) (Singh *et al.* 2004).

Bilekudari *et al.* (2005) revealed that wider spacing in radish (60 × 45 cm) significantly increased the number of branches per plant (9.25).

El-Desuki *et al.* (2005) conducted an experiment in radish cv. White Icicle with inter row spacing of 10 and 20 cm and intra row spacing of 5 and 10 cm. Maximum plant height (33.41 cm) was observed with spacing of 20 cm between row and 10 cm between

plants and maximum number of leaves per plant (11.91) was observed in the treatment with 20 × 10 cm spacing.

In an experiment, conducted at Haryana with different levels of spacing in carrot, Pandita *et al.* (2005) observed that the closer spacing of 40 × 10 cm produced the maximum plant height (134.3 cm) whereas minimum plant height (117.8 cm) was recorded with the wider plant spacing of 50 × 50 cm.

Sachan and Singh (2005) reported that among the three plant spacing (60 × 60 cm, 60 × 45 cm and 60 × 30 cm), the maximum plant height (155.2 cm) was obtained under wider spacing (60 × 60 cm) and minimum plant height (140.1 cm) was recorded at closer spacing (60 × 30 cm) in radish var. Chinese pink.

Kumar *et al.* (2007) studied the performance of carrot under varying plant densities. Among the three spacing tried, the closet spacing 30 × 30 cm significantly highest plant height (107.80 cm) at harvest stage compared wider spacing 45 × 30 cm (112.92 cm) and 45 × 45 cm (107.80 cm).

Kutijabi (2007) noticed that plant height and number of leaves per plant were significantly higher in 40 × 15 cm spacing in carrot.

Rahman *et al.* (2007) reported maximum plant height with the plant spacing of 45 cm (49.33 cm) over the wider spacing of 50 and 55 cm in cauliflower under Pakistan conditions and maximum number of leaves per plant (29.33) was observed in 45 cm spacing.

Criollo and Garcia (2009) reported that the maximum leaf area was observed with the lower densities (1 and 2 plants / pot) as compared to higher plant densities (3 and 4 plants / pot) in radish under green house conditions. Jilani *et al.* (2010) observed that widest plant spacing (25 cm) produced the maximum plant height and leaves per plant in onion.

Mengistu and Yamoah (2010) reported that maximum plant height (154.82 cm), number of branches per plant (8.22) and less number of days for 50 per cent flowering under low planting density of 133333 plants per hectare as compared to high planting density in carrot.

Dawuda *et al.* (2011) recorded the maximum plant height (42.2 cm), number of leaves (7.7) and canopy spread (38.8 cm) in wider spacing (30 × 5 cm) over closer spacing (20 × 5 cm) in carrot.

Manoj *et al.* (2012) noticed that plant height, number of primary branches per plant, length of longest primary branches, weight of plants with pods, number of pods per plant, seed weight per plant, 100-seed weight and seed yield per plant were found maximum at 60 × 60 cm .

Shah *et al.* (2013) studied the effect of row spacing on yield of onion. The maximum plant height (47.1 cm) and number of leaves per plant (8.67) were recorded at 25 cm row spacing. While, maximum leaf width (1.26 cm) was observed at spacing 20 cm row spacing.

Lavanya *et al.* (2014) recorded that the closer spacing (45 x 10 cm) resulted in maximum plant height (30.87 cm), whereas the number of leaves (11.83) and leaf area (110.59 cm²) were found maximum with wider spacing (45 × 30 cm) in radish.

2.1.2 Effect of spacing on yield and seed yield parameters

2.1.2.1 Effect of spacing on yield parameters

Sharma and Lal (1986) reported that the higher root yield (165.61 q / ha) was obtained at 60 × 45 cm spacing in radish cv. Pusa Rashmi. Maurya *et al.* (1990) observed that closer spacing of 60 × 45 cm produced the maximum root length but wider spacing of 60 × 75 cm had produced significantly maximum root girth in radish variety Pusa Chetki under Varanasi conditions.

Rao and Manohar (1990) revealed that the highest mean yields of good quality roots was observed with closer spacing of 30 × 10 cm in radish variety Nerima Long. Chatterjee and Som (1991) reported significantly superior gross weight of root (0.60 kg) at 40 x 20 cm spacing over other spacings (40 × 10 & 40 × 15 cm) in radish cv. Improved Chinese Pink.

Joshi and Patil (1992) noticed significantly higher root weight (70.5 / plant) at 30 cm inter row spacing over others, whereas significantly superior yield (66.57 t / ha) was obtained at 10 cm inter row spacing over other spacings in radish cv. Japanese White.

Sirkar *et al.* (1998) conducted an experiment with different plant densities of 72, 24, and 12 plants / m² in radish cv. Contai Long. Increase in the root length and root yield per plot were observed with increase in plant density and increase in the root girth and root weight were observed with decrease in plant density.

Aziz-Ur-Rehman and Nawab (2000) observed that wider spacing of 60 × 40 cm gave the maximum root diameter and the closer spacing of 60 × 20 cm gave the highest yield with good quality roots in turnip cv. Purple Top.

Sarker *et al.* (2002) found that the maximum head diameter (22.56 cm) was obtained with the wider spacing of 60 × 60 cm than that of 60 × 45 cm spacing (20.74 cm) and maximum yield ha⁻¹ (91.99 t) was observed in closer spacing of 60 × 45 cm over the wider plant spacing of 60 x 60 cm (79.39 t) in cabbage under Bangladesh conditions.

Pervez *et al.* (2004) revealed that maximum root length was produced with the spacing of 37.5 × 15 cm (36.2 cm) which was at par with 37.5 × 10 cm (35.4 cm) spacing, maximum root girth with plant spacing of 15 cm (4.9 cm) and is on par with 10 cm (4.6 cm) spacing compared to the closer plant spacing of 5 cm and maximum root yield per plot (15.6 kg) in 10 cm plant spacing which was statistically at par with 5 cm plant spacing (16.3 kg) in radish under Faisalabad conditions.

Sogut and Agrioglu (2004) reported that the maximum root yield with quality was observed at intra row spacing of 15 and 20 cm compared to the wider spacing of 35 cm in sugarbeet.

El-Desuki *et al.* (2005) conducted an experiment in radish cv. White Icicle with inter-row spacings of 10 and 20 cm and intra-row spacings of 5 and 10 cm. Maximum root length (20.11 cm) and root yield ha⁻¹ (15.54 t) was observed in closer spacing of 10 × 5 cm as compared to wider spacing but maximum root girth (3.43 cm) was observed in wider spacing of 20 × 10 cm. Similarly, Kutijabi (2007) noticed that days to 50 per cent flowering root length, root weight and root diameter were significantly higher in 40 × 15 cm spacing in carrot.

Rahman *et al.* (2007) reported that maximum curd diameter (19.13 cm) and curd yield (30.77 t / ha) were observed with 45 cm optimum plant spacing which was statistically at par with 50 cm spacing (29.30 t / ha) and curd weight with an optimum plant spacing of 45 cm (1.23 kg) followed by the plant spacing of 40 (1.07 kg) and 50 cm (1.02 kg) in cauliflower.

Criollo and Garcia (2009) reported that maximum root yield per plot was observed with the highest densities (3 and 4 plants/pot) as compared to lower plant densities (1 and 2 plants/pot) in radish under green house conditions.

Jilani *et al.* (2010) reported that among the plant spacings, although the widest plant spacing (25 cm) produced the maximum leaves per plant, plant height, bulb weight and bulb diameter, but it reduced the yield per plot and total yield. However, closest plant spacing (10 cm) produced significantly maximum yield per plot and total yield.

Mengistu and Yamoah (2010) recorded the maximum seed yield per plant (4.57 g) with less planting density, whereas more seed yield per hectare (585.98 kg) was observed with higher planting density (400000 plants / ha) in carrot.

Refay (2010) revealed that the highest yield with good quality roots in sugar beet variety Samo-2 under Saudi Arabia conditions was recorded at 30 cm inter row spacing.

Dawuda *et al.* (2011) reported that wider spacing (30 × 5 cm) recorded maximum root length (13.4 cm), root diameter (2.5 cm) and root weight per plant (47.8 g) compared to closer spacing, whereas, the higher root yield per hectare (12.4 t / ha) was noticed under closer spacing (20 × 5 cm) in carrot.

Asaduzzaman *et al.* (2012) studied the effect of plant spacing on seed production of cv. Taherpuri onion. Four different spacing's such as 25cm × 15 cm, 25cm × 20cm, 30cm × 15 cm and 30cm × 20cm were followed in the experiment. The results revealed that the highest seed yield per hectare was obtained from the spacing of 25cm × 15 cm.

Shah *et al.* (2013) studied the effect row spacing on yield of onion. The maximum bulb diameter (5.64 cm) and average bulb weight (54.92 g) were recorded at 25 cm row spacing. Maximum yield (22.45 ton / ha) was observed at spacing 20 cm row spacing. The maximum bulb per kg (16.92) was observed at 15 cm row spacing and the highest yield was observed with the 20 cm row spacing.

Kabir *et al.* (2013) conducted an experiment with three levels of spacing viz., 20 × 10 cm, 25 × 15 cm and 30 × 20 cm in carrot. The total yield and yield attributing characters were highest at the spacing of 30 × 20 cm.

Lavanya *et al.* (2014) revealed that yield contributing characters like root girth (4.42 cm) and root weight (183.39 g) were maximum with wider spacing of 45 × 30 cm. whereas, root length (20.25 cm) was found maximum with closer plant spacing of 45 × 10 cm in radish cv. Pusa Chetki.

Yemane *et al.* (2014) conducted a study with three different intra row spacing's of 5 cm, 7.5 and 10 cm in onion. The results indicated that intra row spacing of 10 cm was superior in vegetative characters. The highest total yield was recorded in the intra row spacing of 5 cm.

Bunu *et al.* (2014) investigated the effect of spacing on bulb weight and bulb diameter in onion. Spacing of 20 × 14 cm had significantly higher bulb weight and bulb

diameter than other spacing's. Bulb diameter was significantly higher with spacing of 20×14 cm and significantly lower than with spacing of 20×14 cm.

2.1.2.2 Effect of spacing on seed yield parameters

Malik and Kanwar (1969) obtained significantly higher seed yield (14.24 q / ha) at 60×30 cm spacing than wider spacing 75×30 cm (11.56 q/ha) in carrot. Brar and Kaul (1971) recorded significantly higher seed yield (16.18 q / ha), when grown at a spacing of 60×45 cm compared to other spacing (60×60 cm & 60×75 cm) in radish cv. Japanese White.

Significantly higher seed yield (2.09 kg / plot) at a spacing of 30×30 cm was observed when compared to wider spacing (60×30 cm and 90×30 cm) in carrot (Saini and Rastogi, 1976). Gill *et al.* (1981) observed higher seed yield (553.17 g / plot) at a medium spacing of 50×30 cm compared to closer spacing of 40×30 cm (541.83 g / plot) and wider spacing of 60×45 cm (424.16 g / plot) in carrot.

Maximum seed yield (11.34 q / ha) was recorded when the plants were spaced at 60×30 cm apart but increasing spacing reduced the seed yield, although the treatment differences were not significant in carrot (Sharma and Singh, 1981).

Nautiyal and Lal (1982) conducted an experiment with radish cv. Japanese White plants spaced at 45×45 cm or 60×60 cm. Seed yields were highest (10.85 q / ha) followed by (10.5 q / ha) in plants spaced at 60×60 cm and 45×45 cm, respectively.

Malik *et al.* (1983) observed significantly higher seed yield (8.3 q / ha) at 45×20 cm spacing over 45×40 cm wider spacing in carrot. Seed yield at 45×30 cm spacing was on par with 45×20 cm spacing.

Singh and Singh (1985) noticed significantly higher number of pods per plant (380.40) with 90×60 cm spacing, whereas significantly superior seed yield (1.27 kg / plot) was recorded at 30×30 cm closer spacing in radish cv. Japanese White.

Lal and Pandey (1986) reported significantly higher seed yield (9.75 q / ha) at closer spacing of 30 × 30 cm over 45 × 35 cm (9.37 q / ha) and 75 × 75 cm (8.37 q / ha) in carrot.

Sharma and Lal (1986) observed significantly higher seed yield (9.19 q / ha) at 60 × 30 cm spacing over other spacings (60 × 45 cm and 60 × 60 cm). But significantly higher number of pods per plant (734), pod weight per plant (64.06 g) and seed weight per plant (31.38 g) were recorded in 60 × 60 cm spacing in radish cv. Pusa Rashmi.

Highest number of pods per plant (330.50) was observed at 60 × 45 cm spacing and the lowest (312.10) at the closer spacing of 60 × 30 cm in radish cv. Japanese White (Rastogi *et al.*, 1987) and they also reported differences for 100 seed weight and germination percentage. There were non significant differences observed under 60 × 30 cm, 60 × 45 cm and 60 × 60 cm spacings.

Sharma and Lal (1987) recorded significantly maximum seed yield (9.41 q / ha) at 60 × 30 cm spacing over its wider spacing 60 × 45 and 60 × 60 cm in radish cv. Pusa Rashmi (8.39 and 7.61 q/ha, respectively).

Singh *et al.* (1990) reported significantly higher number of pods per plant (319) at 60 × 60 cm spacing while significantly superior seed yield (7.56 q / ha) at 60 × 45 cm spacing in radish cv. Japanese White.

According to Maurya *et al.* (1990), maximum seed yield (11.18 q / ha) was obtained at 60 × 60 cm spacing over 60 × 75 cm (8.97 q / ha) and 60 × 45 cm (8.91q / ha) in radish cv. Pusa Chetki.

Chatterjee and Som (1991) recorded significantly increased seed yield (18.55 q/ha) at 40 × 10 cm spacing over 40 × 15 cm (14.39 q/ha) and 40 × 20 cm (12.85 q / ha) in radish cv. Improved Chinese Pink. Saharan and Baswana (1991) reported that highest 1000 seed weight was produced under widest spacing in radish.

Though the number of pods per plant (734) were significantly more with 60×60 cm spacing, significantly higher seed yield (9.19 q / ha) was obtained at 60×30 cm over wider spacing of 60×45 cm in radish cv. Pusa Chetki (Sharma and Lal, 1991).

In radish cv. Pusa Chetki seed production, Srivastava *et al.* (1992) reported maximum seed yield (6.20 q / ha) at 60×45 cm spacing over 60×30 cm (5.81 q / ha) and 60×60 cm (5.87 q / ha) spacing.

Jamwal and Thakur (1993) noticed significantly superior seed yield of 12.6 q / ha at 60×45 cm spacing over 60×30 (11.8 q / ha) and 60×60 cm (11.1 q / ha) spacing in radish cv. Pusa Himani.

According to Kanwar (1993) maximum number of pods per plant (674.8) were recorded at 60×60 cm spacing but significantly higher seed yield (941.0 kg / ha) was noticed at 45×45 cm spacing in radish cv. Pusa Chetki.

Closer spacing of 60×30 cm recorded seed yield of 12.44 q per hectare over wider spacings of 60×45 (10.6 q/ha) and 60×60 cm (8.33 q / ha) in carrot (Ahmad and Tanki, 1997). Yadav and Singh (1997) obtained maximum seed yield (15.46 q / ha) at 45×30 cm spacing over 45×45 cm (14.61 q / ha) and 45×60 cm (15.43 q / ha) in turnip.

Malav and Yadav (1997) reported that 40 cm row spacing in coriander recorded highest number of umbels per plant (25.20) and seed yield per plant (3.58 g) while, 30 cm row spacing recorded highest seed yield per ha (12.44 q / ha)

Samnotra *et al.* (1998) obtained significantly higher number of pods per plant (800), pod length (4.99 cm), number of seeds per pod (8.37) and maximum seed yield (12.10 q / ha) at 40 cm row spacing in radish cv. Japanese White.

Malik *et al.* (1999) reported significantly more number of pods (303) per plant at 60 × 45 cm spacing and significantly superior seed yield (12.10 q / ha) at 45 × 45 cm over 30 × 45 cm and 60 × 45 cm spacing in radish cv. Pusa Chetki.

Hussain *et al.* (2002) noticed that in row spacing, significantly highest seed yield of 110 kg / ha was obtained in the 50 cm row spacing and the minimum of 62.02 kg / ha was recorded from the 70 cm row spacing. In interactions, minimum plant mortality (1.2 %) was in 15 cm steckling × 60 cm row spacing while the maximum (66.25 %) mortality was in 5 cm steckling × 50 cm row spacing. Maximum seed yield per ha (188.43 kg) was in 15 cm steckling with 50 cm row spacing in radish.

An experiment was conducted to study the effect of four plant spacings (60 × 60 cm, 60 × 45 cm, 60 × 30 cm and 60 × 15 cm) on the performance of seed yield of radish cultivars viz., Pusa Chetki, Pusa Reshmi and Japanese White. Pusa Chetki recorded the highest seed yield (13.47 q / ha). Among the spacings, the closest spacing of 60 × 15 cm produced the highest seed yield (14.01 q / ha) (Jaya *et al.*, 2003)

Pervez *et al.* (2004) reported that spacing at 5, 10 and 15 cm had no effect on seed germination of radish. Maximum plant height (83 cm) was obtained at 10 cm spacing followed by 15 cm spacing (71.1 cm). The maximum root length (38.4 cm) was obtained at 5 cm spacing and 15 cm spacing produced the highest root diameter (4.6 cm).

Warade *et al.* (2003) noticed that among plant spacing, the closest spacings of 60 × 15 cm produced highest seed yield (17.96 q / ha) in radish var. Pusa Chetki .

Bilekudari *et al.* (2005) revealed that wider spacing in radish (60 × 45 cm) significantly increased the number of branches per plant (9.25). The seed yield per plant was significantly higher (11.7 g) in wider spacing, but the closer spacing recorded significantly higher seed yield per hectare (5.07 q).

Sachan and Singh (2005) reported that three plant spacings (60 × 60 cm, 60 × 45 cm and 60 × 30 cm) were compared in all possible combinations. Maximum seed yield was obtained with closer spacing (60 × 30 cm). But the maximum germination per cent

was recorded in the seeds with wider spacing (60 × 60 cm). Maximum seed weight per 1000 seeds was also found with wider spacing in comparison to other combinations in radish.

Kutijabi (2007) noticed that number of umbels per plant, umbel diameter, seed yield per plant and seed yield per ha were significantly higher in spacing 40 × 15 cm in carrot. Dod *et al.* (2010) reported that seed yield per hectare was significantly maximum at closer spacing of 60 × 15 cm in radish var. Pusa Chetki.

Manoj *et al.* (2012) noticed that weight of plants with pods, number of pods per plant, seed weight per plant, 100-seed weight and seed yield per plant were found maximum at 60 × 60 cm and all these characters increased significantly with increase in plant spacing. The seed per pod and seed yield per plant were highest at 60 × 30 cm in radish.

2.1.3 Effect of spacing on seed quality parameters

Malik (1973) observed higher germination (90.0%) and thousand seed weight (2.74 g) when seed production was taken at a spacing of 75 × 30 cm when compared to other spacings (45 × 30 cm and 60 × 30 cm) in carrot cv. Pb. No. 29.

Gray (1981) reported that there was no significant effect of plant density on thousand seed weight, seed germination percentage and seedling emergence in carrot cv. Pusa Kesar.

According to Sharma and Singh (1982), maximum 1000 seed weight (2.0 g) and germination percentage (87.50 %) were observed at 60 × 60 cm spacing over 60 × 15 cm, 60 × 30 cm and 60 × 45 cm spacings in carrot cv. Pusa Kesar. Malik *et al.* (1983) noticed maximum 1000 seed weight (3.8 g) and germination (78.9 %) at 45 × 40 cm spacing over other spacings (45 × 20 and 45 × 30 cm) in carrot cv. Hissar Sel –1.

Higher 1000 seed weight (15.65 g) at 90 × 60 cm and seed germination percentage (90 %) were observed at 30 × 30 cm spacing in a radish cv. Japanese White (Singh and Singh, 1985). Singh and Malik (1986) recorded significantly

higher test weight (2.46 g), germination (89.1 %), seedling shoot length (4.31 cm) and root length (5.44 cm) at 45 × 30 cm spacing over 45 × 20 cm in carrot cv. Hissar Sel-1.

Increased nitrogen accumulation in seed (31.79 kg / ha), seed protein yield (198.72 kg/ha) and oil content (44.83 %) were observed in seed present at 60 × 30 cm spacing over other spacings (60 × 45 and 60 × 60 cm) in radish cv. Pusa Rashmi (Sharma and Lal, 1987).

In radish cv. Improved Chinese Pink, Chatterjee and Som (1991) reported significantly superior test weight (12.14 g) at 40 × 20 cm spacing over 40 × 15 cm (11.60 g) and 40 × 10 cm (10.97 g) spacing.

Srivastava *et al.* (1992) observed more number of seeds (89.0) per gram and seed germination (98.5 %) at 60 × 45cm spacing. But, maximum seed nitrogen content (3.85 %) and seed protein content (24.06 %) were noticed at wider spacing of 60 × 60 cm during radish cv. Pusa Chetki seed production.

Jamwal and Thakur (1993) recorded Significantly higher 1000 seed weight (12.77 g) at 60 × 60 cm spacing over 60 × 30 (11.10 g) and 60 × 45 cm (11.99 g) spacing in radish cv. Pusa Himani. Turnip seeds produced at 45 x 60 cm spacing exhibited maximum test weight (2.42 g) and germination percentage (98.5 %) when compared to other spacings of 45 × 30 cm and 45 × 30 cm (Yadav and Singh, 1997).

Malik *et al.* (1999) obtained maximum test weight (6.79 g), seed germination percentage (81.1%) and seedling vigour (635.80) at 60 × 45 cm spacing over closer spacing of 45 × 45 cm and 30 × 45 cm in radish cv. Pusa Chetki. Kutijabi (2007) noticed that 1000-seed weight was significantly higher in 40 × 15 cm spacing in carrot.

Mengistu and Yamoah (2010) reported the maximum germination per cent (57.72 %) under low planting density as compared to high planting density in carrot.

Lavanya *et al.* (2014) recorded the higher germination per cent (97.75 %) under wider plant spacing (45 × 30 cm) as compared to closer spacing (96.50 %) in radish.

2.2 Effect of growth regulators on growth, root, seed yield and quality parameters in radish

It is well established and documented that normal plant growth and development is controlled by chemicals synthesized by the plant itself. The production of these chemicals inturn its under genetic control and these are called as growth regulators. In modern horticulture, growth regulators are being used widely for increased horticultural production at an unprecedented rate by modifying its source to sink relationship (Nickell, 1982).

Plant growth regulators are involved in coordinating the development of specific plant organs and in controlling plant responses in relation to variable environment and crop management. The plant growth regulators are natural or synthetic compounds applied to the target plants to modify the developmental, morphological structure or both by manipulating the hormonal levels in different plant organs and at various stages in the plant life cycle so as to enhance its seed yield and quality (Setia *et al.*, 1991).

2.2.1 Effect of GA₃ on growth parameters

Maximum yield of fruits by weight was obtained from plants raised from seeds treated with IAA 50 ppm and GA 40 ppm in brinjal (Sadawarte and Gupta, 1963).

In tomato Meharotra *et al.* (1970), obtained increased number of branches per plant (11.3) with 25 ppm GA₃ sprayed at 25 DAT and at the time of flowering against water spray (8.9). Increase in growth of carrot seed plant was observed by Joshi *et al.* (1975) on treatment with GA₃ at 100 and 200 ppm.

Dipping of root of five week old onion seedlings for 24 hours in GA₃ (40 ppm) solution produced highest number of leaves compared to control (Singh *et al.*, 1983). Whereas, Tomer *et al.*, (1988) also observed that the foliar application of GA₃ (200 ppm)

at 120 DAS significantly increased the number of leaves per plant as compared to control in onion.

Mahabir Singh and Rajodia (1989) revealed that foliar spray of GA (30, 35 and 45 ppm) recorded maximum plant height, number of leaves per plant, leaf length, width of leaves and fresh weight of leaf in radish. Salah and Abdul (1989) indicated that the application of GA₃ increased the number of leaves per plant significantly in onion.

Nandekar and Sawarkar (1992) reported that the roots of six week old onion seedlings dipped in GA₃ 40 ppm solution increased the number of leaves per plant significantly as compared to control. Shashank singh *et al.* (1995) noticed that the dipping of onion bulbs in GA₃ (300 ppm) increased number of leaves to a greater extent as compared to other treatments.

Sharma *et al.* (1992) observed that plant sprayed with 300 ppm GA₃ flowered earlier in brinjal.

Gupta *et al.* (1997) observed an increase in plant height (112-122 cm) of brinjal with increase in the GA₃ concentration from 100 to 300 ppm as compared to control (106 cm).

Deotale *et al.* (1998) observed increase in the plant height, number of leaves, branches, leaf area, dry matter and seed yield in soybean cv. JS-335 due to the seed treatment with GA₃ (100 ppm).

Malhotra and Chaudhry (2001) concluded that GA₃ sprayed at 150 ppm at twice, 30 days after steckling planting, resulted in significantly more number of branches per plant (22.7) comparison with control (13.9) in radish.

Abdul *et al.* (2002) revealed that the application of GA₃ @ 200 ppm root treatment during transplanting followed by foliar spray at 28 DAT. The significantly higher leaf number per plant (6.56), leaf length (47.01cm) and leaf diameter (1.15cm) were recorded compared to control (4.95, 40.22 cm and 0.99 cm, respectively) in onion.

Balaraj *et al.* (2002) observed an increase in number of branches and growth parameters in chilli due to application of GA₃ 20 ppm. Bala and Hari (2004) reported that the GA₃ at 100 ppm applied as whole plant sprays 4 times at 15 days interval from 15 days after sowing recorded significantly maximum plant height (100.50 cm) and days to 50 per cent flowering (33.14 days) compared to control (92.80 cm and 38.17 days, respectively) in bhendi cv. Arka Abhay.

Gavaskar and Anburani (2004) recorded that GA₃ at 100 ppm applied three times, starting from 15 days after planting at fortnight intervals gave maximum the plant height (108.40 cm) and number of leaves (84.55) over control (84.03 cm and 60.88, respectively) in brinjal cv. Annamalai.

Mahesh and Sen (2005) reported that the soaking of seeds in 50 ppm of gibberllic acid recorded significantly higher plant height (146.24 cm) compared to control (water soaked) in okra.

Mondal and Shukla (2005) declared that the application of GA₃ at 20, 40 and 60 ppm in root dipping treatment resulted in significantly more bulb yield (> 20 g bulb⁻¹) over control (water spray) in onion.

Natesh *et al.* (2005) found that the application of GA₃ (100 ppm) at the time of flower initiation stage recorded significantly maximum plant height (85.7 cm) over control (water spray) 69.3cm in chilli.

Ganapathi (2006) revealed that the foliar application of GA₃ 40 ppm significantly recorded the maximum plant height (80.7 cm), number of leaves (10.45) and root dry weight per plant (10.675 g) in carrot.

Kutijabi (2007) opined that the application of GA₃ 200 ppm recorded significantly maximum plant height (98.67 cm), number of leaves (15.40), days to 50 per cent flowering (114.33 days) and root length (30.91 cm) over control (water spray) in carrot.

Panda *et al.* (2007) summarized that the GA₃ at 100 ppm applied at 45 and 60 DAS as foliar spray showed significantly maximum the plant height (104.26 cm), primary branches (8.16), secondary branches (30.13), days to 50 per cent flowering (87.66 days) and days taken to maturity (106.33 days) over control (water) in coriander.

Birbal *et al.* (2008) studied that dipping tubers in GA₃ at 10 ppm solution for 30 minutes and then spread on the floor found significantly maximum plant height at 30 and 75 DAS (25.7 and 50.1 cm) over control (19.9 and 41.5 cm respectively) in potato.

Geetharani *et al.* (2008) showed that the GA₃ at 100 ppm sprayed (35 and 45 DAP) plants took less number of days to 50 per cent flowering (47 days) compared to control (50 days) in onion.

Kursat *et al.* (2008) reported that radish seedlings grown under saline condition with the growth regulators pretreatments significantly increased the leaf anatomy of radish seedlings compared to control.

Uddain *et al.* (2009) findings revealed that the application of gibberellic acid 30ppm at 15, 30 and 45 DAT gave maximum number of flower clusters (5.81), number of flowers per plant (59.62) and less days to 1st flowering from transplanting (31.73 days) in tomato.

Chauhan and Tandel (2010) observed that spray of GA₃ at 100 ppm significantly influenced the performance of growth, yield and quality characters of cabbage. Patil and Patel (2010) found that GA₃ 15 mg per liter recorded the maximum stem girth, number of branches, number of leaves per plant and early flowering in okra.

Waghmode *et al.* (2010) revealed that the spray of Gibberllic acid @ 100 ppm resulted in significantly increased plant height (60.34 cm), number of leaves per plant (52.60), height of flower stalk (80.63 cm) and per cent stalk bending (1.44) over control, (56.66 cm, 44.24, 71.17 cm and 1.06, respectively) in onion.

Abbas (2011) studied that the GA₃ 100 ppm spray found significantly maximum plant height (106.66 cm) and number of branches (23.67) compared to control (96.67 cm and 17.66, respectively) in carrot.

Priya *et al.* (2012) proved that the application of GA₃ at 50 ppm before flower initiation and at the time of fruit initiation stage recorded significantly less number of days for initiation of flowering (24.9 days), days to 50 per cent flowering (34.2 days) and peak flowering (44.8 days) compared to more in control (32.3 days, 46.2 days and 58.0 days, respectively) in chilli hybrid HCH-9646.

Muhammad *et al.* (2013a) stated that application of GA₃ 75 ppm at 2-leaf and flower initiation stage significantly took less days for first flower (41.33 days) and first harvest (57.00 days) over control (46.00 and 60.00 days respectively) in bitter gourd.

Muhammad *et al.* (2013b) noticed that 100 ppm GA₃ as a foliar application significantly increased the number of leaves (37.4) and plant height at maturity (44.2 cm) compared to control (28.9 and 39.1cm, respectively) in okra.

Shirzad *et al.* (2013) revealed that the application of GA₃ 75 ppm at the 4 true leaf stage for 3 times gave maximum plant length (119.37 cm) compared to control in pumpkin.

Netam and Sharma (2014) observed that higher plant height (76.10 cm), number of leaves (94.27) and number of branches per plant (24.32) at 90 DAT with foliar application of GA₃ 50 ppm in brinjal.

Deepika (2014) observed that the maximum plant height (32.70 cm), number of leaves (31.3) and days to 50 per cent flowering (56.6 days) with GA₃ 120 ppm in radish.

2.2.2 Effect of GA₃ on yield parameters

The highest yield of okra was obtained when the crop was sprayed with 50 ppm GA₃ as compared to control (Maurya *et al.*, 1985). According to Chattopadhyaya and Sen

(1974), chilli plants sprayed with GA₃ at 10 ppm at pre-bloom stage resulted in increased fruitset (51.92 per cent) over control (35.92 per cent).

Sharma *et al.* (1992) observed that the plants sprayed with 300 ppm GA₃ had the highest number of fruits and yield per hectare in brinjal.

Yoganand (2001) reported that higher fruits per plant (7.30) was obtained when GA₃ 100 ppm was sprayed at 45 DAT and at full bloom stage in chilli.

Application of GA₃ @ 200 ppm root treatment during transplanting followed by foliar spray at 28 DAT resulted significantly higher root number (43.91), root length (11.78cm), bulb diameter (4.84cm), yield (15.57 t ha⁻¹), root weight (0.25g) and bulb weight (13.97g) compared to control (0 ppm) (40.22, 10.11 cm, 3.51 cm, 13.59 t ha⁻¹ , 0.20 g and 10.95 g respectively) in onion (Abdul *et al.*, 2002).

Surendra *et al.* (2006) registered significantly higher number of flowers per plant (26.8), total number of fruits (22.1), fruit length (23.4 cm), total dry weight of fruit (90.49 g) and fruit yield (18.69 t / ha) with the application of GA₃ 50 ppm in okra.

Uddain *et al.* (2009) findings revealed that the application of gibberellic acid 30 ppm at 15, 30 and 45 DAT gave treatment gave maximum number of fruits cluster⁻¹ (4.81) and number of fruits plant⁻¹ (42.66) over control in tomato. Patil and Patel (2010) found that GA₃ 15 mg per liter recorded the maximum stem girth, number of branches, number of leaves per plant and early flowering in okra.

Roy and Nasiruddin (2011) studied the different concentrations of GA₃, viz., 0, 25, 50 and 75 ppm spray after transplanting. 50 ppm GA₃ gave the maximum diameter of cabbage head (23.81 cm), length of root (23.23 cm) and higher yield (45.22 kg plot⁻¹ and 104.66 t ha⁻¹) compared to control.

Netam and Sharma (2014) reported the combined application of GA₃ at 10 ppm and NAA 20 ppm, which resulted in higher number of fruits per plant (18.83) and fruit weight per plant (3.67 kg) in brinjal.

2.2.3 Effect of GA₃ on seed yield parameters

Seed yield was increased with application of GA₃ in many crops. Harrington (1960) reported that spraying of GA₃ (3-10 ppm) on lettuce plant at 4 and 8 leaf stage significantly increased the seed yield. With these treatments the seed crop matured two weeks earlier with extremely uniform maturity among plants.

There was an increase in onion seed yield by 30 to 40 per cent with application of GA₃ (Kruzilin and Svedskaja, 1963).

Chandra and Shivaraj (1972) obtained significantly higher number of seeds per fruit (44.4) with foliar spray of 25 ppm GA₃ compared to water spray (39.8) in chilli.

A combination of root soaking and foliar spray of GA₃ (100 ppm) to non bolting cultivars of carrot produced a higher percentage of flower than did spraying alone (Globerson, 1972). Turnip took less number of days to 50 per cent bolting with GA₃ (400 ppm) (Mohammed *et al.*, 1988).

Vanagamudi *et al.* (1988) found that soaking onion seeds with GA₃ (100 ppm) for three hours increased flowering in onion cv. Rampur Local. While gibberellic acid injection prior to chilling increased the flowering percentage in some genotypes of onion under controlled conditions (Brewster and Butler, 1989).

Ruggeri and Branca (1993) opined that GA₃ (400 ppm) spraying improved flower induction and enhanced percentage of flowered plants in onion.

Maske *et al.* (1998) found that 12.99 and 20.72 per cent increase in seed yield with GA₃ spray of 75 and 100 ppm and with NAA 25 and 50 ppm, 11.39 and 12.66 per cent respectively over control and increase in yield was mainly due to increase in number of pods per plant and number of seeds per pod in soybean.

Malhotra and Chaudhry (2001) concluded that application of GA₃ (150 ppm) at 30 days after steckling planting, resulted in significantly more number of flowers per

branches (47.8), number of siliqua per branches (34.7), number of seeds per siliqua (7.3) and seed yield (8.7q ha⁻¹) comparison with control in radish.

Yoganand (2001) reported that higher number of seeds per plant (224.63), 1000 seed weight (5.10 g), seed yield per plot (432.67 g) and per ha (200.18 kg) were obtained when GA₃ 100 ppm was sprayed at 45 DAT and at full bloom stage in chilli.

Bala and Hari (2004) agreed that the GA₃ at 100 ppm applied as whole plant sprays 4 times at 15 days interval from 15 days after sowing. The significantly higher number of flowers plant⁻¹ (15.17), number of pods plant⁻¹ (10.33), pod weight (14.33 g), pod length (15.33 cm), number of seed per pod (51.50 g), yield plant⁻¹ (0.112 kg) and yield ha⁻¹ (13.24 g) in bhendi cv. Arka Abhay.

Natesh *et al.* (2005) found that the application of GA₃100 ppm at the time of flower initiation stage, the maximum fruit length (16.3cm), fruit diameter (3.7cm), dry fruit yield (1406.1 kg ha⁻¹), number of seeds per fruit (101.0), seed yield per plant (11.95 g) and seed yield (195.5 kg ha⁻¹) over control (7.7 cm, 2.4 cm, 1135 kg ha⁻¹, 56.2, 1.22 g and 150.5 kg ha⁻¹, respectively) in chilli cv. Byadagi kaddi.

Kutijabi (2007) observed that the application of GA₃ (200 ppm) at initiation of flower stage. The significantly maximum number of umbels per plant (43.96), number of seeds per umbel (25.72), umbel diameter (38.33 cm), seed yield per plant (46.30 g), seed yield per plot (189.36 g) and seed yield (473.41 kg ha⁻¹) over control (water spray) in carrot.

Panda *et al.* (2007) reported that the application (GA₃ at 100 ppm) at 45 and 60 DAS as foliar spray significantly produced more number of umbels per plant (61.83), number of seeds per umbel (31.12), seed yield per plant (23.75 g) and seed yield (17.93 q ha⁻¹) over control in coriander.

Geetharani *et al.* (2008) showed that the GA₃ at 100 ppm sprayed (35 & 45 DAP) plants significantly recorded more number of umbel per plant (6.46), seed set (77.0 per cent), seed yield per umbel (0.750 g) and seed yield plant⁻¹ (3.233 g) in onion.

Manjunath *et al.* (2008) noticed that the GA₃ 25 ppm sprayed at 2-4 leaf stage (22-25 days after sowing) significantly increased number of fruits per vine (1.49), number of seeds per fruit (374), seed yield per fruit (34.26 g) and seed yield per vein (52.93 g) compared to control in pumpkin cv. Arka Chandan.

Patil *et al.* (2008) reported that the okra seeds soaking in 100 ppm Gibberlic acid solution for 24 hours gave more the number of pods plant⁻¹ (12.97), number of seeds per pod (54.22), pod length (14.11 cm) seed yield per plant (37.418 g), seed yield per plot (1.220 kg) and seed yield per ha (27.74 q) compared to untreated seeds.

Hilli *et al.* (2010) found that the application of RDF 50:50:50 kg NPK ha⁻¹ + GA₃ 50 ppm treatment significantly increased number of fruits vine⁻¹ (5.60) and fruit yield (2.58 kg ha⁻¹) in ridge gourd.

Mohammad *et al.* (2010) reported that the GA₃ applied at concentration of 250 mg per liter had positive effect on total seed yield especially in the treatment soaking + foliar spray in onion. Waghmode *et al.* (2010) revealed that the spray of Gibberlic acid @100ppm initiate early flower stalks and considerably more seed yield (7.35q ha⁻¹) in onion.

Ghonomie *et al.* (2011) summarized that GA₃ root dipping in carrot for different duration and concentration before planting them for seed production. Root dipping in GA₃ at 400 ppm for 5 seconds significantly recorded higher umbel No.order⁻¹ 2nd, 3rd (8.95 and 13.80) and seed yield order⁻¹ (14.01 g, 16.39 g and 11.79 g, respectively).

Priya *et al.* (2012) showed that the GA₃ at 50 ppm sprayed before flower initiation and at the time of fruit initiation stage recorded significantly more fruit length (13.22 cm), fruit girth (1.24 cm), fruit weight per plant (61.63 g), seed weight per fruit (0.29 g), number of seeds per fruit (65.00 g) and seed yield per plant (8.53 g) in chilli.

Sillu *et al.* (2012) reported that the application of GA₃ at 50 ppm spray gave significantly higher length of main shoot at 30, 45, 60, 75 and 90 DAS (20.26, 36.39, 45.42, 56.67 and 59.50 cm, respectively) and took less days for physiological maturity (84.33 days) compared to control in potato.

Muhammad *et al.* (2013b) noticed that the RDF 125: 75 and 65 kg NPK ha⁻¹ + 100 ppm GA₃ foliar application significantly increased number of pods plant⁻¹ (7.61), pod length (8.7cm) and pod dry weight (0.9 g) in okra.

Shirzad *et al.* (2013) concluded that the application of 100:100:100 kg NPK ha⁻¹ + GA₃ 75 mg per liter solutions were applied at the 4 true leaf stage at 3 times. This treatment gave more seed yield fruit⁻¹ (55.29 g) in pumpkin.

Deepika (2014) recorded maximum number of siliqua per plant (304), siliqua length (5.09 cm), number of seeds per siliqua (5.19), seed yield per plant (6.52 g) and seed yield per hectare (174.81 kg) in radish cv. Arka Nishanth.

2.2.4 Effect of GA₃ on seed quality parameters

Harrington (1960) reported that GA₃ spray on growing plants of lettuce had no effect on germination of the resulting seed. The carrot plants received a foliar spray of GA₃ (250 ppm) produced higher per cent (98.0) of filled seed and germination.

Increased percentage of germination in seeds treated with GA₃ in winter annuals (Bankar, 1980) significantly higher seed germination percentage and shoot length were recorded with foliar spray of GA₃ (25 ppm) in tomato over control (Balakumar and Balasubramanian, 1988).

Agwah *et al.* (1994) reported higher per cent germination of harvested seeds treated with GA₃ (100 ppm) in onion cv. Giza improved. Bhat and Singh (1996) reported that GA₃ application @ 200 ppm to okra seed crop recorded highest germination (79.90 %) and seed vigour (6.41).

Kutijabi (2007) observed that the foliar spray of GA₃ (200 ppm) at flower initiation stage resulted in significantly higher 1000 seed weight (4.75 g), germination (86.94 %), speed of germination (22.37), root length (8.80 cm), shoot length (8.80 cm), vigour index (1512) and seedling dry weight (11.83mg) over control (3.13 g, 83.12 %, 21.33, 7.88 cm, 7.80 cm, 1259 and 11.19 mg, respectively) in carrot.

Panda *et al.* (2007) found that the GA₃ (100 ppm) application at 45 and 60 DAS recorded significantly higher test weight (15.90 g) and less moisture content (7.29 %) was observed in coriander compared to control (11.00 g and 13.15 % respectively).

Geetharani *et al.* (2008) showed that foliar application of GA₃ (100 ppm) at 35 & 45 days after planting recorded significantly more per cent germination (90.0 %), root length (6.3 cm), shoot length (8.7 cm), seedling dry weight (15.5 mg), vigour index (1350) and protein content (18.9 per cent) in onion.

Patil *et al.* (2008) reported that the seeds soaking in 50 ppm GA₃ solution for 24 hours gave maximum 1000 seed weight (53.10 g) compared to untreated seeds (without soaking) (51.60 g) in okra cv. Prabhani Kranti.

Ghonaime *et al.* (2011) conducted an experiment on GA₃ root dipping in carrot for different duration and concentration before planting them for seed production. Root dipping in GA₃ at 400 ppm for 5 seconds resulted with significantly higher weight of 100 seed (0.26 g), plumule length (51.70 mm), radical length (80.35 mm), seedling fresh weight (26.85 mg) and seedling dry weight (8.90 mg).

Priya *et al.* (2012) stated that the GA₃ at 50 ppm sprayed before flower initiation and at the time of fruit initiation stage recorded significantly maximum 100 seed weight (0.66 g), seed germination (81.16 %), seedling vigour index (1347), seedling dry weight (0.30 g) and lowest electrical conductivity (0.84 dSm⁻¹) compared to control (0.50 g, 77.18 %, 1216, 0.26 g and 0.88 dSm⁻¹) in chilli hybrid HCH-9646.

Shirzad *et al.* (2013) revealed that the application of GA₃ (75 ppm) at 4 true leaf stage for 3 times gave maximum 1000 seed weight (143.5 g) in Pumpkin.

Deepika (2014) reported maximum test weight (9.36 g), germination per cent (89.28 %), mean seedling length (19.50 cm), mean seedling dry weight (4.71 mg) and seedling vigour index (1750) in radish with the application of GA₃ 120 ppm.

2.3 Effect of naphthalene acetic acid on growth, root and seed yield of radish

NAA i.e. alpha - Naphthalene acetic acid, belongs to the auxin group of growth regulators. It is a synthetic auxin, reactivity of the naphthalene acetic acid was first observed by Zimmerman *et al.* (1936).

Auxins are essential for enlargement and development of ovary into a fruit. Actually auxins are synthesized in the shoot and root apices and transported through the plant axis. They are characterized principally by their capacity to stimulate stem elongation in excised stem and coleoptile section, but also influence a host of other development responses, including root initiation, vascular differentiation, tropic responses and the development of auxilliary buds, flowers and fruits.

2.3.1 Effect of NAA on growth parameters

Chhonkar and Singh (1959) reported that NAA (40 ppm) treatment at seedling stage increased height and number of branches in tomato. Chauhan and Singh (1972) found that significant increase in leaf area with application of 40 ppm NAA in capsicum.

Chattopadhyya and Sen (1974) reported that spraying of 70 ppm NAA at pre bloom stage not only increased short styled flowers of chilli but also increased the per cent fruit set (51.92 %) compared to water spray (32.92 %). Chandra *et al.* (1976) recorded higher dry matter accumulation (6.75 g / plant) in capsicum plants sprayed with 10 ppm Planofix at flower initiation and peak flowering stage than in control (5.60 g / plant).

Pandita *et al.* (1980) reported that spraying of 10 ppm NAA at flowering stage and three weeks later produced significantly more plant height (62.12 cm) over water

spray (49.46 cm) in chilli. Barholia *et al.* (1982) reported that the foliar application of NAA at 20 ppm increased the plant height in chilli.

Deshpande (1983) in pigeonpea noticed that the seeds obtained from spray of 60 ppm NAA recorded maximum 100 seed weight, field emergence, germination percentage and minimum electrical conductivity indicating the better seed quality as compared to control.

Maurya and Lal (1987) reported that, chilli plants sprayed with NAA (150ppm) at flowering and 15 days interval for three times recorded the highest plant height (63.05 cm) while the lower plant height (49.16 cm) was observed in water spray.

Doddamani (1988) also recorded increased plant height of chilli crop with 20 ppm NAA spray at pre-bloom stage over unsprayed plants. Hulamani (1988) recorded significantly higher plant height in chilli variety Byadagi with the application of 20 ppm NAA along with 2 per cent urea over control under Dharwad conditions.

There was an increase in plant height, number of branches, stem diameter of capsicum plants after spraying with NAA at 50 or 100 ppm (Dod *et al.*, 1989). Katwale and Saraf (1990) noticed significant increase in plant height with all the concentrations of NAA (25-75 ppm) over control in chilli.

Singh *et al.* (1990) stated that spraying of NAA at 10 ppm at 40 and 60 days after transplanting recorded higher number of branches per plant (10.0) against water spray (8.9) in chilli. Nandekar and Sawarkar (1992) opined that application of NAA (40 ppm) gave highest number of leaves per plant as compared to control in onion.

Lata and Singh (1993) sprayed NAA (20, 40 and 60 ppm) at 30 and 60 days after transplanting and observed that the fruit set was higher (42.75%) with 40 ppm NAA and beyond this concentration; the fruit set percentage reduced drastically in chilli.

Shashank Singh *et al.* (1995) recorded increased plant height, number and size of leaves in onion with NAA (300 ppm). Similar results were also reported in radish with

NAA (150 ppm) spray at bolting (Sharma, 1995). Significantly increased dry weight was also reported with NAA (100 ppm) in onion (Padmavati, 1998).

According to Arun et al. (1997) spray of GA₃ at 200 ppm resulted in highest plant height followed by seed soaking with GA₃ at 15 ppm in brinjal cv. Pusa purple long.

Shukla *et al.* (1997) obtained increased plant height (52.7 cm), number of branches per plant (4.93), pods per plant (57.2), pod weight per plant (16.7 g) and seed yield (1686.6 g) over control by spraying NAA (40 ppm) in soybean.

In an experiment two sprays of NAA at 10 ppm with two varieties of chilli (NP-46A and Pusa jwala) at flowering and three weeks later, produced better growth and increased plant height (Pandita *et al.*, 1980).

Goudappalavar (2000) reported significantly higher plant height (115.7 cm) with NAA 100 ppm sprayed at 50 per cent flowering stage as compared to control (70.6 cm) in tomato. Manoj *et al.* (2011) revealed that vegetative growth parameters such as plant height (58.43 cm), number of branches per plant (82.65) and number of leaves per plant (998.72) were found maximum with NAA at 75 ppm in chilli.

Moresh *et al.* (2011) observed that application of NAA at 40 ppm recorded the maximum plant height (34, 51.86, 63.00 cm) and number of branches per plant (8.40, 12.33, 14.26) at 30, 60, 90 DAT, respectively in chilli and minimum was found under control.

2.3.2 Effect of NAA on yield and yield parameters

Mathur (1971) reported that the foliar application of NAA 300 ppm (at two weeks interval) significantly increased the fresh weight of leaves as compared to other treatments in onion genotypes.

Chandra and Shivaraj (1972) reported that chilli plants sprayed with NAA (10 ppm) at 25 and 50 days after transplanting produced more number of fruits

per plant (176.80). Whereas, water sprayed plants produced less (76.00) of fruits per plant.

Raghuveer and Shivaraj (1973) recorded higher production of fruits in chillies when planofix, fruitofix and fixox were given as seed treatment, or as sprays at pre - bloom and full bloom stages. Chattopadhyaya and Sen (1974) sprayed 50 and 75 ppm NAA at prebloom stage and observed the higher fruit length (4.00 cm) by application of 50 ppm NAA in chilli.

Application of planofix (NAA) either as seed treatment or spray at early stages of growth induced early flowering in chilli (Chandramony and George, 1976).

Spraying of NAA at 10 ppm once at flower initiation stage and 15 days later, increased the yield of chillies to an extent of 20 per cent (Chandra *et al.* 1976). According to Warade and Singh (1977) the volume of the fruit increased against control significantly due to the application of NAA at 100, 200 and 300 ppm as seed treatment and foliar spray during 4th to 6th leaf stage, bud stage and bloom stage in chilli.

Pandita *et al.* (1980) obtained increased yield (70.49 and 107.98 q per ha respectively) in chilli cv. pusa Jwala and NP-46A when they were sprayed with 10 ppm of planofix once during flowering and again after 3 weeks.

Sharma *et al.* (1980) reported that when planofix (NAA) was applied to capsicum cultivars NP-46A at 10, 20, 30 or 40 ppm after 25, 50 or 75 days of transplanting, maximum fruitset (80%) was obtained with 10 ppm when sprayed 25 'days after transplanting.

Sinha and Pal (1980) reported that when planofix 40 ppm, ethrel and CCC 100 ppm were applied to capsicum plants at flowering and 10 days after transplanting respectively, only planofix resulted in the maximum productivity (464.6 g / plant) as compared to control (280.6 g / plant).

Singh *et al.* (1983) reported that the application of NAA 40 ppm improved the weight of the green leaves per plant and length of leaves significantly when applied as root treatment for five old onion seedlings for 24 hours.

Hariharan and Unnikrishnan (1983) observed the formation of larger fruits due to application of 30 and 50 ppm NAA treatments over control. According to Patil *et al.* (1985) the increased number of fruits per plant in chilli was observed with NAA at 20 ppm sprayed thrice at the time of flowering followed by two sprays at an interval of 30 days.

Sarmah and Dey (1986) observed that seed yield was increased when one of three NAA formulations (Bardhak, planofix and selmen) or 5g per liter of trace element mixture was applied to soybean compared to control.

Hulmani (1988) obtained significantly increased mean fruit length (9.07 cm) of chilli by spraying of NAA 20 ppm at 40 and 60 days after transplanting as against water spray (8.21 cm) in chilli. Increased fruit size due to NAA application was ascribed to its involvement in high rate of cell-division and cell-elongation or both and also due to translocation of metabolites from source to sink.

Lata and Singh (1993) reported that foliar spray of NAA (20 - 60 ppm) at 30 and 60 days after transplanting recorded higher number of fruit per plant (155) as compared to the water spray (120) in chilli.

Revanappa (1993) noticed that foliar spray of NAA at 10 and 40 ppm recorded maximum fruit girth of 1.43 and 1.49 cm respectively as compared to the water spray in chilli.

Gedam *et al.* (1996) stated that the number of seeds per fruit (340) and seed yield per ha (789.3 kg) increased significantly due to spraying of NAA 50 ppm compared to control (184 and 459.4 kg) in onion and bitter gourd respectively.

Singh and Gulshanlal (1996) reported that 2,4-D at 1 ppm followed by NAA @ 40 ppm showed the best response with respect to fruit set, fruit yield and seed yield in chilli.

Bhople *et al.* (1998) recorded highest seed yield per ha, 1000 seed weight and percentage germination were obtained by spraying plants with 100 ppm NAA in radish cv. Pusa Chetki.

Alagukannan and Vijayalakumar (1999) reported that NAA spray at 20 ppm to fenugreek recorded highest seed yield per plot (390 g) and seed yield per ha (702 kg).

Gollagi (1999) observed increased number of seeds per fruit (85.2) with application of 100 ppm NAA at 45 and 65 DAT against unsprayed plants (63.3) in chilli.

Geetharani *et al.* (2008) conducted an experiment to know the effect of growth regulators on onion seed production. Among the different sprays, spraying of NAA 100 ppm at first flower stalk emergence and second spray at 10 per cent flowering stage (i.e. 35 and 45 DAP) enhanced seed recovery and yield by 22.7 per cent.

Moresh *et al.* (2011) revealed that the maximum length of fruit (9.65 cm), girth (3.14 cm), number of fruits per plant (68.53), highest fresh weight (25.36 g), dry weight (8.01 g), number of fruits per plot (2308.80), yield per plot (2.93 kg), yield per hectare (30.13 q) and seed yield per plant (10.55 g) in chilli were recorded with foliar application of NAA at 40 ppm.

Manoj *et al.* (2011) recorded the maximum length of fruit (5.64 cm), yield of green fruits (68.49 q/ha) and yield of dry fruits (6.74 q / ha) with NAA 75 ppm in chilli.

2.3.2 Effect of NAA on quality parameters

Deshpande (1983) reported that in pigeonpea cultivars, the seeds obtained from foliar spray of TIBA 50 ppm and NAA 50 ppm recorded higher 100 seed weight, field emergence, germination percentage and reduced EC values compared to control (water spray).

Singh and Gulshanlal (1996) sprayed NAA (10 to 80 ppm) at 40 and 60 days after transplanting and reported that higher (66.1 %) seed germination in chilli was recorded with 20 ppm NAA compared to water spray (56.1 %).

Gedam *et al.* (1996) recorded significantly higher number of seeds (27.41 / fruit), 100 seed weight (21.42 g), germination (68.00 %) and vigour index (2111) with foliar spray of NAA 100 ppm as compared to control (26.25, 30.12 g, 63.0 % and 1975, respectively) in bitter gourd.

Yoganand (2001) reported that the higher germination (67.64 %) root length (5.01 cm) and shoot length (6.75 cm) were obtained when sprayed chilli plants with 40 ppm NAA as against control (64.91 %, 4.25 cm and 5.22 cm, respectively).

Geetharani *et al.* (2008) reported that improvement of seed germination and vigour index due to NAA over control was 16 and 55 per cent respectively, followed by GA₃ 100 ppm which was found to be the next best treatment. Moresh *et al.* (2011) recorded maximum 1000 seed weight (6.03 g) with foliar application of NAA at 40 ppm in chilli.

2.4. Economic studies

2.4.1. Economics of spacing and growth regulators in radish

Surendra *et al.* (2006) reported that foliar application of GA₃ 50 ppm gave maximum gross return (112140 ₹ / ha), net return (93481 ₹ / ha) and higher B : C ratio (5.00) in okra.

Singh *et al.* (2009) carried out 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.

Patil and Patel (2010) observed that application of NAA 10 ppm was found to be more profitable as compared to GA₃ treatments in okra.

Dawuda *et al.* (2011) reported that in carrot, the maximum income (₹ 7144.9) and profit (₹ 4972.1) were recorded at closer spacing (20 × 5 cm). Whereas, minimum income and profit (₹ 5689.1 and ₹ 3394.3 respectively) were noticed with wider spacing (30 × 5 cm).

Kabir *et al.* (2013) revealed that highest (2.95) benefit cost ratio was observed in closer spacing (20 × 10 cm). While, lowest (-0.03) was noticed with 25 × 15 cm spacing in carrot.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation on “Effect of plant geometry and growth regulators on growth, root and seed 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 2014 to March 2015. The details of the material used and methods adopted during the course of investigations are presented below.

3.1 Geographical location of the experimental site

Mudigere is situated in Hilly region (Zone - 9) of Western Ghats in Karnataka state at 13⁰25' N latitude and 75⁰ 57' E longitude at an altitude of 982 m above mean sea level.

3.2 Climate

The average maximum and minimum temperature, relative humidity and rainfall of the area during the period of experimentation are furnished in the Appendix - I. The meteorological data recorded at the meteorological observatory, Zonal Agricultural and Horticultural Research Station (ZAHRS), Mudigere.

3.3 Soil

The soil of the experimental site was having the pH of 5.39. Composite soil samples were collected from experimental site up to a depth of 30 cm and analysed for chemical properties. The results are presented in Appendix - II.

3.4 Source of seed

Seeds of radish cv. Pusa Chetki were obtained from IARI, New Delhi.

3.5 Experimental details

3.5.1 Design and Layout of experiment

The experiment was laid out in open field with factorial randomized complete block design (FRCBD). There were three replications in the experiment. The treatments in each replication were allotted randomly based on random number table according to definite laws of probability. The plan of layout of the experiment is given in figure.1 and general view of experimental plot at vegetative stage is depicted in plate. 1.

The experimental details:

Location	:	College of Horticulture, Mudigere
Crop	:	Radish
Variety	:	Pusa Chetki
Statistical design	:	Factorial randomized complete block design (FRCBD)
Date of sowing	:	5- November -2014
Treatments	:	10
Number of replications	:	03
Gross plot	:	3 m × 2 m (6 m ²)

Treatments details:

Factor I – Spacing (S)

S₁ – 30 × 30 cm

S₂ – 45 × 45 cm

Factor II – Growth regulators (G)

G₁ - GA₃ 200 ppm

G₂ - GA₃ 250 ppm

G₃ - NAA 200 ppm

G₄ - NAA 250 ppm

G₅ - Control

Treatment combinations

Treatment	Spacings (cm)	Growth Regulators
S ₁ G ₁	30 × 30	GA ₃ 200 ppm
S ₁ G ₂	30 × 30	GA ₃ 250 ppm
S ₁ G ₃	30 × 30	NAA 200 ppm
S ₁ G ₄	30 × 30	NAA 250 ppm
S ₁ G ₅	30 × 30	Control
S ₂ G ₁	45 × 45	GA ₃ 200 ppm
S ₂ G ₂	45 × 45	GA ₃ 250 ppm
S ₂ G ₃	45 × 45	NAA 200 ppm
S ₂ G ₄	45 × 45	NAA 250 ppm
S ₂ G ₅	45 × 45	Control

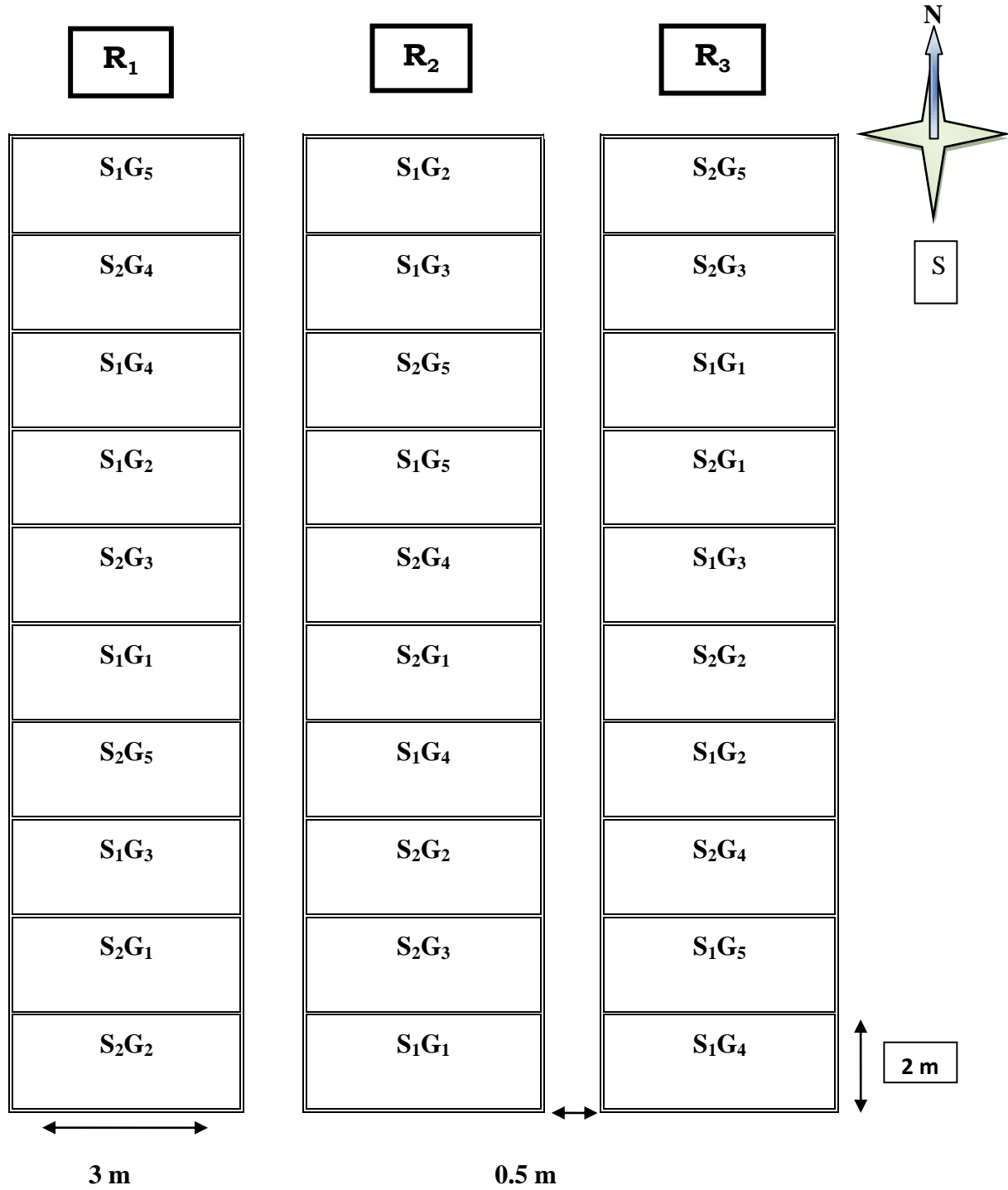


Fig. 1. Plan and layout of the experimental plot



Plate 1. General view of the experimental plot at vegetative stage

3.6. General description of radish cv. Pusa Chetki

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.

3.7 Cultural practices

3.7.1 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.

3.7.2 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.

3.7.3 Fertilizer application

The crop was fertilized with nitrogen, phosphorus and potassium at 75: 38: 38 kg ha⁻¹ 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 in two split doses at the time of pre-flowering and flowering.

3.7.4 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 treatments (30 × 30 cm and 45 × 45 cm). Thinning was done at 20 days after sowing by retaining one seedling per hill.

3.7.5 Intercultivation

The crop needs earthing-up at least twice to the seed crop 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 seen to keep the plot clean and free from weeds competition.

3.7.6 Irrigation

Protective irrigations were given at 5-7 days interval throughout the cropping period of seed production.

3.7.7 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. Mustard sawfly and aphids were observed during the crop growth period. Mustard sawfly was managed by spraying of chloropyriphos @ 2 ml / lit and imidachloprid @ 0.3 ml/lit was used for control aphid population.

3.7.8 Harvesting

The crop was harvested at physiological maturity stage based on visual observations (pods are turn to brown and yellow tinge). The harvested pods from each treatment and replication were sun dried separately and threshed each manually by beating with wooden sticks. The seeds were cleaned and sun dried to reduce moisture content to optimum level.

3.8 Collection of experimental data

3.8.1 Selection of plants

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

3.8.2 Morphological parameters

Observations on growth parameters such as plant height, number of leaves, leaf length, leaf width, spread of the plant, fresh weight and dry weight of leaves were recorded at 40, 80 and 120 days after sowing.

3.8.2.1 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.

3.8.2.2 Number of leaves

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

3.8.2.3 Leaf length

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

3.8.2.4 Leaf width

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

3.8.2.5 Spread of the plant

The plant spread was measured in both East-West and North-South directions and the distance were multiplied and the mean was expressed as plant spread in square centimeters.

3.8.2.6 Number of branches per plant

The number of branches arises from the main stem were counted from the earlier tagged plants and recorded at 50 per cent flowering and expressed in numbers.

3.8.2.7 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.

3.8.2.8 Fresh weight of leaves

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

3.8.2.9 Dry weight of leaves

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

3.8.2.10 Fresh weight of stem

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

3.8.2.11 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.

3.8.3 Growth parameters

3.8.3.1 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 leaf area meter (LAI-2000, LICOR) and was expressed as square centimeters per plant.

3.8.3.2 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).

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

3.8.3.3 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).

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

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

3.8.3.4 Crop Growth Rate (CGR)

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

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

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

3.8.3.5 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 / dm² / day.

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

Where,

L₁ and W₁ = Leaf area (cm²) and total dry weight of the plant (g) respectively at time t₁.

L₂ and W₂ = Leaf area (cm²) and total dry weight of the plant (g) respectively at time t₂.

t₂ - t₁ = time interval between two stages.

3.8.4. Root parameters

3.8.4.1 Root length

The length of the root was measured in five randomly selected plants at 40, 80 and 120 DAS from the base of the root to top of the root and average root length was expressed in centimeters.

3.8.4.2 Root girth

The girth of five roots selected randomly at 40, 80 and 120 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.

3.8.4.3 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.

3.8.4.4 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.

3.8.4.5 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

3.8.4.6 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,

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

3.8.5 Biochemical parameters

3.8.5.1 Chlorophyll content in leaves

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

Chlorophyll-‘a’, Chlorophyll-‘b’ and total chlorophyll content of leaf tissue were determined by using dimethyl sulfoxide (DMSO) as suggested by Shaof and Lium (1976). Fresh 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- vis double beam spectro 1203).

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)

3.8.6 Seed yield parameters

3.8.6.1 Days to 50 per cent flowering

The days required for attaining 50 per cent flowering was judged when the 50 per cent of the total number of plants in each treatment initiated flowering.

3.8.6.2 Number of siliqua per plant

The numbers of siliqua in five tagged plants were counted and average worked out and expressed in number.

3.8.6.3 Pod weight per plant

The siliqua obtained in each of the five earlier tagged plants from each plot were dried under sunlight. The total pod weight obtained from each plant was recorded in grams. The average was calculated and expressed as pod yield in gram per plant.

3.8.6.4 Length of pod

After harvest of tagged plants, the five siliqua were selected at randomly for recording the length of siliqua. The length of siliqua was measured from tip of siliqua to point of attachment at the base. The mean of five siliqua were computed and expressed in centimeter.

3.8.6.5 Number of seeds per pod

The five siliquas used for measuring length were used for recording the number of seeds per siliqua. The seeds from each siliqua separated manually by hand and counted. The average number of five siliquas from five plants was calculated and expressed in numbers per pod.

3.8.6.6 Seed yield per plant

The seeds were separated from the siliqua of five earlier randomly tagged plants. The weight of seeds from each plant was recorded carefully with the help of electronic balance. The average of five plants seed yield were computed and expressed in grams per plant.

3.8.6.7 Seed yield per plot

The siliqua obtained from each treatment and replication, threshed separately, recorded the seed yield per plot and expresses as seed yield per plot in kilograms.

3.8.6.8 Seed yield per ha

The seeds separated from the siliqua of net plot were weighed using electronic balance and converted to seed yield per hectare in quintals.

3.8.7 Seed quality parameters

3.8.7.1. Test weight

Thousand seeds were counted manually from a sample drawn randomly from each treatment in four replications and weighed as per the procedure given by ISTA

(Anon, 2007). The mean weight of the sample was recorded as thousand seed weight and expressed in grams.

3.8.7.2 Seed germination per cent

The germination test was conducted in the laboratory by using blotter paper methods as per ISTA (Anon., 2007). Hundred seeds in four replicates were placed on germination paper and rolled towels were incubated in germination chamber maintained at $26 \pm 1^\circ\text{C}$ and 90 per cent relative humidity. The germinated seedlings were evaluated on fourth and tenth day as first and final count, respectively and per cent germination was expressed based on normal seedlings.

3.8.7.3 Seedling length

From the standard germination test, ten normal seedlings from each replication as per treatment were randomly selected on the day of final count. The length of shoot and root was measured and expressed in centimetres.

3.8.7.4 Seedling dry weight

Ten seedlings randomly selected for shoot and root length were dried in hot air oven maintained at 110°C for 17 hours, then cooled in a desiccators and mean seedling dry weight was recorded and expressed in milligrams.

3.8.7.5 Seedling vigour index

The vigour index was determined by multiplying the percentage germination with the mean shoot and root length in centimeters (Abdul Baki and Anderson, 1973).

$$\text{Vigour index} = \text{Germination percentage} \times \text{Seedling length.}$$

3.8.8 Economics

In order to assess the effects of each treatment with the combination of growth regulators, the cost of cultivation was worked out. This included the cost of growth regulators (GA_3 and NAA) and the cost of fertilizers, FYM, was taken at the current

existing rates. The labour cost, including fertilizer application, irrigation and plant protection, weeding *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- III and IV). 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.

3.8.8.1 Cost of cultivation

The prices 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.

3.8.8.2 Gross return

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

3.8.8.3 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.

3.8.8.4 Benefit : cost ratio

$$\text{Benefit: Cost Ratio} = \frac{\text{Net return (₹ / ha)}}{\text{Cost of cultivation (₹ / ha)}}$$

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 Sunderaraju *et al.* (1972) for factorial randomized complete block design. The test of significance (F-test) and critical difference (CD) were made at 0.05 probability.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

A field experiment was conducted at College of Horticulture, Mudigere during the year 2014-15 in *rabi* season on “Effect of plant geometry and growth regulators on growth, root and seed yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki”. The results obtained in the present investigation with respect to growth, yield and quality parameters are presented in this chapter.

4.1 Morphological parameters

4.1.1 Plant height

The data on plant height as influenced by spacing and growth regulators recorded at 40, 80 and 120 days after sowing (DAS) are presented in Table 1. Plant height of radish varied significantly among different spacing and growth regulators treatments at all stages of plant growth.

The plant height at 40 days after sowing recorded significantly maximum (33.73 cm) at 45 × 45 cm spacing (S_2). While, minimum plant height (27.19 cm) was recorded at 30 × 30 cm (S_1) spacing. Plant height at 80 days after sowing showed significant differences among different spacing. The plants sown at 45 × 45 cm (S_2) spacing recorded maximum plant height (73.81 cm), while minimum plant height (67.98 cm) was recorded at 30 × 30 cm (S_1) spacing. At 120 days after sowing, plant height varied significantly due to the influence of different levels of spacing. At 45 × 45 cm (S_2) spacing recorded significantly highest plant height (75.47 cm), whereas the lowest plant height (70.03 cm) was recorded in 30 × 30 cm (S_1) spacing (plate. 2).

The plant height differed significantly with respect to different growth regulator treatments. At 40 days after sowing, the maximum (35.73 cm) plant height was found at GA_3 250 ppm (G_2) and it was followed by GA_3 200 ppm (G_1) (33.47cm). Whereas, minimum plant height (22.83 cm) was recorded in control (G_5). Plant height at 80 days after sowing varied significantly among different growth regulator treatments. The result shows that maximum plant height (77.12 cm) was recorded in GA_3 250 ppm. While, minimum plant height (61.83 cm) was recorded in control. The plant height at 120 days

Table 1. Effect of spacing and growth regulators on plant height at different intervals in radish cv. Pusa Chetki

Growth regulators	Plant height (cm)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	28.93	38.00	33.47	70.80	77.23	74.02	72.80	80.77	76.78
G ₂ - GA ₃ 250 ppm	31.80	39.67	35.73	71.67	82.57	77.12	73.93	85.53	79.73
G ₃ - NAA 200 ppm	24.97	32.33	28.65	66.93	72.10	69.52	68.67	75.60	71.83
G ₄ - NAA 250 ppm	27.90	35.33	31.62	69.50	74.50	72.00	71.73	77.17	74.45
G ₅ – Control	22.33	23.37	22.83	61.00	62.67	61.83	63.00	64.67	63.83
Mean	27.19	33.73	30.46	67.98	73.81	70.89	70.03	75.47	73.33
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.98		2.91	1.83		5.45	1.95		5.79
Growth regulators (G)	1.55		4.62	2.90		8.61	3.08		9.16
Interaction (S x G)	2.19		6.51	4.10		12.18	4.36		12.95

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.



45 × 45 cm + GA₃ 250 ppm



30 × 30 cm + control

Plate 2. Influence of spacing and growth regulators on plant height

after sowing varied significantly among different growth regulator treatments. The results indicated that maximum plant height (79.73 cm) was recorded in GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (76.78 cm) and are statistically on par each other. While, minimum plant height (63.83 cm) was recorded in control (G₅).

The interaction effect of spacing and growth regulators on plant height was significant at 40, 80 and 120 days after sowing (DAS). The treatment combination 45 x 45 cm spacing and GA₃ 250 ppm (S₂G₂) recorded maximum plant height (39.67, 82.57 and 85.53 cm) at 40, 80 and 120 DAS respectively, while minimum plant height (22.33, 61.00 and 63.00 cm) was noticed in S₁G₁ (control) treatment combination.

4.1.2 Number of leaves per plant

The data pertaining to number of leaves per plant are presented in Table 2. Leaf production varied significantly at all stages of plant growth with respect to spacing and growth regulators.

The number of leaves per plant differed significantly among the different spacing at 40 days after sowing. Significantly more number of leaves per plant (14.22) was observed at wider spacing (45 × 45 cm). While, less number of leaves per plant (10.87) was found at narrow spacing (30 × 30 cm). The number of leaves per plant at 80 days after sowing showed significant differences among different spacing. The plants sown at 45 × 45 cm (S₁) spacing recorded more number of leaves per plant (19.37). While, less number of leaves per plant (15.07) was registered at 30 x 30 cm (S₁) spacing. At 120 days after sowing, number of leaves per plant varied significantly among different spacing. At 45 × 45 cm (S₂) spacing recorded significantly highest number of leaves per plant (20.05), whereas the lowest number of leaves per plant (14.71) was recorded in 30 × 30 cm (S₁) spacing.

The number of leaves per plant differed significantly at different concentration of growth regulator treatments. At 40 days after sowing, the number of leaves per plant was found to be maximum (15.10) at GA₃ 250ppm (G₂) which was statistically on par with number of leaves per plant (13.72) at GA₃ 200 ppm (G₁). Whereas, minimum number of

Table 2. Effect of spacing and growth regulators on number of leaves per plant at different intervals in radish cv. Pusa Chetki

Growth regulators	Number of leaves per plant								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	11.83	15.60	13.72	17.50	21.93	19.72	17.00	22.67	19.83
G ₂ - GA ₃ 250 ppm	12.50	17.70	15.10	18.60	23.83	21.22	18.27	24.43	21.35
G ₃ - NAA 200 ppm	10.43	13.57	12.00	13.33	19.17	16.25	13.00	19.83	16.42
G ₄ - NAA 250 ppm	10.83	14.23	12.53	15.10	19.93	17.52	14.77	20.67	17.72
G ₅ – Control	8.77	10.00	9.38	10.83	12.00	11.42	10.50	12.67	11.58
Mean	10.87	14.22	12.54	15.07	19.37	17.22	14.71	20.05	17.38
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.38		1.12	0.52		1.53	0.52		1.55
Growth regulators (G)	0.60		1.77	0.82		2.43	0.82		2.45
Interaction (S x G)	0.84		2.50	1.15		3.43	1.16		3.46

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

leaves per plant (9.38) was recorded at control (G_5). The number of leaves per plant at 80 days after sowing varied significantly among different growth regulator treatments. The results noticed that higher number of leaves per plant (21.22) was recorded in GA_3 250 ppm. While, lower number of leaves per plant (11.42) was recorded in control. The number of leaves per plant at 120 days after sowing varied significantly among different growth regulators. The results indicated that maximum number of leaves per plant (21.35) was recorded in GA_3 250 ppm (G_2) followed by GA_3 200 ppm (G_1) (19.83). While, minimum number of leaves per plant (11.58) was recorded in control (G_5).

The interaction effect between spacing and growth regulators differed significantly on production of more number of leaves per plant at 40, 80 and 120 DAS. At 40 DAS, maximum number of leaves per plant (17.70) was observed in S_2G_2 treatment combination and the minimum (8.77) numbers of leaves per plant was recorded in treatment S_1G_5 (control). Maximum number of leaves per plant (23.83) observed in S_2G_2 treatment combination at 80 DAS and which was found on par with the treatment S_2G_1 (21.93). The minimum (10.83) numbers of leaves per plant was recorded in S_1G_5 treatment combination. At 120 DAS, maximum number of leaves per plant (24.43) was observed in S_2G_2 treatment combination and the minimum (10.50) numbers of leaves per plant was recorded in treatment S_1G_5 (control).

4.1.3 Leaf length

The data pertaining to leaf length are presented in Table 3. Leaf length varied significantly at all stages of plant growth with respect to spacing and growth regulators.

Leaf length increased with wider spacing (45×45 cm). At 40 days after sowing, maximum leaf length (26.23 cm) at 45×45 cm (S_2). While, minimum leaf length (21.15 cm) was recorded at 30×30 cm (S_1) spacing. At 80 DAS, maximum leaf length (34.94 cm) was found at 45×45 cm (S_2) spacing, whereas least leaf length (30.03) was recorded at 30×30 cm (S_1) spacing. At 120 days after sowing, plant height varied significantly due to the influence of different levels of spacing. At 45×45 cm (S_2) spacing recorded significantly highest leaf length (36.43cm), whereas the lowest leaf length (31.20 cm) was recorded in 30×30 cm (S_1) spacing.

The leaf length differed significantly among different growth regulator treatments. At 40 DAS, application GA₃ 250 ppm (G₂) recorded significantly higher (27.42 cm) leaf length which was statistically on par with G₁ (25.42 cm) and G₄ (23.98 cm). Whereas, minimum leaf length (19.03 cm) was recorded in control (G₅). The leaf length at 80 days after sowing varied significantly among different growth regulator treatments. The results registered that maximum leaf length (37.18 cm) was recorded in GA₃ 250 ppm, while minimum leaf length (25.67 cm) was recorded in control. The leaf length at 120 days after sowing varied significantly among different growth regulators. The results indicated that maximum leaf length (39.00 cm) was recorded in GA₃ 250 ppm (G₂) over GA₃ 200 ppm (36.25 cm) (G₁) and it was statistically on par each other. While, minimum leaf length (26.67 cm) was recorded in control (G₅).

The interaction effect of spacing and growth regulators on leaf length was significant at all the stages of plant growth. The treatment combination 45 × 45 cm spacing with GA₃ 250 ppm foliar spray (S₂G₂) recorded maximum leaf length (30.33, 40.37 and 42.67 cm) at 40, 80 and 120 DAS respectively, while minimum leaf length (18.73, 25.50 and 26.33 cm) was noticed in S₁G₁ (control) treatment combination.

4.1.4 Leaf width

The data on leaf width as influenced by spacing and growth regulators recorded at 40, 80 and 120 days after sowing (DAS) are presented in Table 4. The leaf width of radish varied significantly among different spacing and growth regulators treatment.

The leaf width at 40 days after sowing registered significantly maximum of (11.87 cm) at 45 × 45 cm (S₂). While, minimum leaf width (10.22 cm) was recorded at 30 × 30 cm (S₁) spacing. The leaf width at 80 days after sowing showed significant differences among different spacing. The plants sown at 45 × 45 cm (S₂) spacing observed maximum leaf width (14.17 cm). While, minimum leaf width (11.13 cm) was recorded at 30 × 30 cm (S₁) spacing. At 120 days after sowing, maximum leaf width (16.03 cm) was found at 45 × 45 cm (S₂), while least leaf width (13.40 cm) was recorded at 30 × 30 cm (S₁) spacing.

Table 3. Effect of spacing and growth regulators on leaf length at different intervals in radish cv. Pusa Chetki

Growth regulators	Leaf length (cm)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	22.37	28.47	25.42	31.83	38.17	35.00	33.00	39.50	36.25
G ₂ - GA ₃ 250 ppm	24.50	30.33	27.42	34.00	40.37	37.18	35.33	42.67	39.00
G ₃ - NAA 200 ppm	19.40	25.80	22.60	28.83	34.50	31.67	30.00	36.00	33.00
G ₄ - NAA 250 ppm	20.77	27.20	23.98	30.00	35.83	32.92	31.33	37.00	34.17
G ₅ - Control	18.73	19.33	19.03	25.50	25.83	25.67	26.33	27.00	26.67
Mean	21.15	26.23	23.69	30.03	34.94	32.49	31.20	36.43	33.81
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.63		1.87	0.86		2.55	0.93		2.76
Growth regulators (G)	0.99		2.95	0.82		4.03	1.47		4.36
Interaction (S x G)	1.40		4.17	1.92		5.70	2.08		6.17

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

The leaf width of plant differed significantly with respect to different growth regulator treatments. At 40 days after sowing, the leaf width was found to be higher (12.63 cm) at GA₃ 250 ppm (G₂) and it was followed by GA₃ 200 ppm (11.17 cm), which was statistically on par with G₄ (11.08 cm) and G₃ (10.67 cm). Whereas, minimum leaf width (9.67 cm) was recorded at control (G₅). The leaf width at 80 days after sowing varied significantly among different growth regulators. The result observed that maximum leaf width (15.17 cm) was recorded in GA₃ 250 ppm, while minimum leaf width (9.92 cm) was recorded in control. The leaf width at 120 days after sowing varied significantly among different growth regulators. The results showed that maximum leaf width (17.42 cm) was recorded in GA₃ 250 ppm (G₂) over (G₁) GA₃ 200 ppm (15.42) and are statistically on par each other. While, minimum leaf width (11.83 cm) was recorded in control (G₅).

The interaction effect between spacing and growth regulators was significant with respect to leaf width at different intervals after sowing (DAS). At 40 DAS, maximum leaf width (14.33 cm) was observed in S₂G₂ treatment combination and the minimum (9.50 cm) leaf width was recorded in treatment S₁G₅ (control). Maximum leaf width (17.67 cm) observed in S₂G₂ treatment combination at 80 DAS and which was found on par with the treatment S₂G₁ (15.50 cm). The minimum (9.83) leaf width was recorded in S₁G₅ treatment combination. At 120 DAS, maximum leaf width (20.33 cm) was observed in S₂G₂ treatment combination and the minimum (11.67 cm) leaf width was recorded in treatment S₁G₅ (control).

4.1.5 Spread of the plant

The data pertaining to plant spread (North-South and East- West) due to spacing, growth regulators and their interaction are presented in Table 5.

At all the stages of plant growth (40, 80 and 120 DAS), significant variation was observed for plant spread (N-S and E-W) due to spacing. The maximum plant spread (1053.33, 1087.53 and 1099.07 cm²) was recorded in 45 × 45 cm (S₂) at 40, 80 and 120 DAS respectively and minimum (862.73, 902.60 and 926.07 cm²) was observed in 30 × 30 cm (S₁) spacing respectively at 40, 80 and 120 DAS.

Table 4. Effect of spacing and growth regulators on leaf width at different intervals in radish cv. Pusa Chetki

Growth regulators	Leaf width (cm)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	10.50	11.83	11.17	11.67	15.50	13.58	14.17	16.67	15.42
G ₂ - GA ₃ 250 ppm	10.93	14.33	12.63	12.67	17.67	15.17	14.50	20.33	17.42
G ₃ - NAA 200 ppm	9.83	11.50	10.67	10.50	13.33	11.92	13.00	14.83	13.92
G ₄ - NAA 250 ppm	10.33	11.83	11.08	11.00	14.33	12.67	13.67	16.33	15.00
G ₅ - Control	9.50	9.83	9.67	9.83	10.00	9.92	11.67	12.00	11.83
Mean	10.22	11.87	11.04	11.13	14.17	12.65	13.40	16.03	14.71
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	0.29		0.86	0.60		1.78	0.63		1.87
Growth regulators (G)	0.46		1.37	0.95		2.82	1.00		2.96
Interaction (S x G)	0.65		1.93	1.34		3.98	1.41		4.19

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

Spread of the plant varied significantly at all the stages of plant growth due to different growth regulator treatments. At 40 DAS, GA₃ 250 ppm (G₂) was recorded significantly higher plant spread (N-S and E-W) of 1103.67 cm² over control (738.83 cm²) and it was found to be on par with G₁ (1045.83 cm²). Similarly at 80 and 120 DAS, GA₃ 250ppm (G₂) recorded significantly higher plant spread of (1165.50 and 1182.00 cm²) respectively over control (747.67 and 749.83 cm²) and it was found on par with G₁ (1112.83 and 1149.17 cm²) respectively at 80 and 120 DAS. The least plant spread (747.67 and 749.83 cm²) was observed in control (G₅).

The interaction effect of spacing and growth regulators had shown significant difference with respect to plant spread at 40, 80 and 120 DAS. Among the different treatment combination at 40 DAS, S₂G₅ recorded significantly higher plant spread (1194.00 cm²) over other treatment combinations. The least plant spread (736.67 cm²) was noticed in S₁G₅ treatment combination. At 80 DAS, among the different treatment combinations S₂G₂ recorded significantly higher plant spread (1247.33 cm²) over other treatment combinations and which was on par with S₂G₁ (1211.67 cm²), S₂G₄ (1136.67 cm²) and S₁G₂ (1083.67 cm²). The lowest plant spread (743.33cm²) was noticed in S₁G₅ treatment combination. Similarly, at 120 DAS, the treatment combination S₂G₂ recorded significantly higher plant spread (1264.00 cm²) over other treatment combinations and it was on par with S₂G₁ (1218.33 cm²), S₂G₄ (1153.33 cm²), S₂G₃ (1103.33 cm²), and S₁G₂ (1100 cm²). The least plant spread (744.00 cm²) was noticed in S₁G₅ (control) treatment combination.

4.1.6 Number of branches per plant

The data pertaining to number of branches per plant are presented in Table 6. Number of branches per plant varied significantly at all stages of plant growth with respect to spacing and growth regulators.

The number of branches per plant differed significantly among the different spacing at 80 days after sowing. Significantly more number of branches per plant (12.57) was observed at wider spacing (45 × 45 cm). While, less number of branches per plant (8.16) was found at narrow spacing (30 × 30 cm). The number of branches per plant at

Table 5. Effect of spacing and growth regulators on spread of the plant at different intervals in radish cv. Pusa Chetki

Growth regulators	Spread of the plant (cm ²)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	923.33	1168.33	1045.83	1014.00	1211.67	1112.83	1080.00	1218.33	1149.17
G ₂ - GA ₃ 250 ppm	1013.33	1194.00	1103.67	1083.67	1247.33	1165.50	1100.00	1264.00	1182.00
G ₃ - NAA 200 ppm	810.33	1066.67	938.50	825.33	1090.00	957.67	828.67	1103.33	966.00
G ₄ - NAA 250 ppm	830.00	1096.67	963.33	846.67	1136.67	991.67	878.33	1153.33	1015.83
G ₅ - Control	736.67	741.00	738.83	743.33	752.00	747.67	744.00	756.33	749.83
Mean	862.73	1053.33	958.03	902.60	1087.53	995.06	926.07	1099.07	1012.57
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	26.50		78.73	27.13		80.62	27.27		81.02
Growth regulators (G)	41.90		124.49	42.90		127.47	43.12		128.10
Interaction (S x G)	59.25		176.05	60.67		180.27	60.97		181.16

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

120 days after sowing showed significant differences among different spacing. The plants sown at 45×45 cm (S_2) spacing recorded more number of branches per plant (13.71). While, less number of branches per plant (9.39) was observed at 30×30 cm (S_1) spacing.

The number of branches per plant differed significantly at different concentration of growth regulator treatments. At 80 days after sowing, the number of branches per plant was found to be maximum (13.17) at GA_3 250 ppm (G_2) which was statistically on par with number of branches per plant (11.27) at GA_3 200 ppm (G_1). Whereas, minimum number of branches per plant (6.77) was recorded at control (G_5). The number of branches per plant at 120 days after sowing varied significantly among different growth regulator treatments. The results noticed that higher number of branches per plant (14.65) was recorded in GA_3 250 ppm. While, lower number of leaves per plant (7.68) was recorded in control.

The interaction effect of spacing and growth regulators on number of branches per plant was significant at 80, 120 days after sowing. At 80 DAS, maximum number of branches per plant (16.83) was observed in S_2G_2 treatment combination and the minimum (6.53) numbers of branches per plant was recorded in treatment S_1G_5 (control). At 120 DAS, maximum number of branches per plant (18.07) observed in S_2G_2 treatment combination and which was found on par with the treatments S_2G_1 (15.20). The minimum (7.60) numbers of branches per plant was recorded in S_1G_5 treatment combination.

4.1.7 Stem diameter

The data on stem diameter as influenced by spacing and growth regulators recorded at 40, 80 and 120 days after sowing (DAS) are presented in Table 7. The stem diameter of radish varied significantly among different spacing and growth regulators treatments.

The stem diameter at 80 days after sowing registered significantly maximum of (2.87 cm) at 45×45 cm (S_2). While, minimum stem diameter (2.10 cm) was recorded at 30×30 cm (S_1) spacing. At 120 days after sowing, maximum stem diameter (3.00 cm)

Table 6. Effect of spacing and growth regulators on number of branches per pant at different intervals in radish cv. Pusa Chetki

Growth regulators	Number of branches per plant					
	80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	8.53	14.00	11.27	9.68	15.20	12.44
G ₂ - GA ₃ 250 ppm	9.50	16.83	13.17	11.23	18.07	14.65
G ₃ - NAA 200 ppm	8.00	11.83	9.92	9.17	13.10	11.13
G ₄ - NAA 250 ppm	8.23	13.17	10.70	9.29	14.40	11.84
G ₅ - Control	6.53	7.00	6.77	7.60	7.77	7.68
Mean	8.16	12.57	10.36	9.39	13.71	11.55
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	0.47		1.39	0.49		1.45
Growth regulators (G)	0.74		2.20	0.77		2.30
Interaction (S x G)	1.05		3.12	1.09		3.25

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

was found at 45×45 cm (S_2), while least stem diameter (2.22 cm) was recorded at 30×30 cm (S_1) spacing.

The diameter of stem differed significantly with respect to different growth regulator treatments. At 80 days after sowing, stem diameter was found to be higher (2.90 cm) at GA_3 250 ppm (G_2) and it was followed by GA_3 200 ppm (2.72 cm). Whereas, minimum stem diameter (2.08 cm) was recorded at control (G_5). The stem diameter at 120 days after sowing varied significantly among different growth regulators. The result observed that maximum stem diameter (3.00 cm) was recorded in GA_3 250 ppm. While, minimum stem diameter (2.21 cm) was recorded in control.

At 80 and 120 DAS, significant difference was noticed among the interaction with respect the stem diameter. The treatment combination of 45×45 cm spacing with GA_3 250 ppm (S_2G_2) recorded maximum stem diameter (3.57 cm and 3.70 cm) at 80 and 120 DAS respectively. While, the minimum stem diameter (2.07 cm and 2.17 cm) was noticed in S_1G_5 (control) treatment combination at 80 and 120 DAS respectively.

4.1.8 Fresh weight of leaves

The data presented on fresh weight of leaves as influenced by spacing and plant growth regulators at different stages showed significant differences among the different treatments (Table 8). The interaction effects between the spacing and plant growth regulator treatments varied significantly at all stages of plant growth.

The fresh weight of leaves at 40 days after sowing recorded significantly maximum (64.45 g) at 45×45 cm (S_2). While, minimum fresh weight of leaves (51.86 g) was recorded at 30×30 cm (S_1) spacing. Fresh weight of leaves at 80 days after sowing showed significant differences among different spacing. The plants sown at 45×45 cm (S_2) spacing recorded maximum fresh weight of leaves (71.53 g), while minimum fresh weight of leaves (60.36 g) was recorded at 30×30 cm (S_1) spacing. At 120 days after sowing, fresh weight of leaves varied significantly due to the influence of different levels of spacing. At 45×45 cm (S_2) spacing recorded significantly highest fresh weight of

Table 7. Effect of spacing and growth regulators on diameter of the stem at different intervals in radish cv. Pusa Chetki

Growth regulators	Stem diameter (cm)					
	80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	2.17	3.27	2.72	2.23	3.40	2.82
G ₂ - GA ₃ 250 ppm	2.23	3.57	2.90	2.30	3.70	3.00
G ₃ - NAA 200 ppm	1.94	2.59	2.27	2.11	2.74	2.43
G ₄ - NAA 250 ppm	2.08	2.82	2.45	2.23	2.95	2.59
G ₅ – Control	2.07	2.08	2.08	2.17	2.22	2.21
Mean	2.10	2.87	2.49	2.22	3.00	2.61
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.09		0.28	0.10		0.30
Growth regulators (G)	0.15		0.44	0.16		0.47
Interaction (S x G)	0.21		0.62	0.22		0.67

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

leaves (73.98 g), whereas the lowest fresh weight of leaves (63.22 g) was recorded in 30 × 30 cm (S₁) spacing.

The fresh weight of leaves differed significantly with respect to different growth regulator treatments. At 40 days after sowing, the maximum (70.02 g) fresh weight of leaves was found at GA₃ 250 ppm (G₂) and it was followed by GA₃ 200 ppm (G₁) (66.25 g). Whereas, minimum fresh weight of leaves (42.62 g) was recorded in control (G₅). In general, all the treatments showed significantly higher fresh weight of leaves compared to control. Fresh weight of leaves at 80 days after sowing varied significantly among different growth regulator treatments. The results revealed that maximum fresh weight of leaves (77.82 g) were recorded in GA₃ 250 ppm, while minimum fresh weight of leaves (48.62 g) was recorded in control. The leaves fresh weight at 120 days after sowing varied significantly among different growth regulator treatments. The results indicated that maximum fresh weight of leaves (80.47 g) was recorded in GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (76.97 g) and are statistically on par each other. While, minimum fresh weight of leaves (50.62 g) was recorded in control (G₅).

Among the interaction of spacing and growth regulators, significant variation was observed with respect to fresh weight of leaves. At 40 DAS, maximum (76.30 g) and minimum (42.33 g) fresh weight of leaves was recorded in S₂G₂ and S₁G₅ treatment combination respectively. At 80 DAS, maximum fresh weight of leaves (83.70 g) was observed in S₂G₂ treatment combination and the minimum (48.33 g) fresh weight of leaves was recorded in treatment S₁G₅ (control). The maximum fresh weight of leaves (86.27 g) observed in S₂G₂ treatment combination at 120 DAS and which was found on par with the treatment S₂G₁ (80.13 g) and S₂G₄ (76.60 g). The minimum (50.33 g) fresh weight of leaves was recorded in S₁G₅ treatment combination.

4.1.9 Dry weight of leaves

The data with respect to the effect of spacing and growth regulators treatment on dry weight of leaves are presented in Table 9. The dry weight of leaves was found to be significantly influenced by spacing and plant growth regulators at all stages of plant growth.

Table 8. Effect of spacing and growth regulators on fresh weight of leaves at different intervals in radish cv. Pusa Chetki

Growth regulators	Fresh weight of leaves (g)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	61.07	71.43	66.25	70.90	78.03	74.47	73.80	80.13	76.97
G ₂ - GA ₃ 250 ppm	63.73	76.30	70.02	71.93	83.70	77.82	74.67	86.27	80.47
G ₃ - NAA 200 ppm	45.00	64.33	54.67	51.00	72.67	61.83	54.30	76.00	65.15
G ₄ - NAA 250 ppm	47.17	67.30	57.67	59.63	74.33	66.98	63.00	76.60	69.80
G ₅ – Control	42.33	42.90	42.62	48.33	48.90	48.62	50.33	50.90	50.62
Mean	51.86	64.45	58.15	60.36	71.53	65.94	63.22	73.98	68.6
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	1.51		4.49	1.77		5.27	1.86		5.53
Growth regulators (G)	2.39		7.10	2.80		8.33	2.94		8.74
Interaction (S x G)	3.38		10.04	3.97		11.78	4.16		12.36

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

The maximum dry weight of leaves was recorded at 45×45 cm (S_2) spacing as compared to 30×30 cm (S_1) spacing throughout the growth period. At 40 DAS, the dry weight of leaves was found to be maximum (6.48 g) at S_2 spacing (45×45 cm). While, minimum dry weight of leaves (5.24 g) was recorded at S_1 spacing (30×30 cm). At 80 DAS, the dry weight of leaves was found to be maximum (7.24 g) at S_2 spacing (45×45 cm) but minimum dry weight (6.15 g) was recorded at S_1 spacing (30×30 cm). At 120 DAS, the dry weight of leaves was found to be maximum (7.55 g) at S_2 spacing (45×45 cm) and minimum dry weight of leaves (6.59 g) was recorded at S_1 spacing (30×30 cm).

The dry weight of leaves differed significantly with respect to different growth regulator treatments. At 40 DAS, the dry weight of leaves was found to be maximum (7.03 g) at GA_3 250 ppm (G_2), which was on par at GA_3 200 ppm (6.69 g), while minimum dry weight of leaves (4.31g) was recorded in control. At 80 DAS, the dry weight of leaves was found to be maximum (7.92 g) at GA_3 250 ppm (G_2) and it was followed by GA_3 200 ppm (7.60 g). Whereas, minimum dry weight of leaves (4.88 g) was recorded in control. At 120 DAS, the dry weight of leaves was found to be maximum (8.28 g) at GA_3 250 ppm (G_2), which was on par at GA_3 200ppm (7.88 g) but minimum dry weight of leaves (5.12 g) was recorded in control.

At 40, 80 and 120 DAS, significant difference was noticed among the interaction with respect to dry weight of leaves. The treatment combination of 45×45 cm spacing with GA_3 250 ppm (S_2G_2) recorded maximum dry weight of leaves (7.61, 8.47 and 8.77 g) at 40, 80 and 120 DAS respectively. While, the minimum (4.27, 4.83 and 5.03 g) dry weight of leaves was noticed in S_1G_5 (control) treatment combination at 40, 80 and 120 DAS respectively.

4.1.10 Fresh weight of stem

The data presented on fresh weight of stem as influenced by spacing and plant growth regulators at 80 and 120 days after sowing showed significant differences among the different treatments (Table 10). The interaction effects between the spacing and plant growth regulator treatments varied significantly at all stages of plant growth.

Table 9. Effect of spacing and growth regulators on dry weight of leaves at different intervals in radish cv. Pusa Chetki

Growth regulators	Dry weight of leaves (g)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	6.18	7.19	6.69	7.27	7.93	7.60	7.73	8.03	7.88
G ₂ - GA ₃ 250 ppm	6.45	7.61	7.03	7.37	8.47	7.92	7.80	8.77	8.28
G ₃ - NAA 200 ppm	4.53	6.47	5.50	5.20	7.37	6.28	5.73	7.80	6.77
G ₄ - NAA 250 ppm	4.77	6.77	5.77	6.08	7.50	6.79	6.63	7.93	7.28
G ₅ – Control	4.27	4.35	4.31	4.83	4.93	4.88	5.03	5.20	5.12
Mean	5.24	6.48	5.86	6.15	7.24	6.69	6.59	7.55	7.07
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.15		0.45	0.19		0.56	0.19		0.57
Growth regulators (G)	0.24		0.72	0.30		0.89	0.30		0.90
Interaction (S x G)	0.34		1.01	0.42		1.25	0.43		1.27

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

The fresh weight of stem at 80 days after sowing recorded significantly maximum (96.69 g) at 45×45 cm (S_2). While, minimum fresh weight of stem (87.93 g) was recorded at 30×30 cm (S_1) spacing. At 120 days after sowing, fresh weight of stem varied significantly due to the influence of different levels of spacing. At 45×45 cm (S_2) spacing recorded significantly highest fresh weight of stem (118.51 g), whereas the lowest fresh weight of stem (109.57 g) was recorded in 30×30 cm (S_1) spacing.

The fresh weight of stem differed significantly with respect to different growth regulator treatments. At 80 days after sowing, the maximum (102.52 g) fresh weight of stem was found at GA_3 250 ppm (G_2) and it was followed by (G_1) GA_3 200 ppm (98.00 g), which was statistically on par with G_4 (95.72 g) and G_3 (92.73 g). Whereas, minimum fresh weight of stem (72.58 g) was recorded in control (G_5). The stem fresh weight at 120 days after sowing varied significantly among different growth regulator treatments. The results indicated that maximum fresh weight of stem (124.47 g) was recorded in GA_3 250 ppm (G_2) followed by GA_3 200 ppm (120.03 g) and are statistically on par each other. While, minimum fresh weight of stem (92.08 g) was recorded in control (G_5).

Among the interaction of spacing and growth regulators, significant variation was observed with respect to fresh weight of stem. At 80 DAS, maximum (108.70 g) and minimum (69.67 g) fresh weight of stem was recorded in S_2G_2 and S_1G_5 treatment combination respectively. The maximum fresh weight of stem (129.07 g) observed in S_2G_2 treatment combination at 120 DAS and which was on par with the treatment combinations like S_2G_1 (125.57 g), S_2G_4 (123.00 g), S_2G_3 (120.73 g), S_1G_2 (119.87 g), S_1G_1 (114.50 g) and S_1G_3 (111.33 g). The minimum (90.00 g) fresh weight of stem was recorded in S_1G_5 treatment combination.

4.1.11 Dry weight of stem

The data pertaining to dry weight of stem as influenced by spacing and growth regulators recorded at 80 and 120 days after sowing (DAS) are presented in Table 11. The dry weight of stem was found to be significantly influenced by spacing and plant growth regulators at all stages of plant growth.

Table 10. Effect of spacing and growth regulators on fresh weight of stem at different intervals in radish cv. Pusa Chetki

Growth regulators	Fresh weight of stem (g)					
	80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	93.87	102.13	98.00	114.50	125.57	120.03
G ₂ - GA ₃ 250 ppm	96.33	108.70	102.52	119.87	129.07	124.47
G ₃ - NAA 200 ppm	88.00	97.47	92.73	111.33	120.73	116.03
G ₄ - NAA 250 ppm	91.80	99.63	95.72	112.13	123.00	117.57
G ₅ – Control	69.67	75.50	72.58	90.00	94.17	92.08
Mean	87.93	96.69	92.31	109.57	118.51	114.04
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	2.43		7.21	3.14		9.33
Growth regulators (G)	3.84		11.40	4.97		14.76
Interaction (S x G)	5.43		16.12	7.02		20.87

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

The dry weight of stem was recorded higher at (45 × 45 cm) S₂ spacing as compared to (30 × 30 cm) S₁ spacing throughout the growth period. At 80 DAS, the dry weight of stem was found to be maximum (10.76 g) at S₂ spacing (45 × 45 cm), while minimum dry weight of stem (9.57 g) was recorded at S₁ spacing (30 × 30 cm). At 120 DAS, the dry weight of stem was found to be maximum (24.83 g) at S₂ spacing (45 × 45 cm) and minimum dry weight of stem (23.07 g) was recorded at S₁ spacing (30 × 30 cm).

The dry weight of stem differed significantly at different concentration of growth regulator treatments. At 80 DAS, the dry weight of stem was found to be maximum (11.45 g) at GA₃ 250 ppm (G₂), while minimum stem dry weight (7.88 g) was recorded in control. At 120 DAP, the dry weight of stem was found to be maximum (26.65 g) at GA₃ 250 ppm (G₂), followed by GA₃ 200 ppm (25.45 g) and are statistically on par with each other. Whereas, minimum dry weight of stem (19.05 g) was recorded in control.

The interaction effects have significant influence on the dry weight of stem at 80 and 120 days after sowing. At 80 and 120 DAS, treatment combination of 45 × 45 cm spacing with GA₃ 250 ppm (S₂G₂) recorded maximum dry weight of stem (12.30 and 27.90 g) at 80 and 120 DAS respectively. While, the minimum (7.67 and 20.33 g) dry weight of stem was noticed in S₁G₅ (control) treatment combination at 80 and 120 DAS respectively.

4.2 Growth parameters

4.2.1 Leaf area

The data pertaining to leaf area are presented in Table 12. Leaf area varied significantly at all stages of plant growth with respect to spacing and growth regulators. As far as interaction was concerned, the leaf area also showed significant difference at all stages of plant growth.

Leaf area increased with wider spacing. At 40 DAS, maximum leaf area (257.07 cm²) was found at 45 × 45 cm (S₂) spacing, while least (175.89 cm²) was recorded at 30 × 30 cm (S₁) spacing. At 80 DAS, maximum leaf area (409.73 cm²) was found at 45 × 45 cm (S₂) spacing and least (270.33 cm²) was recorded at 30 × 30 cm (S₁) spacing. At 120

Table 11. Effect of spacing and growth regulators on dry weight of stem at different intervals in radish cv. Pusa Chetki

Growth regulators	Dry weight of stem (g)					
	80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	10.30	11.50	10.90	23.90	27.00	25.45
G ₂ - GA ₃ 250 ppm	10.60	12.30	11.45	25.40	27.90	26.65
G ₃ - NAA 200 ppm	9.40	10.73	10.07	22.50	25.53	24.02
G ₄ - NAA 250 ppm	9.87	11.17	10.52	23.23	25.97	24.60
G ₅ - Control	7.67	8.10	7.88	20.33	17.77	19.05
Mean	9.57	10.76	10.16	23.07	24.83	23.95
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.29		0.85	0.77		2.28
Growth regulators (G)	0.45		1.34	1.21		3.61
Interaction (S x G)	0.64		1.89	1.72		5.10

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

DAS, maximum leaf area (459.93 cm^2) was found at $45 \times 45 \text{ cm}$ (S_2) spacing, while least (323.73 cm^2) was recorded at $30 \times 30 \text{ cm}$ (S_1) spacing.

The leaf area was found to increase significantly at GA_3 250 ppm (G_2) compared to other growth regulator treatments. At 40 DAS, maximum leaf area (287.47 cm^2) was recorded at GA_3 250 ppm (G_2) followed by GA_3 200 ppm (231.77 cm^2), while the lower under control (G_5) (147.67 cm^2). At 80 DAS, maximum leaf area (465.17 cm^2) was recorded at GA_3 250ppm (G_2) followed by GA_3 200 ppm (390.98 cm^2), while the least under control (194.67 cm^2). At 120 DAP, maximum leaf area (530.67 cm^2) was recorded at GA_3 250 ppm (G_2) followed by GA_3 200 ppm (439.33 cm^2), while the lower leaf area was recorded in control (232.00 cm^2).

With respect to interaction, a significant difference was recorded at all stages of plant growth. At 40 DAS, maximum leaf area (358.33 cm^2) was recorded at ($45 \times 45 \text{ cm} + \text{GA}_3$ 250 ppm) S_2G_2 combination. Whereas, reduced leaf area (144.00 cm^2) was recorded at ($30 \times 30 \text{ cm}$ with control) S_1G_5 combination of treatments. At 80 DAS, maximum leaf area (580.33 cm^2) was recorded at ($45 \times 45 \text{ cm} + \text{GA}_3$ 250 ppm) S_2G_2 combination, while reduced leaf area (186.67 cm^2) was recorded in (control) S_1G_5 combination of treatments. The leaf area at 120 DAS was not significantly influenced by interaction of spacing and growth regulator treatments. However, maximum leaf area was measured at ($45 \times 45 \text{ cm} + \text{GA}_3$ 250 ppm) S_2G_2 (664.33 cm^2) combination of treatments and reduced leaf area (231.33 cm^2) was observed in (control) S_2G_1 combination of treatments.

4.2.2 Leaf Area Index (LAI)

The data on leaf area index as influenced by spacing and growth regulators recorded at 40, 80 and 120 days after sowing (DAS) are presented in Table 13.

At early stage of plant growth (40 DAS), no significant variation was noticed in leaf area index due to spacing. The maximum leaf area index (2.10) was recorded in S_1 ($30 \times 30 \text{ cm}$) spacing and the minimum (1.96) was recorded in S_2 ($45 \times 45 \text{ cm}$) spacing. The results were exhibit significant effect of spacing on leaf area index at 80 and

Table 12. Effect of spacing and growth regulators on leaf area at different intervals in radish cv. Pusa Chetki

Growth regulators	Leaf area (cm ²)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	190.20	273.33	231.77	300.97	481.00	390.98	361.00	517.67	439.33
G ₂ - GA ₃ 250 ppm	216.60	358.33	287.47	350.00	580.33	465.17	397.00	664.33	530.67
G ₃ - NAA 200 ppm	155.67	240.33	198.00	246.33	367.67	307.00	301.00	406.00	353.50
G ₄ - NAA 250 ppm	173.00	262.00	217.50	267.67	417.00	342.33	328.33	479.00	403.67
G ₅ – Control	144.00	151.33	147.67	186.67	202.67	194.67	231.33	232.67	232.00
Mean	175.89	257.07	216.48	270.33	409.73	340.03	323.73	459.93	391.83
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	8.85		26.31	18.43		54.75	19.42		57.70
Growth regulators (G)	14.00		41.59	29.13		86.56	30.71		91.24
Interaction (S x G)	19.80		58.82	41.20		122.42	43.43		129.03

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

120 DAS. Plants spaced at 30×30 cm (S_1) recorded maximum leaf area index (4.70 and 5.38) respectively. The lowest leaf area index (4.11 and 4.75) was noticed in plants spaced at 45×45 cm (S_2) respectively at 80 and 120 DAS.

Significant difference was observed for leaf area index due to different growth regulator treatments at all the stages of crop growth. Among the growth regulator treatments G_2 (GA_3 250 ppm) recorded the maximum leaf area index (3.08), while the minimum (1.05) leaf area index were recorded at G_5 (control) at 40 DAP. Whereas, at 80 DAS the growth regulator treatments, G_2 (GA_3 250ppm) recorded the maximum leaf area index of (6.50) and it was on par with G_1 (5.62). The lowest leaf area index (2.03) was observed in control (G_5). At 120 DAS, G_2 (GA_3 250 ppm) recorded the maximum leaf area index (7.65), but the least leaf area index (2.04) was noticed in control (G_5).

The interaction of spacing and growth regulators was non significant at 40 and 120 DAS with respect to leaf area index. While, at 80 DAS S_1G_2 combination recorded significantly higher leaf area index (6.57) and minimum (1.18) was noticed in S_2G_5 combination and it was on par with S_2G_2 (6.43) and S_1G_1 (5.87) treatment combinations.

4.2.3 Absolute Growth Rate (AGR)

The data pertaining to absolute growth rate are presented in Table 14. Absolute growth rate was recorded at 40-80 DAS and 80-120 DAS. AGR varied significantly at all stages of plant growth with respect to spacing and growth regulators. As far as interaction was concerned, Absolute growth rate showed non-significant difference throughout the crop growth.

Absolute growth rate increased with 45×45 cm spacing. At 40-80 DAS, maximum absolute growth rate (0.38 g per day) was found at (45×45 cm) S_2 spacing, while minimum (0.31g per day) was recorded at (30×30 cm) S_1 spacing. At 80-120 DAS, maximum absolute growth rate (0.44 g per day) was found at (45×45 cm) S_2 spacing and minimum (0.34 g per day) was recorded at (30×30 cm) S_1 spacing.

Table 13. Effect of spacing and growth regulators on Leaf Area Index (LAI) at different intervals in radish cv. Pusa Chetki

Growth regulators	Leaf Area Index (LAI)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	2.49	2.10	2.30	5.87	5.37	5.62	6.71	5.94	6.33
G ₂ - GA ₃ 250 ppm	3.02	3.15	3.08	6.57	6.43	6.50	7.74	7.56	7.65
G ₃ - NAA 200 ppm	1.85	1.63	1.9	3.71	3.48	3.59	4.39	3.94	4.16
G ₄ - NAA 250 ppm	2.09	1.87	1.98	4.49	4.11	4.30	5.39	4.88	5.13
G ₅ – Control	1.03	1.07	1.05	2.87	1.18	2.03	2.66	1.43	2.04
Mean	2.10	1.96	2.03	4.70	4.11	4.40	5.38	4.75	5.06
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.11		NS	0.28		0.84	0.31		0.93
Growth regulators (G)	0.17		0.50	1.33		1.33	0.49		1.47
Interaction (S x G)	0.24		NS	1.88		1.88	0.70		NS

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30cm, S₂- 45 × 45cm, NS – Non significant.

The absolute growth rate was differed significantly at all the stages of the crop growth. At 40-80 DAS, maximum absolute growth rate (0.41 g per day) was recorded at GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (G₁) (0.38 g per day), while least was noticed under control (0.24 g per day). At 80-120 DAS, maximum absolute growth rate (0.47 g per day) was recorded at GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (G₁) (0.43 g per day), while the minimum absolute growth rate (0.29 g per day) was recorded in control.

As far as interaction was concerned, the absolute growth rate showed non-significant difference at all the stages of plant growth.

4.2.4 Crop Growth Rate (CGR)

The data pertaining to crop growth rate are presented in Table 15. Crop growth rate was recorded at 40-80 DAS and 80-120 DAS. CGR varied significantly at all stages of plant growth with respect to spacing and growth regulators.

At 40-80 DAS, maximum crop growth rate (3.40 g per m² per day) was found at 30 × 30 cm (S₁), while least (1.85 g per m² per day) was recorded at 45 × 45 cm (S₂) spacing. At 80-120 DAS, maximum crop growth rate (3.78 g per m² per day) was found at 30 × 30 cm (S₁) spacing and least (2.18 g per m² per day) was recorded at 45 × 45 cm S₂ spacing.

The crop growth rate was differed significantly at all the stages of the crop growth. At 40-80 DAS, maximum crop growth rate (3.18 g per m² per day) was observed at GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (G₁) (2.96 g per m² per day), while least was noticed under control (1.85 g per m² per day). At 80-120 DAS, maximum crop growth rate (3.54 g per m² per day) was recorded at GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (G₁) (3.31 g per m² per day), while the minimum crop growth rate (2.22 g per m² per day) was recorded in control.

As far as interaction was concerned, the absolute growth rate showed non-significant difference at 40-80 DAS and 80-120 DAS.

Table 14. Effect of spacing and growth regulators on Absolute Growth Rate (AGR) at different intervals in radish cv. Pusa Chetki

Growth regulators	Absolute Growth Rate (AGR, g / day)					
	40 - 80 DAS			80 - 120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	0.35	0.41	0.38	0.39	0.47	0.43
G ₂ - GA ₃ 250 ppm	0.37	0.46	0.41	0.40	0.53	0.47
G ₃ - NAA 200 ppm	0.27	0.37	0.32	0.30	0.44	0.37
G ₄ - NAA 250 ppm	0.32	0.40	0.36	0.35	0.46	0.41
G ₅ – Control	0.22	0.25	0.24	0.26	0.32	0.29
Mean	0.31	0.38	0.35	0.34	0.44	0.39
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.02		0.06	0.03		0.07
Growth regulators (G)	0.03		0.10	10.04		0.12
Interaction (S x G)	0.05		NS	0.06		NS

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm, NS – Non significant.

Table 15. Effect of spacing and growth regulators on Crop Growth Rate (CGR) at different intervals in radish cv. Pusa Chetki

Growth regulators	Crop Growth Rate (CGR, g/ m ² / day)					
	40 - 80 DAS			80 - 120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	3.92	2.00	2.96	4.29	2.33	3.31
G ₂ - GA ₃ 250 ppm	4.11	2.24	3.18	4.48	2.59	3.54
G ₃ - NAA 200 ppm	3.00	1.82	2.41	3.37	2.15	2.76
G ₄ - NAA 250 ppm	3.51	1.95	2.73	3.88	2.28	3.08
G ₅ - Control	2.48	1.23	1.85	2.88	1.56	2.22
	3.40	1.85	2.62	3.78	2.18	2.98
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	0.16		0.48	0.19		0.56
Growth regulators (G)	0.25		0.76	0.30		0.88
Interaction (S x G)	0.36		NS	0.42		NS

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm, NS – Non significant.

4.2.5 Net Assimilation Rate (NAR)

The data on net assimilation rate as influenced by spacing and growth regulators recorded at 40-80 DAS and 80-120 DAS are presented in Table 16. NAR varied significantly at all stages of plant growth with respect to spacing, but at early stage of plant growth (40 DAS), non significant variation was noticed on net assimilation rate due to plant growth regulator treatments.

At 40-80 DAS, maximum net assimilation rate ($0.061 \text{ g / dm}^2 / \text{day}$) was found at S_1 ($30 \times 30 \text{ cm}$), while minimum ($0.051 \text{ g / dm}^2 / \text{day}$) was recorded at ($45 \times 45 \text{ cm}$) S_2 spacing. At 80-120 DAS, maximum net assimilation rate ($0.055 \text{ g / dm}^2 / \text{day}$) was found at ($30 \times 30 \text{ cm}$) S_1 spacing and least (0.044) was observed at ($45 \times 45 \text{ cm}$) S_2 spacing.

At 40-80 DAS, maximum net assimilation rate ($0.0061 \text{ g/dm}^2/\text{day}$) was recorded in (control) G_5 , followed by (G_3) NAA 200 ppm ($0.058 \text{ g / dm}^2 / \text{day}$), while the least under (GA_3 250 ppm) G_2 ($0.049 \text{ g / dm}^2 / \text{day}$). At 80-120 DAS, maximum net assimilation rate ($0.071 \text{ g / dm}^2 / \text{day}$) was recorded at (control) G_5 , followed by (NAA 200 ppm) G_3 ($0.047 \text{ g / dm}^2 / \text{day}$), while the least under (GA_3 250 ppm) G_2 ($0.042 \text{ g / dm}^2 / \text{day}$).

The interaction of spacing and growth regulators was non significant at 40-80 and 80-120 DAS with respect to net assimilation rate.

4.3 Root parameters

4.3.1 Root length

The data pertaining to root length are presented in Table 17. Root length varied significantly at all stages of plant growth with respect to spacing and growth regulators.

Root length increased with wider spacing ($45 \times 45 \text{ cm}$). At 40 days after sowing, maximum root length (22.19 cm) was recorded at $45 \times 45 \text{ cm}$ (S_2). While, minimum root length (18.62 cm) was recorded at $30 \times 30 \text{ cm}$ (S_1) spacing. At 80 DAS, maximum root length (27.69 cm) was found at $45 \times 45 \text{ cm}$ (S_2) spacing, whereas least root length (23.44 cm) was recorded at $30 \times 30 \text{ cm}$ (S_1) spacing. At 120 days after sowing, root length

Table 16. Effect of spacing and growth regulators on Net Assimilation Rate (NAR) at different intervals in radish cv. Pusa Chetki

Growth regulators	Net Assimilation Rate (NAR, g/dm ² /day)					
	40 - 80 DAS			80 -120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	0.063	0.048	0.056	0.051	0.039	0.045
G ₂ - GA ₃ 250 ppm	0.056	0.042	0.049	0.048	0.036	0.042
G ₃ - NAA 200 ppm	0.062	0.054	0.058	0.052	0.041	0.047
G ₄ - NAA 250 ppm	0.063	0.050	0.057	0.052	0.035	0.043
G ₅ - Control	0.062	0.060	0.061	0.072	0.069	0.071
Mean	0.061	0.051	0.056	0.055	0.044	0.0495
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	0.03		0.009	0.003		0.010
Growth regulators (G)	0.05		0.014	0.005		0.016
Interaction (S x G)	0.06		NS	0.008		NS

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm, NS – Non significant.

varied significantly due to the influence of different levels of spacing. At 45×45 cm (S_2) spacing recorded significantly highest root length (30.40 cm), whereas the lowest root length (25.79 cm) was recorded in 30×30 cm (S_1) spacing.

The root length differed significantly among different growth regulator treatments. At 40 DAS, application of GA₃ 250 ppm (G_2) recorded significantly higher (24.48 cm) root length. Whereas, minimum root length (15.60 cm) was recorded in control (G_5). The root length at 80 days after sowing varied significantly among different growth regulator treatments. The results registered that maximum root length (30.17 cm) was recorded in GA₃ 250 ppm, while minimum root length (20.00 cm) was recorded in control. The root length at 120 days after sowing varied significantly among different growth regulators. The results indicated that maximum root length (32.40 cm) was recorded in GA₃ 250 ppm (G_2) over GA₃ 200 ppm (29.90 cm) (G_1) and it was statistically on par each other. While, minimum root length (22.40 cm) was recorded in control (G_5).

The interaction effect of spacing and growth regulators on root length was significant at all the stages of plant growth. The treatment combination 45×45 cm spacing with GA₃ 250 ppm foliar spray (S_2G_2) recorded maximum root length (28.57, 34.40 and 36.80 cm) at 40, 80 and 120 DAS respectively, while minimum root length (15.00, 19.33 and 21.47 cm) was noticed in S_1G_5 (control) treatment combination.

4.3.2 Root girth

The data on root girth as influenced by spacing and growth regulators recorded at 40, 80 and 120 days after sowing (DAS) are presented in Table 18. The root girth of radish varied significantly among different spacing and growth regulators treatment.

The root girth at 40 days after sowing registered significantly maximum of (10.33 cm) at 45×45 cm (S_2). While, minimum root girth (8.20 cm) was recorded at 30×30 cm (S_1) spacing. The root girth at 80 days after sowing showed significant differences among different spacing. The plants sown at 45×45 cm (S_2) spacing observed maximum root girth (13.33 cm). While, minimum root girth (11.39 cm) was recorded at 30×30 cm (S_1) spacing. At 120 days after sowing, maximum root girth (14.63 cm) was found at 45×45

Table 17. Effect of spacing and growth regulators on root length at different intervals in radish cv. Pusa Chetki

Growth regulators	Root length (cm)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	19.93	23.30	21.62	24.90	29.93	27.42	27.23	32.57	29.90
G ₂ - GA ₃ 250 ppm	20.40	28.57	24.48	25.93	34.40	30.17	28.00	36.80	32.40
G ₃ - NAA 200 ppm	18.57	21.13	19.85	23.23	26.30	24.77	25.73	29.23	27.48
G ₄ - NAA 250 ppm	19.20	21.77	20.48	23.80	27.13	25.47	26.53	30.07	28.30
G ₅ - Control	15.00	16.20	15.60	19.33	20.67	20.00	21.47	23.33	22.40
Mean	18.62	22.19	20.40	23.44	27.69	25.56	25.79	30.40	28.09
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.54		1.59	0.67		1.98	0.75		2.22
Growth regulators (G)	0.85		2.52	1.05		3.13	1.18		3.50
Interaction (S x G)	1.20		3.56	1.49		4.43	1.67		4.96

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

cm (S_2), while least root girth (12.61 cm) was recorded at 30×30 cm (S_1) spacing (plate. 3).

The root girth of plant differed significantly with respect to different growth regulators treatments. At 40 days after sowing, the root girth was found to be higher (11.50 cm) at GA_3 250 ppm (G_2) and it was followed by GA_3 200 ppm (9.90 cm). Whereas, minimum root girth (6.53 cm) was recorded at control (G_5). The root girth at 80 days after sowing varied significantly among different growth regulators. The result observed that maximum root girth (14.57 cm) was recorded in GA_3 250 ppm, while minimum root girth (9.20 cm) was recorded in control. The root girth at 120 days after sowing varied significantly among different growth regulators. The results showed that maximum root girth (15.60 cm) was recorded in GA_3 250 ppm (G_2) over GA_3 200 ppm (14.45) and are statistically on par each other. While, minimum root girth (10.47 cm) was recorded in control (G_5).

The interaction effect between spacing and growth regulators was significant with respect to root girth at different intervals after sowing (DAS). At 40 DAS, maximum root girth (13.70 cm) was observed in S_2G_2 treatment combination and the minimum (5.80 cm) root girth was recorded in treatment S_1G_5 (control). Maximum root girth (16.67 cm) observed in S_2G_2 treatment combination at 80 DAS, while minimum (9.00 cm) root girth was recorded in S_1G_5 treatment combination. At 120 DAS, maximum root girth (17.63 cm) was observed in S_2G_2 treatment combination and the minimum (10.17 cm) root girth was recorded in treatment S_1G_5 (control).

4.3.3 Fresh weight of root

The data presented on fresh weight of root as influenced by spacing and plant growth regulators at different stages showed significant differences among the different treatments (Table 19). The interaction effects between the spacing and plant growth regulator treatments varied significantly at all stages of plant growth.

The fresh weight of root at 40 days after sowing recorded significantly maximum (270.27 g) at 45×45 cm (S_2). While, minimum fresh weight of root (224.83 g) was

Table 18. Effect of spacing and growth regulators on root girth at different intervals in radish cv. Pusa Chetki

Growth regulators	Root girth (cm)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	9.07	10.73	9.90	12.33	14.00	13.17	13.20	15.70	14.45
G ₂ - GA ₃ 250 ppm	9.30	13.70	11.50	12.47	16.67	14.57	13.57	17.63	15.60
G ₃ - NAA 200 ppm	8.00	9.47	8.73	11.17	12.87	12.02	12.70	14.00	13.35
G ₄ - NAA 250 ppm	8.83	10.50	9.67	12.00	13.70	12.85	13.40	15.03	14.22
G ₅ - Control	5.80	7.27	6.53	9.00	9.40	9.20	10.17	10.77	10.47
Mean	8.20	10.33	9.26	11.39	13.33	12.36	12.61	14.63	13.62
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.27		0.80	0.40		1.18	0.42		1.25
Growth regulators (G)	0.43		1.26	0.63		1.87	0.66		1.97
Interaction (S x G)	0.60		1.79	0.89		2.64	0.94		2.78

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.



45 × 45 cm + GA₃ 250 ppm



30 × 30 cm + control

Plate 3. Influence of spacing and growth regulators on root girth

recorded at 30×30 cm (S_1) spacing. Fresh weight of root at 80 days after sowing showed significant differences among different spacing. The plants sown at 45×45 cm (S_1) spacing recorded maximum fresh weight of root (343.41 g), while minimum fresh weight of root (270.13 g) was recorded at 30×30 cm (S_1) spacing. At 120 days after sowing, fresh weight of root varied significantly due to the influence of different levels of spacing. At 45×45 cm (S_2) spacing recorded significantly highest fresh weight of root (392.33 g), whereas the lowest fresh weight of root (320.40 g) was recorded in 30×30 cm (S_1) spacing.

The fresh weight of root differed significantly with respect to different growth regulator treatments. At 40 days after sowing, the maximum (289.42 g) fresh weight of root was found at GA_3 250 ppm (G_2) and it was followed by GA_3 200 ppm (G_2) (272.17 g). Whereas, minimum fresh weight of root (186.33 g) was recorded in control (G_5). Fresh weight of root at 80 days after sowing varied significantly among different growth regulator treatments. The results revealed that maximum fresh weight of root (375.17 g) were recorded in GA_3 250 ppm, while minimum fresh weight of root (216.20 g) was recorded in control. The root fresh weight at 120 days after sowing varied significantly among different growth regulator treatments. The results indicated that maximum fresh weight of root (420.33 g) was recorded in GA_3 250 ppm (G_2) followed by GA_3 200 ppm (392.33 g), which was statistically on par with all other treatments except control. While, minimum fresh weight of root (268.67 g) was recorded in control (G_5).

Among the interaction of spacing and growth regulators, significant variation was observed with respect to fresh weight of root. At 40 DAS, maximum (335.00 g) and minimum (185.00 g) fresh weight of root was recorded in S_2G_2 and S_1G_5 treatment combination respectively. At 80 DAS, maximum fresh weight of root (438.00 g) was observed in S_2G_2 treatment combination and the minimum (213.33 g) fresh weight of root was recorded in treatment S_1G_5 (control). The maximum fresh weight of root (480.00 g) observed in S_2G_2 treatment combination at 120 DAS and which was found on par with the treatment S_2G_1 (444.67 g) and S_2G_4 (385.00 g). The minimum (258.00 g) fresh weight of root was recorded in S_1G_5 treatment combination.

Table 19. Effect of spacing and growth regulators on fresh weight of root at different intervals in radish cv. Pusa Chetki

Growth regulators	Fresh weight of root (g)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	237.00	307.33	272.17	299.67	392.33	346.00	340.00	444.67	392.33
G ₂ - GA ₃ 250 ppm	243.83	335.00	289.42	312.33	438.00	375.17	360.67	480.00	420.33
G ₃ - NAA 200 ppm	227.67	255.33	241.50	254.67	320.33	287.50	317.00	372.67	344.83
G ₄ - NAA 250 ppm	230.67	266.00	248.33	270.67	347.33	309.00	326.33	385.00	355.67
G ₅ - Control	185.00	187.67	186.33	213.33	219.07	216.20	258.00	279.33	268.67
Mean	224.83	270.27	247.55	270.13	343.41	306.77	320.40	392.33	356.36
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	6.42		19.07	15.82		46.99	17.55		52.14
Growth regulators (G)	10.15		30.15	25.01		74.30	27.75		82.45
Interaction (S x G)	14.35		42.63	35.37		105.08	39.24		116.60

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

4.3.4 Dry weight of root

The data with respect to the effect of spacing and growth regulators treatment on dry weight of root are presented in Table 20. The dry weight of root was found to be significantly influenced by spacing and plant growth regulators at all stages of plant growth.

The maximum dry weight of root was recorded at 45×45 cm (S_2) spacing as compared to 30×30 cm (S_1) spacing throughout the growth period. At 40 DAS, the dry weight of root was found to be maximum (13.53 g) at S_2 spacing (45×45 cm). While, minimum dry weight of root (11.28 g) was recorded at S_1 spacing (30×30 cm). At 80 DAS, the dry weight of root was found to be maximum (17.33 g) at S_2 spacing (45×45 cm) but minimum root dry weight (13.51 g) was recorded at S_1 spacing (30×30 cm). At 120 DAS, the dry weight of root was found to be maximum (19.63 g) at S_2 spacing (45×45 cm) and minimum dry weight of leaves (16.03 g) was recorded at S_1 spacing (30×30 cm).

The dry weight of root differed significantly with respect to different growth regulator treatments. At 40 DAS, the dry weight of root was found to be maximum (14.50 g) at GA_3 250 ppm (G_2), which was on par at GA_3 200 ppm (13.68 g), while minimum dry weight of root (9.23 g) was recorded in control. At 80 DAS, the dry weight of root was found to be maximum (18.95 g) at GA_3 250 ppm (G_2) and it was followed by GA_3 200 ppm (17.37 g). Whereas, minimum dry weight of root (10.67 g) was recorded in control. At 120 DAS, the dry weight of root was found to be maximum (21.03 g) at GA_3 250 ppm (G_2), which was on par at GA_3 200 ppm (19.63 g) but minimum dry weight of root (13.43 g) was recorded in control.

The interaction effect showed significant variation for dry weight of root at all the stages of plant growth. At 40, 80 and 120 DAS, significant difference was noticed among the interaction with respect to dry weight of root. The treatment combination of 45×45 cm spacing with GA_3 250 ppm (S_2G_2) recorded maximum dry weight of root (16.77, 22.10 and 24.03 g) at 40, 80 and 120 DAS respectively. While, the minimum (9.17, 10.37 and 12.90 g) dry weight of root was noticed in S_1G_5 (control) treatment combination at 40, 80 and 120 DAS respectively.

Table 20. Effect of spacing and growth regulators on dry weight of root at different intervals in radish cv. Pusa Chetki

Growth regulators	Dry weight of root (g)								
	40 DAS			80 DAS			120 DAS		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	11.92	15.43	13.68	14.97	19.77	17.37	17.00	22.25	19.63
G ₂ - GA ₃ 250 ppm	12.23	16.77	14.50	15.80	22.10	18.95	18.03	24.03	21.03
G ₃ - NAA 200 ppm	11.40	12.77	12.08	12.77	16.17	14.47	15.87	18.67	17.27
G ₄ - NAA 250 ppm	11.67	13.40	12.53	13.63	17.63	15.63	16.33	19.25	17.79
G ₅ - Control	9.17	9.30	9.23	10.37	10.97	10.67	12.90	13.97	13.43
Mean	11.28	13.53	12.40	13.51	17.33	15.42	16.03	19.63	17.83
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.36		0.80	2.38		1.18	0.87		2.60
Growth regulators (G)	0.57		1.26	3.76		1.87	1.38		4.11
Interaction (S x G)	0.80		1.79	5.31		2.64	1.96		5.81

DAS – Days After Sowing, G - Growth regulators, S – Spacing, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

4.3.5 Root yield per plot

The data pertaining to root yield per plot are presented in Table 21. Root yield per plot varied significantly with respect to spacing and growth regulators and their interaction.

Among the different spacing levels, plants spaced at 30×30 cm (S_1) recorded significantly higher root yield per plot (14.10 kg). Whereas, S_2 recorded lowest root yield per plot (12.31 kg).

Among the growth regulators, GA_3 250 ppm (G_2) recorded the maximum root yield per plot (14.37 kg) and it was on par with G_2 (14.07 kg), G_4 (13.83 kg) and G_3 (13.63 kg). The lowest root yield per plot (10.13 kg) was observed in control (G_5).

Among the interaction of spacing and growth regulators, significant variation was observed with respect to root yield per plot. However, maximum (13.73 kg) and minimum (7.63 kg) root yield per plot was recorded in S_1G_2 and S_2G_5 treatment combination, respectively.

4.3.6 Root yield per hectare

The data with respect to the effect of spacing and growth regulators treatment on root yield per hectare are presented in Table 21.

Data indicated that spacing and growth regulators had significant effect on root yield per hectare. Among different spacing levels, spacing of 30×30 cm (S_1) recorded significantly higher root yield per hectare (23.52 t). Whereas, the lowest root yield per hectare (20.57 t) was noticed in S_2 .

The root yield per hectare differed significantly with respect to different growth regulator treatments. Among the growth regulators, GA_3 250 ppm (G_2) recorded maximum root yield per hectare (23.98 t) and it was on par with G_1 (23.48 t), G_4 (23.10 t) and G_3 (22.75 t). The lowest root yield per hectare (16.90 t) was observed in control (G_5).

Table 21. Root yield per plot and per hectare as influenced by spacing and growth regulators in radish cv. Pusa Chetki

Growth regulators	Root yield per plot (kg)			Root yield per ha (t)		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	14.57	13.57	14.07	24.30	22.67	23.48
G ₂ - GA ₃ 250 ppm	15.00	13.73	14.37	25.02	22.93	23.98
G ₃ - NAA 200 ppm	14.03	13.23	13.63	23.40	22.10	22.75
G ₄ - NAA 250 ppm	14.27	13.40	13.83	23.80	22.40	23.10
G ₅ - Control	12.63	7.63	10.13	21.07	12.73	16.90
Mean	14.10	12.31	13.20	23.52	20.57	22.04
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.34		1.01	0.57		1.71
Growth regulators (G)	0.54		1.60	0.91		2.70
Interaction (S x G)	0.76		2.27	1.28		3.81

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂ - 45 × 45 cm.

The data indicates that interaction of spacing and growth regulators show significant effect on root yield per hectare. The maximum (25.02 t) and minimum (12.73 t) root yield per hectare was recorded in treatment combination S₁G₂ and S₂G₅ respectively.

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 50 per cent flowering stage are presented in Table 22. The chlorophyll content in leaves was found to be significantly influenced by spacing and plant growth regulators.

Wider (45 × 45 cm) spacing recorded maximum chlorophyll 'a', chlorophyll 'b' and total chlorophyll (1.91, 0.32 and 2.18 mg/g fresh weight, respectively), whereas closer spacing (30 × 30 cm) recorded minimum chlorophyll 'a', chlorophyll 'b' and total chlorophyll (1.33, 0.19 and 1.53 mg/g fresh weight, respectively). Chlorophyll 'a' in leaves was significantly influenced by growth regulators. Maximum chlorophyll 'a' content in leaves (2.07 mg/g fresh weight) was recorded at (GA₃ 250 ppm) G₂ followed by (GA₃ 200 ppm) G₁ (1.91 mg/g fresh weight), while minimum (1.12 mg/g fresh weight) was recorded in control.

Chlorophyll 'b' content in leaves was significantly influenced by growth regulators. Maximum chlorophyll 'b' content in leaves (0.36 mg / g fresh weight) was recorded at (GA₃ 250 ppm) G₂ followed by (GA₃ 200 ppm) G₁ (0.30 mg / g fresh weight) and are on par with each other, while minimum (0.12 mg / g fresh weight) was recorded in control.

Maximum total chlorophyll content in leaves (2.43 mg / g fresh weight) was recorded at (GA₃ 250 ppm) G₂ followed by (GA₃ 200 ppm) G₁ (2.08 mg / g fresh weight), while minimum (1.22 mg / g fresh weight) was recorded in control (G₅).

Table 22. Effect of spacing and growth regulators on chlorophyll content in leaves in radish cv. Pusa Chetki

Growth regulators	Chlorophyll content in leaves (mg/g fr. wt)								
	Chlorophyll 'a'			Chlorophyll 'b'			Total Chlorophyll		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	1.45	2.37	1.91	0.22	0.37	0.30	1.67	2.50	2.08
G ₂ - GA ₃ 250 ppm	1.53	2.61	2.07	0.24	0.47	0.36	1.77	3.08	2.43
G ₃ - NAA 200 ppm	1.24	1.59	1.42	0.19	0.29	0.24	1.43	1.89	1.66
G ₄ - NAA 250 ppm	1.38	1.82	1.60	0.21	0.35	0.28	1.59	2.17	1.88
G ₅ - Control	1.07	1.17	1.12	0.12	0.12	0.12	1.18	1.25	1.22
Mean	1.33	1.91	1.62	0.19	0.32	0.25	1.53	2.18	1.85
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.07		0.21	0.01		0.04	0.08		0.25
Growth regulators (G)	0.11		0.34	0.02		0.06	0.13		0.40
Interaction (S x G)	0.16		0.47	0.03		0.09	0.19		0.56

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

Significant difference was noticed among the interaction with respect to chlorophyll content in leaves. The treatment combination of 45×45 cm spacing with GA₃ 250ppm (S₂G₂) recorded maximum chlorophyll 'a', chlorophyll 'b' and total chlorophyll (2.61, 0.47 and 3.08 mg / g fresh weight, respectively), whereas 30×30 cm with control (S₁G₅) recorded minimum chlorophyll 'a', chlorophyll 'b' and total chlorophyll (1.07, 0.12 and 1.18 mg / g fresh weight, respectively).

4.5 Seed yield parameters

4.5.1 Days taken to 50 per cent flowering

The data presented on days to 50 per cent flowering as influenced by spacing and plant growth regulators showed significant differences among the different treatments (Table 23).

Among the different spacing levels, plants spaced at 45×45 cm (S₂) took less number of days (83.93 days) for 50 per cent flowering. Whereas, plants spaced at 30×30 cm (S₁) took more number of days (95.24 days) for 50 per cent flowering (plate. 4).

The advanced 50 per cent flowering (78.50 days) was observed at (GA₃ 250 ppm) G₂ as followed by (GA₃ 200 ppm) G₁ (85.67 days) and (NAA 250 ppm) G₄ (89.33 days), whereas in control (G₅) delayed (102.33 days) the days taken for 50 per cent flowering.

Among the interaction of spacing and growth regulators, significant variation was observed with respect to days taken for 50 per cent flowering. The minimum days taken to 50 per cent flowering was recorded in S₂G₂ (66.00 days), followed by S₂G₁ (76.67 days) treatment combination. However, the maximum was recorded in S₂G₅ (104.00 days).

4.5.2 Number of siliqua per plant

The data pertaining to number of siliqua per plant are presented in Table 23. Number of siliqua per plant varied significantly with respect to spacing and growth regulators and their interaction.

The number of siliqua per plant differed significantly among the different spacing. Significantly more number of siliqua per plant (229.54) was observed at wider spacing (45 × 45 cm), While, less number of siliqua per plant (183.96) was found at narrow spacing (30 × 30 cm) (plate. 5).

The number of siliqua per plant differed significantly at different concentration of growth regulator treatments. Number of siliqua per plant was found to be maximum (234.07) at GA₃ 250 ppm (G₂) which was statistically on par with number of siliqua per plant (220.73) at GA₃ 200 ppm (G₁). Whereas, minimum number of siliqua per plant (175.00) was recorded at control (G₅).

The interaction effect between spacing and growth regulators differed significantly on number of siliqua per plant. Maximum number of siliqua per plant (264.00) was observed in S₂G₂ treatment combination and the minimum (174.67) number of siliqua per plant was recorded in treatment S₁G₅ (control).

4.5.3 Number of seeds per pod

Data from table 23 indicated that spacing and growth regulators had significant effect on number of seeds per pod. Among different spacing levels, spacing of 45 × 45 cm (S₂) recorded significantly maximum number of seeds per pod (5.75). Whereas, the minimum number of seeds per pod (4.03) was noticed in 30 × 30 cm (S₁).

The number of number of seeds per pod differed significantly at different growth regulator treatments. Number of seeds per pod was found to be maximum (6.33) at GA₃ 250 ppm (G₂). Whereas, the minimum number of seeds per pod (3.17) was recorded at control (G₅).

The interaction effect between spacing and growth regulators differed significantly on number of seeds per pod. Maximum number of seeds per pod (7.33) was observed in S₂G₂ treatment combination and the minimum (3.00) number of seeds per pod was recorded in treatment S₁G₅ (control).

Table 23. Effect of spacing and growth regulators on days to 50 per cent flowering, number of siliqua per plant and number of seeds per pod in radish cv. Pusa Chetki

Growth regulators	Days to 50 per cent flowering			Number of siliqua per plant			Number of seeds per pod		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	94.67	76.67	85.67	181.67	259.80	220.73	4.67	6.40	5.53
G ₂ - GA ₃ 250 ppm	91.00	66.00	78.50	204.13	264.00	234.07	5.33	7.33	6.33
G ₃ - NAA 200 ppm	94.20	90.00	92.10	179.00	213.27	196.13	3.33	5.67	4.50
G ₄ - NAA 250 ppm	95.67	83.00	89.33	180.33	235.30	207.82	3.83	6.00	4.92
G ₅ - Control	100.67	104.00	102.33	174.67	175.33	175.00	3.00	3.33	3.17
Mean	95.24	83.93	89.58	183.96	229.54	206.75	4.03	5.75	4.89
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	2.25		6.69	5.70		16.62	0.14		0.43
Growth regulators (G)	3.56		10.58	9.01		26.76	0.23		0.68
Interaction (S x G)	5.04		14.96	12.74		37.84	0.32		0.96

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.



Plate 4. General view of the experimental plot at flowering stage



Plate 5. General view of the experimental plot at pod setting stage

4.5.4 Pod weight per plant

The data with respect to the effect of spacing and growth regulators treatment on pod weight per plant are presented in Table 24. The pod weight per plant was found to be significantly influenced by spacing and plant growth regulators.

The maximum pod weight per plant was recorded at 45×45 cm (S_2) spacing as compared to 30×30 cm (S_1) spacing. The pod weight per plant was found to be maximum (21.49 g) at S_2 spacing (45×45 cm). While, minimum pod weight per plant (15.97 g) was recorded at S_1 spacing (30×30 cm).

The pod weight per plant differed significantly with respect to different growth regulator treatments. The pod weight per plant was found to be maximum (22.83 g) at GA_3 250 ppm (G_2), which was on par at GA_3 200 ppm (21.20 g), while minimum pod weight per plant (12.92 g) was recorded in control.

Significant difference was noticed among the interaction with respect to pod weight per plant. The treatment combination of 45×45 cm spacing with GA_3 250 ppm (S_2G_2) recorded maximum pod weight per plant (25.97g). While, the minimum (11.83 g) pod weight per plant was noticed in S_1G_5 (control) treatment combination.

4.5.5 Length of pod

The data pertaining to length of pod are presented in Table 24. Length of pod varied significantly with respect to spacing and growth regulators.

Pod length increased with wider spacing (45×45 cm). The maximum length of pod (7.10 cm) was recorded at 45×45 cm (S_2). While, the minimum pod length (5.68 cm) was recorded at 30×30 cm (S_1) spacing.

The length of pod differed significantly among different growth regulator treatments. Application of GA_3 250 ppm (G_2) recorded significantly higher (7.63 cm) pod length over GA_3 200 ppm (7.12 cm) (G_1). Whereas, minimum pod length (4.83 cm) was recorded in control (G_5).

Table 24. Effect of spacing and growth regulators on pod weight and length of pod in radish cv. Pusa Chetki

Growth regulators	Pod weight (g)			Length of pod (cm)		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	18.33	24.07	21.20	6.37	7.87	7.12
G ₂ - GA ₃ 250 ppm	19.70	25.97	22.83	6.57	8.70	7.63
G ₃ - NAA 200 ppm	14.40	21.17	17.78	5.07	6.90	5.98
G ₄ - NAA 250 ppm	15.57	22.23	18.90	5.60	7.17	6.38
G ₅ - Control	11.83	14.00	12.92	4.80	4.87	4.83
Mean	15.97	21.49	18.73	5.68	7.10	6.39
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.55		1.64	0.20		0.58
Growth regulators (G)	0.87		2.59	0.31		0.92
Interaction (S x G)	1.23		3.66	0.44		1.30

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

The interaction effect of spacing and growth regulators on pod length was significant. The treatment combination 45×45 cm spacing with GA₃ 250 ppm foliar spray (S₂G₂) recorded maximum pod length (8.70 cm), minimum pod length (4.80 cm) was noticed in S₁G₅ (control) treatment combination.

4.5.6 Seed yield per plant

The data presented on seed yield per plant as influenced by spacing and plant growth regulators at different stages showed significant differences among the different treatments (Table 25). The interaction effects between the spacing and plant growth regulator treatments varied significantly.

Seed yield per plant recorded significantly maximum (7.28 g) at 45×45 cm (S₂). While, minimum seed yield per plant (5.84 g) was recorded at 30×30 cm (S₁) spacing.

The seed yield per plant differed significantly with respect to different growth regulator treatments. The maximum (8.03 g) seed yield per plant was found at GA₃ 250 ppm (G₂) and it was followed by GA₃ 200 ppm (G₂) (7.40 g). Whereas, minimum seed yield per plant (3.94 g) was recorded in control (G₅).

Among the interaction of spacing and growth regulators, significant variation was observed with respect to seed yield per plant. Maximum (8.53 g) and minimum (3.93 g) seed yield per plant was recorded in S₂G₂ and S₁G₅ treatment combination respectively.

4.5.7 Seed yield per plot

The data pertaining to Seed yield per plot are presented in Table 25. Seed yield per plot varied significantly with respect to spacing and growth regulators and their interaction.

Among the different spacing levels, plants spaced at 30×30 cm (S₁) recorded significantly seed yield per plot higher (0.36 kg). Whereas, S₂ recorded lowest seed yield per plot (0.23 kg).

Among the growth regulators, GA₃ 250 ppm (G₂) recorded the maximum seed yield per plot (0.42 kg) and it was on par with G₂ (0.37 kg). The lowest seed yield per plot (0.18 kg) was observed in control (G₅).

Among the interaction of spacing and growth regulators, significant variation was observed with respect to seed yield per plot. However, maximum (0.55 kg) and minimum (0.17 kg) seed yield per plot was recorded in S₁G₂ and S₂G₅ treatment combinations, respectively.

4.5.8 Seed yield per ha

The data with respect to the effect of spacing and growth regulators treatment on seed yield per hectare are presented in Table 25.

Data indicated that spacing and growth regulators had significant effect on root yield per hectare. Among different spacing levels, spacing of 30 × 30 cm (S₁) recorded significantly higher seed yield per hectare (5.99 q). Whereas, the lowest seed yield per hectare (3.75 q) was noticed in S₂.

The seed yield per hectare differed significantly with respect to different growth regulator treatments. Among the growth regulators, GA₃ 250 ppm (G₂) recorded maximum seed yield per hectare (7.05 q). The lowest seed yield per hectare (2.87 q) was observed in control (G₅).

The data indicates that interaction of spacing and growth regulators show significant effect on seed yield per hectare. The maximum (9.16 q) and minimum (2.79 q) seed yield per hectare was recorded in treatment combination S₁G₂ and S₂G₅ respectively.

4.6 Seed quality parameters

4.6.1 Seed germination per cent

The results on the germination as influenced by the spacing, growth regulators and their interaction are presented in Table 26.

Table 25. Seed yield per plant, per plot and per hectare as influenced by spacing and growth regulators in radish cv. Pusa Chetki

Growth regulators	Seed yield per plant (g)			Seed yield per plot (kg)			Seed yield per hectare (q)		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	6.63	8.17	7.40	0.45	0.28	0.37	7.50	4.56	6.03
G ₂ - GA ₃ 250 ppm	7.53	8.53	8.03	0.55	0.30	0.42	9.16	4.94	7.05
G ₃ - NAA 200 ppm	5.47	7.53	6.60	0.30	0.19	0.25	5.06	3.11	4.09
G ₄ - NAA 250 ppm	5.62	8.03	6.83	0.32	0.22	0.28	5.28	3.33	4.31
G ₅ - Control	3.93	3.94	3.94	0.18	0.17	0.18	2.94	2.79	2.87
Mean	5.84	7.28	6.56	0.36	0.23	0.29	5.99	3.75	4.87
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.19		0.56	0.01		0.03	0.19		0.56
Growth regulators (G)	0.30		0.89	0.02		0.05	0.30		0.89
Interaction (S x G)	0.42		1.26	0.03		0.08	0.42		1.26

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45× 45 cm

Germination differed significantly among the different levels of spacing. The maximum germination was recorded in S_2 (86.93%) and the least was recorded in S_1 (81.73%).

Germination differed significantly among the different growth regulator treatments. The maximum germination was recorded in G_2 (89.33 %), which was statistically on par with G_4 (88.00%), G_1 (87.00 %), and G_3 (84.00 %). However, the least was recorded in G_5 (76.00 %).

Significant differences were recorded for the interaction between spacing and growth regulators. Maximum germination (93.33%) was recorded at (45×45 cm + GA_3 250 ppm) S_2G_2 combination. Whereas, minimum germination (75.33 %) was recorded in (30×30 cm with control) S_1G_5 .

4.6.2 Seedling length

The data pertaining to seedling length are presented in Table 26. Seedling length varied significantly with respect to spacing and growth regulators.

Seedling length increased with wider spacing (45×45 cm), maximum seedling length (14.99 cm) was recorded at 45×45 cm (S_2). While, minimum seedling length (12.61 cm) was recorded at 30×30 cm (S_1) spacing.

The seedling length differed significantly among different growth regulator treatments. GA_3 250 ppm (G_2) recorded significantly higher (15.88 cm) seedling length, which was statistically on par with G_1 (14.85 cm), G_4 (14.22 cm) and G_3 (13.45 cm). Whereas, minimum seedling length (10.42 cm) was recorded in control (G_5).

The interaction effect of spacing and growth regulators on seedling length was significant. The treatment combination 45×45 cm spacing with GA_3 250 ppm foliar spray (S_2G_2) recorded maximum seedling length (17.83 cm), while minimum seedling length (10.17 cm) was noticed in S_2G_5 (control) treatment combination.

Table 26. Effect of spacing and growth regulators on seed germination per cent and seedling length in radish cv. Pusa Chetki

Growth regulators	Seed germination per cent			Seedling length (cm)		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	84.00 (66.42)*	90.67 (72.21)	87.00 (68.86)	13.53	16.53	14.85
G ₂ - GA ₃ 250 ppm	85.33 (67.47)	93.33 (75.03)	89.33 (70.93)	13.93	17.83	15.88
G ₃ - NAA 200 ppm	81.33 (64.40)	86.67 (68.59)	84.00 (66.42)	12.27	14.63	13.45
G ₄ - NAA 250 ppm	82.67 (65.40)	88.00 (69.73)	88.00 (69.73)	13.13	15.30	14.22
G ₅ - Control	75.33 (48.87)	76.00 (49.46)	76.00 (49.46)	10.17	10.67	10.42
Mean	81.73 (64.70)	86.93 (68.80)	84.33 (66.70)	12.61	14.99	13.76
For comparing means of	S.Em _±		CD (5%)	S.Em _±		CD (5%)
Spacing (S)	2.25		6.68	0.67		2.00
Growth regulators (G)	3.55		10.56	1.07		3.17
Interaction (S x G)	5.02		14.93	1.51		4.48

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

*values in parenthesis are arc sign transformed

4.6.3 Seedling dry weight

The data pertaining to seedling dry weight as influenced by spacing and growth regulators are presented in Table 27.

The seedling dry weight was found to be significantly influenced by spacing and plant growth regulator treatments.

The seedling dry weight was recorded higher at (45 × 45 cm) S₂ spacing as compared to (30 × 30 cm) S₁ spacing, the dry weight of seedling was found to be maximum (11.33 mg) at S₂ spacing (45 × 45 cm), while minimum seedling dry weight (9.07 mg) was recorded at S₁ spacing (30 × 30 cm).

The seedling dry weight differed significantly at different growth regulator treatments. The dry weight of seedling was found to be maximum (12.22 mg) at GA₃ 250 ppm (G₂), followed by GA₃ 200 ppm (11.85), while minimum seedling dry weight (6.58 mg) was recorded in control.

The interaction effects have significant influence on seedling dry weight. The treatment combination of 45 × 45 cm spacing with GA₃ 250 ppm (S₂G₂) recorded maximum dry weight of seedling (13.13 mg). While, the minimum (6.40 mg) seedling dry weight was noticed in S₁G₅ (control) treatment combination.

4.6.4 Seedling vigour index (SVI)

The results on the seedling vigour index as influenced by spacing and growth regulators and their interaction are presented in Table 27.

Seedling vigour index differed significantly among the different spacing. The highest SVI was recorded in S₂ (1318) and the least was recorded in S₁ (1062).

Seedling vigour index differed significantly among the different growth regulator treatments. The highest SVI was recorded in G₂ (1439) followed by G₁ (1325) and are on par with each other. However, the least was recorded in G₅ (787).

Table 27. Effect of spacing and growth regulators on seedling dry weight, seedling vigour index and test weight in radish cv. Pusa Chetki

Growth regulators	Seedling dry weight (mg)			Seedling vigour index			Test weight (g)		
	S ₁	S ₂	Mean	S ₁	S ₂	Mean	S ₁	S ₂	Mean
G ₁ - GA ₃ 200 ppm	11.00	12.70	11.85	1166	1484	1325	7.10	9.97	8.53
G ₂ - GA ₃ 250 ppm	11.30	13.13	12.22	1201	1677	1439	7.40	12.00	9.70
G ₃ - NAA 200 ppm	8.17	11.63	9.90	1030	1270	1150	6.40	8.13	7.27
G ₄ - NAA 250 ppm	8.50	12.43	10.47	1130	1368	1249	6.77	8.83	7.80
G ₅ – Control	6.40	6.77	6.58	783	791	787	5.23	5.87	5.55
Mean	9.07	11.33	10.2	1062	1318	1190	6.58	8.96	7.77
For comparing means of	S.Em±		CD (5%)	S.Em±		CD (5%)	S.Em±		CD (5%)
Spacing (S)	0.26		0.78	63.74		189.38	0.29		0.85
Growth regulators (G)	0.42		0.24	100.78		299.43	0.45		1.34
Interaction (S x G)	0.59		1.75	142.52		422.46	0.64		1.90

DAS – Days After Sowing, S – Spacing, G - Growth regulators, S₁- 30 × 30 cm, S₂- 45 × 45 cm.

Table 28. Cost economics of radish seed production

Treatment	Total seed yield (q/ha)	Total cost of cultivation (₹/ ha)	Gross return (₹/ ha)	Net return (₹/ ha)	Benefit : cost ratio
S ₁ G ₁ - 30 × 30cm + GA ₃ 200 ppm	7.50	103398.65	225000	121601.35	1.17
S ₁ G ₂ - 30 × 30cm + GA ₃ 250 ppm	9.16	110337.05	274800	164462.95	1.49
S ₁ G ₃ - 30 × 30cm + NAA 200 ppm	5.06	76509.95	151800	75290.05	0.98
S ₁ G ₄ - 30 × 30cm + NAA 250 ppm	5.28	76851.36	158400	81548.64	1.06
S ₁ G ₅ - 30 × 30cm + control	2.94	73593.05	88200	14606.95	0.19
S ₂ G ₁ - 45× 45cm + GA ₃ 200 ppm	4.56	102358.65	273600	171241.35	1.67
S ₂ G ₂ - 45 × 45cm + GA ₃ 250 ppm	4.94	109297.05	296400	187102.95	1.70
S ₂ G ₃ - 45 × 45cm + NAA 200 ppm	3.11	75469.95	186600	111130.05	1.47
S ₂ G ₄ - 45 × 45cm + NAA 250 ppm	3.33	75811.36	199800	123988.64	1.62
S ₂ G ₅ -45 × 45cm + control	2.79	72553.05	97650	25096.95	0.34

Seed price (₹) = 520 per kg.

Significant differences were recorded for the interaction between spacing and growth regulators. Maximum seedling vigour index (1677) was recorded at (45 × 45 cm + GA₃ 250 ppm) S₂G₂ combination. Whereas, minimum seedling vigour index (783) was recorded at (30 × 30 cm with control).

4.6.5 Test weight

The data with respect to the effect of spacing and growth regulators treatment on test weight are presented in Table 27. The test weight was found to be significantly influenced by spacing and plant growth regulators.

The maximum test weight was recorded at 45 × 45 cm (S₂) spacing as compared to 30 × 30 cm (S₁) spacing. The test weight was found to be maximum (8.96 g) at S₂ spacing (45 × 45 cm). While, minimum test weight (6.58 g) was recorded at S₁ spacing (30 × 30 cm).

The test weight differed significantly with respect to different growth regulator treatments. The maximum test weight (9.70 g) was recorded at GA₃ 250 ppm (G₂), which was on par at GA₃ 200 ppm (8.53 g), while minimum test weight (5.55 g) was recorded in control.

Significant difference was noticed among the interaction with respect to test weight per plant. The treatment combination of 45 × 45 cm spacing with GA₃ 250 ppm (S₂G₂) recorded maximum test weight (12.00 g). While, the minimum (5.23 g) test weight was noticed in S₁G₅ (control) treatment combination.

4.7 Economics

The data on effect of different spacing and growth regulators on cost economics of radish seed production is presented in Table 28. The maximum benefit cost ratio (1.70) was recorded at (45 × 45 cm + GA₃ 250 ppm) S₂G₂ treatment combination followed by (45 × 45 cm + GA₃ 200 ppm) S₂G₁ (1.67). The minimum cost benefit ratio (0.19) was recorded in the treatment combination (30 × 30 cm + control) S₁G₅.

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. Good seed is essential prerequisite for successful production of any crop. There is a great demand for quality seed in radish.

The productivity of cv. Pusa Chetki of radish is low mainly because of improper spacing and it has become difficult to meet even the minimum demand of the total seed requirement for seed production. To increase the seed production in radish, it is imperative to increase the yield by following improved cultural practices, spraying of plant growth regulators, manipulation of nutrients and control of pest and diseases. It is known that, among the cultural practices, suitable spacing is the most important from the point of high yields.

The plant growth regulators are new generation chemicals and are expected to play an important role in overcoming the hurdles in manifestation of biological yield even in root crops. Various plant growth regulators are known to affect different physiological processes. The gibberellic acid is known to stimulate cell division, cell elongation, auxin metabolism altering, cell wall plasticity and permeability of cell membranes, RNA synthesis and induction of hydrolytic enzymes.

Growth, productivity and quality of any crop is influenced by several factors, such as environmental factors, genetic constitution of the variety and agronomic practices. Several attempts have been made in radish cultivation in the past to increase the productivity, quality of root and seed production, out of which use of spacing and growth regulators play an important role to boost the productivity with quality seeds. The investigation was carried out to study the growth, root and seed yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki as affected by spacing and growth regulators, at College of

Horticulture, Mudigere during the year 2014-15 in *rabi* season. The results of the studies are discussed herewith the support of available literature.

5.1. Effect of spacing

5.1.1. Morphological parameters

In the present study, the plant height was significantly influenced by different spacing levels. At final stage, wider spacing (45 × 45 cm) was found to be optimum which recorded maximum plant height (75.47 cm), whereas the lowest plant height (70.03 cm) was recorded in 30 × 30 cm (S₁) spacing. The increase in plant height under wider spacing may be due to the vigorous growth in wider spacing between the plants as a result of less competition for light, water and nutrition. The similar findings were reported by Pervez *et al.* (2004), Sachan and Singh (2005) and Manoj *et al.* (2012) in radish.

In the present study, spacing had a profound and significant effect on production of number of leaves per plant, leaf length (fig. 2) and leaf width (fig. 3). Wider spacing S₂ (45 × 45 cm) increased the number of leaves per plant, leaf length and leaf width (20.05, 36.43 cm and 16.03 cm respectively). While, minimum number of leaves per plant, leaf length and leaf width (14.71, 31.20 cm and 13.40 cm respectively) was found at narrow spacing (30 × 30 cm) in radish. This might be attributed to more number of branches put forth by the plants at wider spacing and also due to the availability of more space, light and nutrition. These results are in line with the observations made by Maurya *et al.* (1990), Sharma and Lal (1991), Warade *et al.* (2003), El-Desuki *et al.* (2005) and Lavanya *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 spacing. The highest plant spread (N-S and E-W) of 1099.07 cm² was recorded at wider spacing (45 × 45 cm). This might be due to availability of sufficient space for the spread of the plant and which could be attributed to the higher surface area, which resulted in more plant spread. Similar, results were reported by Dawuda *et al.* (2011) in carrot.

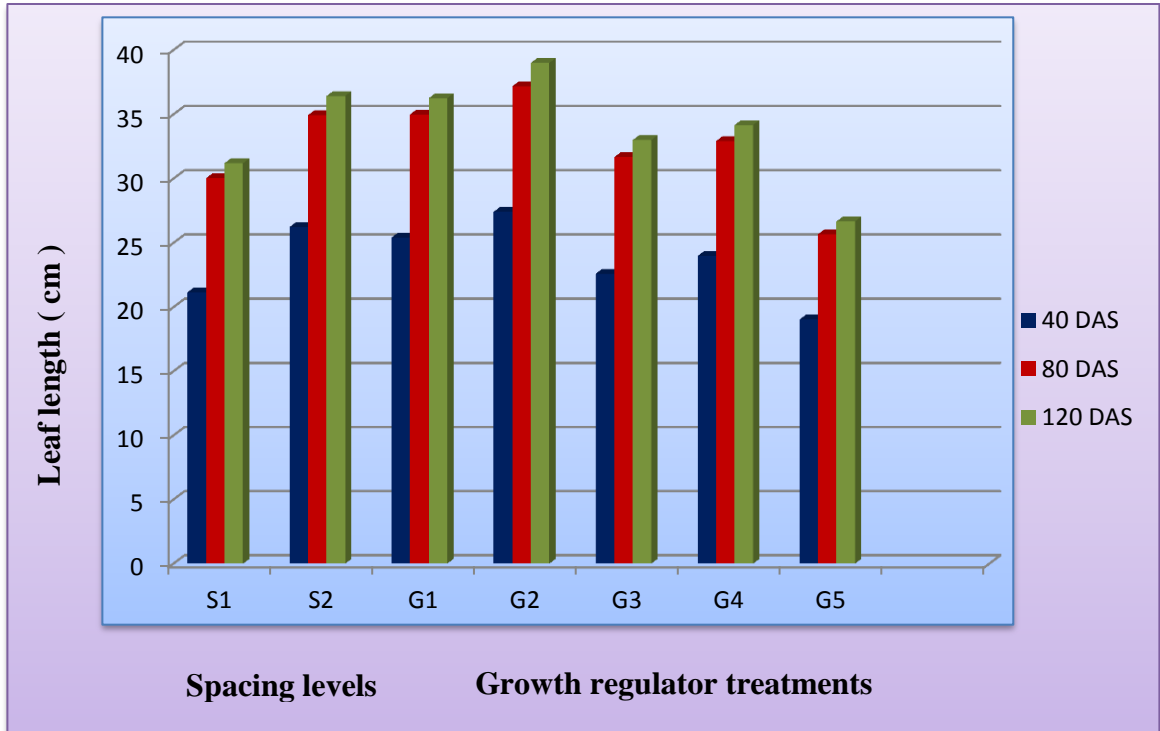


Fig. 2. Leaf length as influenced by spacing and growth regulators at different intervals after sowing in radish.

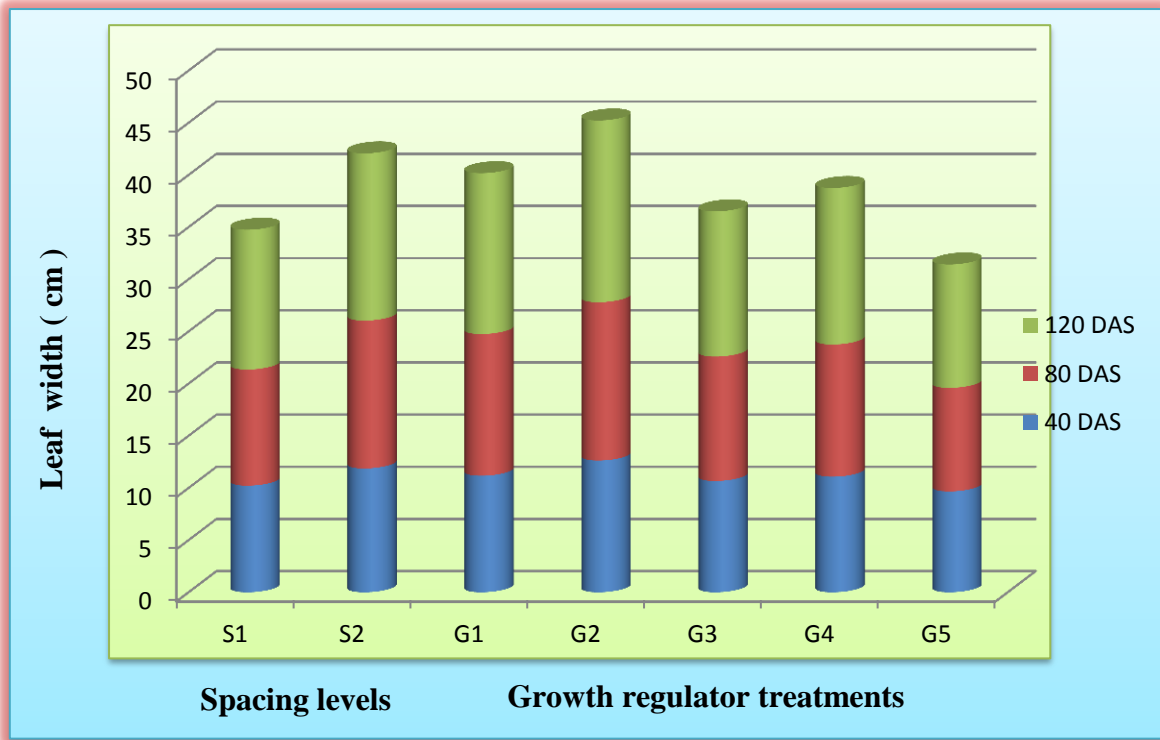


Fig. 3. Leaf width as influenced by spacing and growth regulators at different intervals after sowing in radish.

The number of branches per plant differed significantly among the different spacing levels. At harvest, more number of branches per plant (13.71) was noticed in wider spacing (45 × 45 cm). While, less number of branches per plant (9.39) was recorded in narrow spacing (30 × 30 cm). The increased number of branches could be attributed to the more interception of light due to higher surface area and availability of both spatial and floor space resulting in less competition between the plants for light, nutrition and water which resulted in vertical growth of the plant rather than horizontal growth. These results are in agreement with Bilekudari *et al.* (2005), Sachan and Singh (2005) and Manoj *et al.* (2012) in radish.

The stem diameter at 120 days after sowing registered significantly maximum (3.00 cm) at 45 × 45 cm (S₂). While, minimum stem diameter (2.22 cm) was recorded at 30 × 30 cm (S₁) spacing. This may be attributed to the increased plant growth and due to lesser competition between plants for moisture and nutrients in wider spacing. Whereas, competition between plants for light, water and nutrition under closer spacing resulted less increase in stem girth.

The influence of spacing was significant on fresh weight of leaves and stem. The wider spacing of 45 × 45 cm (S₂) recorded highest fresh weight of leaves and stem (73.98 g and 118.51 g respectively). The minimum fresh weight of leaves and stem (63.22 g and 109.57 respectively) was noticed in 30 × 30 cm narrow spacing (S₁). The higher fresh weight of leaves and stem may be attributed to the translocation of more photosynthates in wider space may put up better vegetative growth. Similar, result was obtained by Parashar *et al.* (1975) in sugarbeet.

Spacing showed significant variation on dry weight of leaves and stem. The wider spacing of 45 × 45 cm (S₂) recorded maximum dry weight of leaves and stem (7.55 g and 24.83 g respectively), while the minimum dry weight of leaves and stem (6.59 g and 23.07 g respectively) was noticed in the closer spacing of 30 × 30 cm (S₁). This may be due to the fact that the widely spaced plants have accumulated more dry matter through better utilization of light, moisture, space and nutrients. Similar, results have been quoted by Parashar *et al.* (1975) in sugarbeet.

5.1.2. Growth parameters

In the present study, spacing had a profound and significant effect on leaf area and it was increased with wider spacing. At final stage, maximum leaf area (459.93 cm²) was found at 45 × 45 cm (S₂) spacing, while least (323.73 cm²) was recorded at 30 × 30 cm (S₂) spacing. This might be due to the fact that under wider spacing plants utilise all the resources (light, moisture, nutrients, space and aeration) efficiently thereby more cell division and cell elongation takes place, which in turn enhances more number of leaves and also the photosynthetic area. These results are in agreement with the results of Criollo and Garcia (2009) and Lavanya *et al.* (2014) in radish.

At early stage of plant growth (40 DAS), no significant variation was noticed in leaf area index however significant differences were noticed at 80 and 120 DAS. The maximum leaf area index (5.38) was recorded in S₁ (30 × 30 cm) spacing and the minimum (4.75) was recorded in S₂ (45 × 45 cm) spacing. The increased leaf area index was due to more number of leaves per unit land area.

At 40-80 DAS, maximum absolute growth rate (0.38 g per day) was found in S₂ (45 × 45 cm) spacing, while minimum (0.31 g per day) was recorded in S₁ (30 × 30 cm) spacing. At 80-120 DAS, maximum absolute growth rate (0.44 g per day) was found at (45 × 45 cm) S₂ spacing and minimum (0.34 g per day) was recorded at (30 × 30 cm) S₁ spacing. This might be due to better utilization of solar radiation, moisture and nutrients by the plant.

Maximum crop growth rate (3.40 g per m² per day) at 40-80 DAS was found at 30 × 30 cm (S₁), while least (1.85 g per m² per day) was recorded at 45 × 45 cm (S₂) spacing. At 80-120 DAS, maximum crop growth rate (3.78 g per m² per day) was found at 30 × 30 cm (S₁) spacing and least (2.18 g per m² per day) was recorded at 45 × 45 cm (S₂) spacing.

At 40-80 DAS, maximum net assimilation rate (0.061 g / dm² / day) was found at S₁ (30 × 30 cm), while minimum (0.051 g / dm² / day) was recorded at (45 × 45 cm) S₂ spacing. At 80-120 DAS, maximum net assimilation rate (0.055 g / dm² / day) was found

at (30 × 30 cm) S₁ spacing and least (0.044 g / dm² / day) was observed at (45 × 45cm) S₂ spacing.

5.1.3. Root parameters

The root length and girth was significantly influenced by different spacing levels (fig. 4 and 5). Root length and girth increased with wider spacing (45 × 45 cm). The wider spacing of 45 × 45 cm (S₂) recorded maximum root length and girth (30.40 cm and 14.63 cm respectively), while the minimum root length and girth (25.79 cm and 12.61 cm respectively) was noticed in the closer spacing of 30 × 30 cm spacing (S₁). Root girth decreased as the plant density increased which may be due to competition for light, moisture and nutrients. The wider spacing provides more space for the development of root which resulted in maximum root length and girth. Similar results were reported by Aziz-Ur-Rehman and Ali (2000), Pervez *et al.* (2004), El-Desuki *et al.* (2005), Kutijabi (2007) and Lavanya *et al.* (2014) in radish and Dawuda *et al.* (2011) in carrot.

Significant variations were observed for the fresh weight of root. At 45 × 45 cm (S₂) spacing recorded significantly highest fresh weight of root (392.33 g), whereas the lowest fresh weight of root (320.40 g) was recorded in 30 × 30 cm (S₁) spacing (fig. 6). This might be due to the proper utilization of accumulates which were conserved by the plant, under optimally spaced crop. These results are well supported by the previous findings of Chatterjee and Som (1991), Rahman *et al.* (2007) and Kutijabi (2007) in radish.

The maximum dry weight of root was recorded at 45 × 45 cm (S₂) spacing as compared to 30 × 30 cm (S₁) spacing throughout the growth period. The dry weight of root was found to be maximum (19.63 g) at wider spacing (45 × 45 cm) and minimum dry weight of root (16.03 g) was recorded at narrow spacing (30 × 30 cm). This may be due to the fact that the widely spaced plants have accumulated more dry matter through better utilization of light, moisture and space. These results are in conformity with the results quoted by Parashar *et al.* (1975) in sugarbeet.

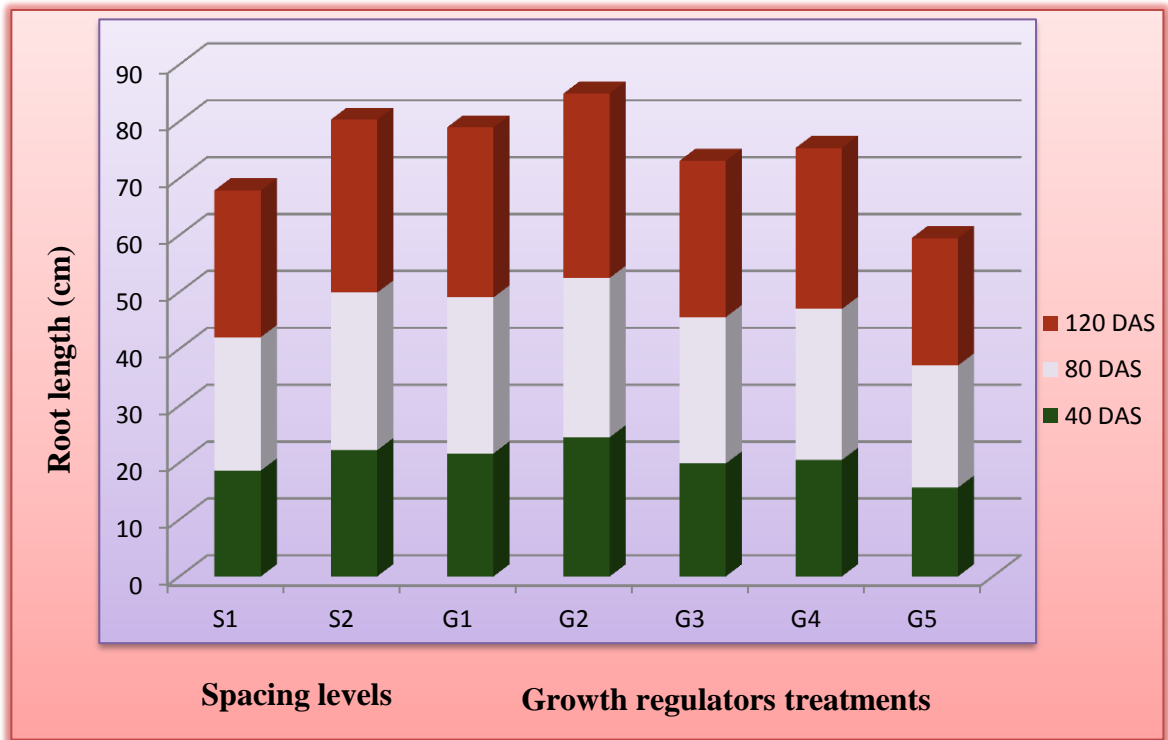


Fig. 4. Root length as influenced by spacing and growth regulators at different intervals after sowing in radish.

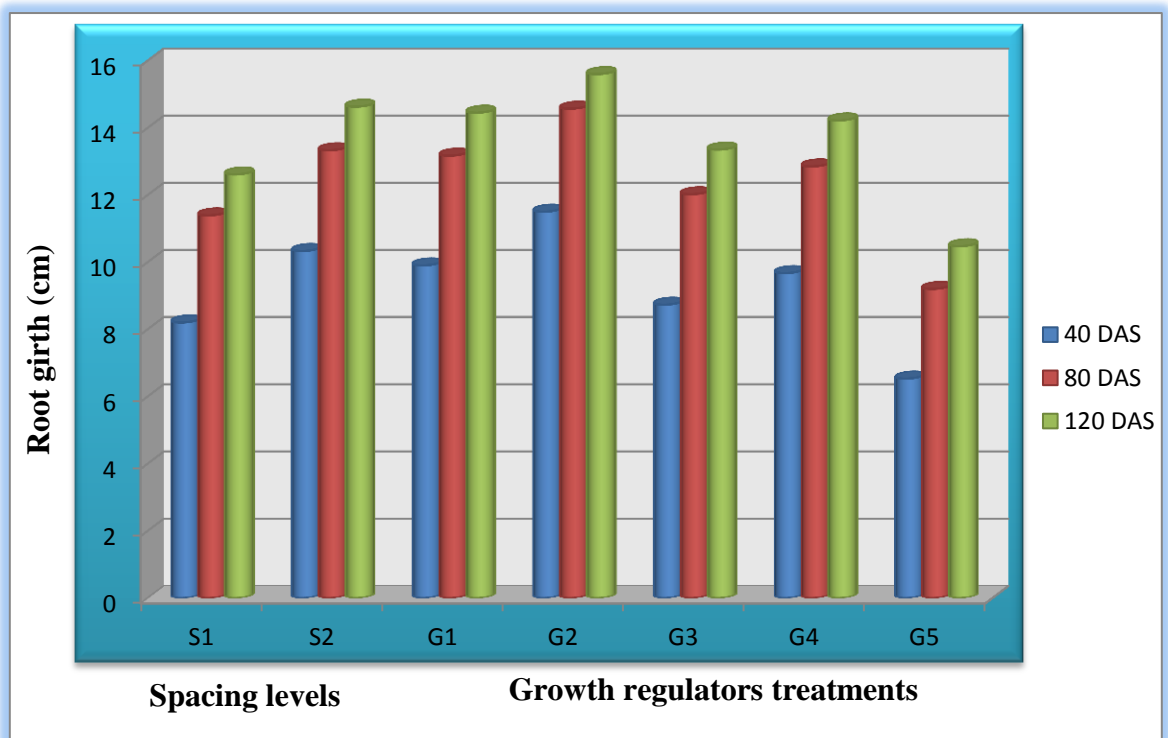


Fig. 5. Root girth as influenced by spacing and growth regulators at different intervals after sowing in radish.

Among the different spacing levels, plants spaced at 30 × 30 cm recorded significantly higher root yield per plot and per hectare (14.10 kg and 23.52 t respectively). Whereas, wider spacing of 45 × 45 cm recorded lowest root yield per plot and per hectare (12.31 kg 20.57 t respectively) (fig. 7). The maximum root yield per plot and per hectare at closer spacing of 30 × 30 cm was found superior which was possibly due to more number of plants per unit area. Increase in total yield production due to increased plant density may be brought about by the higher ground cover of leaf area resulted in higher light interception and hence, higher assimilate production and translocation to economic parts. Similar results have been reported by Rao and Manohar (1990). Sirkar *et al.* (1998) and El-Desuki *et al.* (2005) in radish.

5.1.4 Biochemical parameter

Wider spacing (45 × 45 cm) recorded maximum chlorophyll 'a', chlorophyll 'b' and total chlorophyll (1.91, 0.32 and 2.18 mg / g fresh weight, respectively) content, whereas closer spacing (30 × 30 cm) recorded minimum chlorophyll 'a', chlorophyll 'b' and total chlorophyll (1.33, 0.19 and 1.53 mg/g fresh weight, respectively) content. Variation in chlorophyll content in leaf might be attributed to better utilization of all available resources (light, water, nutrients *etc.*) under wider spacing and these resources might have influenced the better growth and development of plant which enhances the biosynthesis of chlorophyll content in the leaves.

5.1.5 Seed yield parameters

Among the different spacing levels, plants spaced at 45 × 45 cm took less number of days (83.93) for 50 per cent flowering. Whereas, plants spaced at 30 × 30 cm took more number of days (95.24) for 50 per cent flowering. Early flowering was observed in wider spacing compared to closer spacing. This might be due to extended vegetative growth phase of radish plants at closer spacing. These results are in accordance with the findings of Singh *et al.* (1990) and Malik *et al.* (1999) in radish and Kutijabi (2007) in carrot.

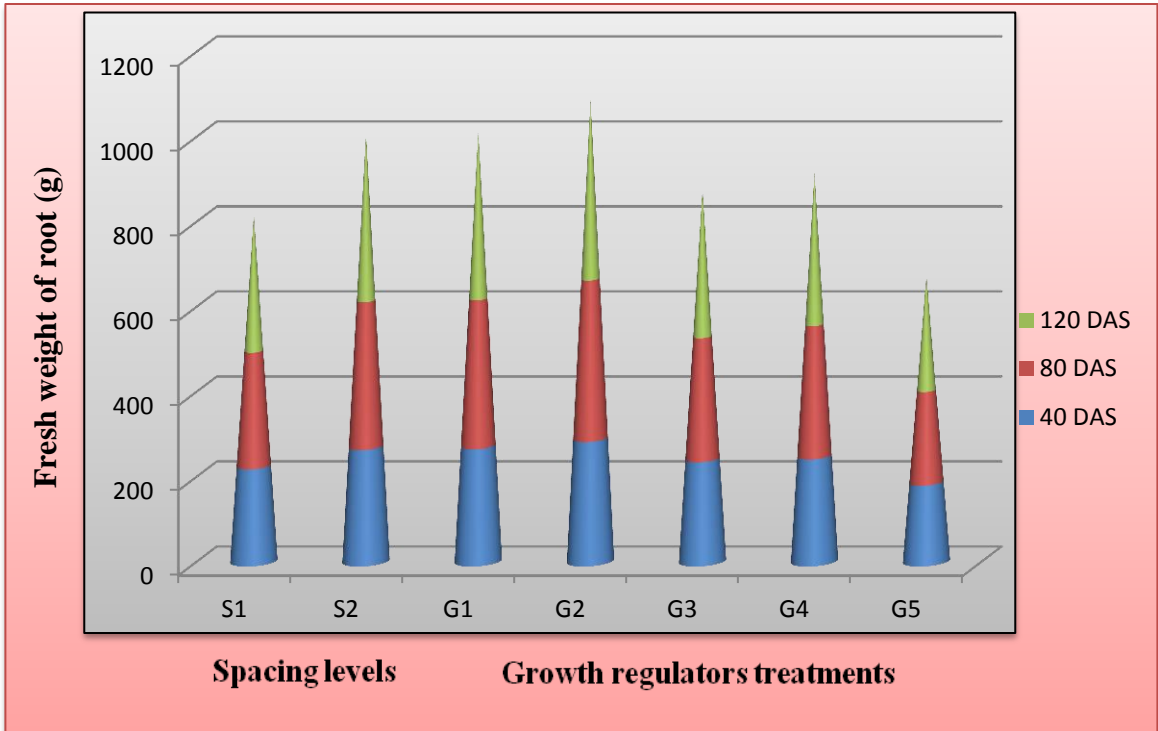


Fig. 6. Fresh weight of root as influenced by spacing and growth regulators at different intervals after sowing in radish.

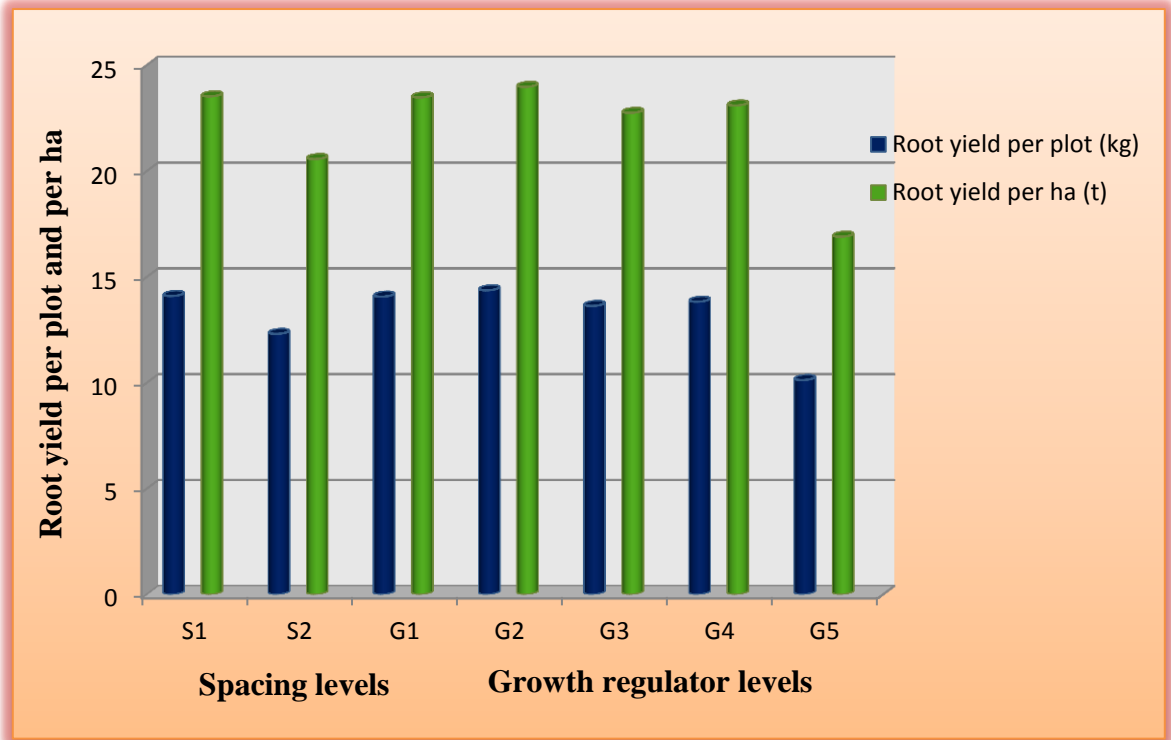


Fig. 7. Root yield per plot and per hectare as influenced by spacing and growth regulators at different intervals after sowing in radish.

The number of siliqua per plant differed significantly among the different spacing levels. Significantly more number of siliqua per plant (229.54) was observed at wider spacing (45 × 45 cm), while, less number of siliqua per plant (183.96) was found at narrow spacing (30 × 30 cm). The difference in spacing brought significant variation in number of pods harvested per plant in wider spacing than in closer spacing which seems to be mainly due to more number of branches per plant and also less competition among the plants for nutrients and light. Similar results were reported by Manoj *et al.* (2012) in radish.

Number of seeds per pod showed significant differences among different spacing. Among different spacing levels, wider spacing of 45 × 45 cm recorded significantly maximum number of seeds per pod (5.75), whereas minimum number of seeds per pod (4.03) was noticed in closer spacing (30 × 30 cm). More number of seeds per pod were observed in wider spacing as compared to closer spacing, which seems to be mainly due to more photosynthetic area which was enhanced by more nutrients and light availability to individual plants due to lack of competition. These results are in agreement with the results of Samnotra *et al.* (1998) and Sachan and Singh (2005) in radish.

The pod weight per plant, length of pod (fig. 8) and seed yield per plant was found to be maximum (21.49 g, 7.10 cm and 7.28 g respectively) at wider spacing (45 × 45 cm). While, minimum pod weight per plant, length of pod and seed yield per plant (15.97 g, 5.68 cm and 5.84 g respectively) was recorded at narrow spacing (30 × 30 cm). This shows that wider spacing is optimum to get maximum pod weight, pod length and seed yield per plant. This increase pod yield and seed yield per plant at wider spacing may be due to well establishment of the plant, which in turn resulted in production of more number of pods per plant which leads to more seed yield per plant. Similar results were obtained by Malav and Yadav (1997) in coriander, Sharma and Lal (1986) and Samnotra *et al.* (1998) in radish. Malik *et al.* (1999) and Kutijabi (2007) in carrot.

Among different spacing levels, plants spaced at 30 × 30 cm (S₁) recorded significantly higher seed yield per plot and per hectare (0.36 kg and 5.99 q). Whereas, S₂ recorded lowest seed yield per plot and per hectare (0.23 kg and 3.75 q). Though, seed yield per plant were low (5.84 g) in closer spacing, significantly higher seed yield per plot and per hectare were recorded at closer spacing (fig. 9). This may be because of increased plant population per unit area. These results are in conformity with the findings of Saini and Rastogi (1976), Malik *et al.* (1983) and Ahmad and Tanki (1997) in carrot seed production, Yadav and Singh (1997) in turnip, Brar and Kaul (1971), Sharma and Lal (1986), Sharma and Lal (1987), Sharma and Lal (1991) and Malik *et al.* (1999) in radish.

5.1.6 Seed quality parameters

Seed quality parameters differed significantly among two different spacing. The maximum per cent germination, seedling length, seedling dry weight and seedling vigour index was recorded at 45 × 45 cm S₂ spacing (86.93%, 14.99 cm, 11.33 mg and 1318 respectively) and the least was recorded at 30 x 30 cm S₁ (81.73 % , 12.61 cm, 9.07 mg and 1062 respectively) spacing. The higher seed quality attributes at wider spacing might be due to better establishment of plants due to less competition among them for nutrients and light. Ultimately resulting in proper development of seed reflecting in higher 1000 seed weight and higher seed quality which inturn might have supplied adequate food reserves during germination. Higher seedling vigour of these were attributed to higher root, shoot growth and seedling dry weight which ultimately exhibited higher field emergence. These results are in accordance with the findings of Malik (1973), Sharma and Singh (1982), Malik *et al.* (1983) in carrot, Singh and Singh (1985), Srivastava *et al.* (1992), Chatterjee and Som (1991), Jamwal and Thakur (1993), Malik *et al.* (1999) and Sachan and Singh (2005) in radish.

The maximum test weight was recorded at 45 × 45 cm (S₂) spacing as compared to 30 × 30 cm (S₁) spacing. The test weight was found to be maximum (8.96 g) at wider spacing (45 × 45 cm). While, minimum test weight (6.58 g) was recorded at closer

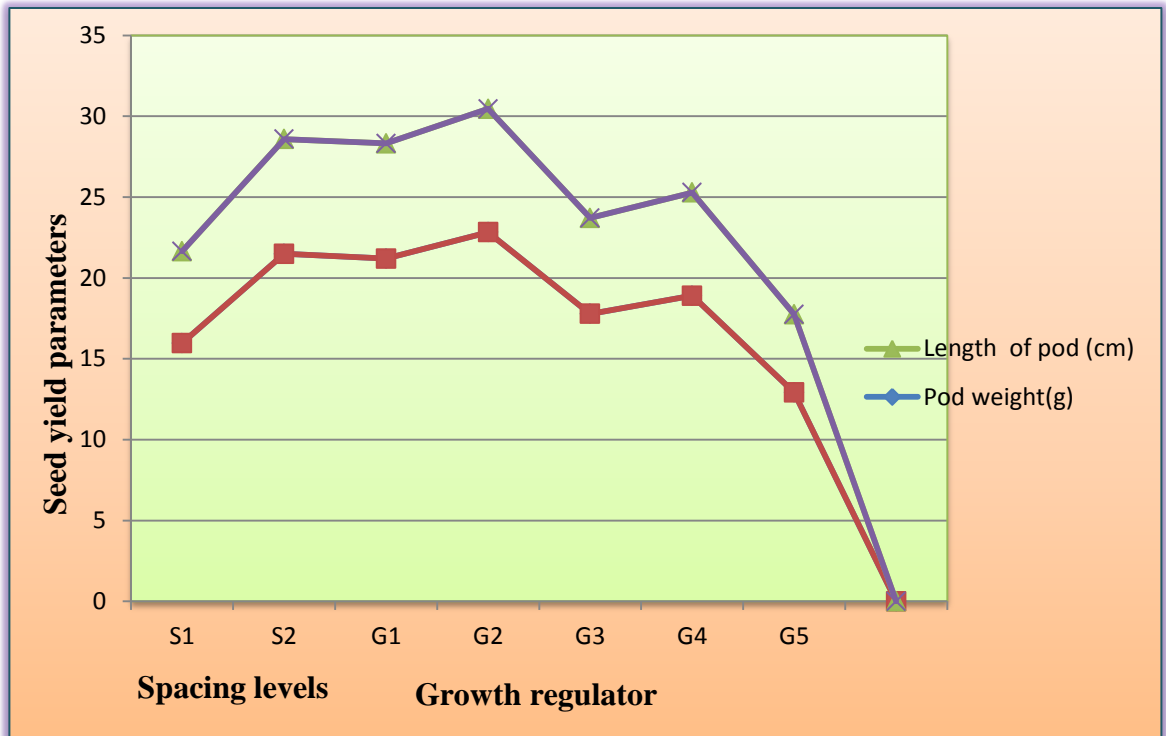


Fig. 8. Length of pod and pod weight as influenced by spacing and growth regulators at different intervals after sowing in radish.

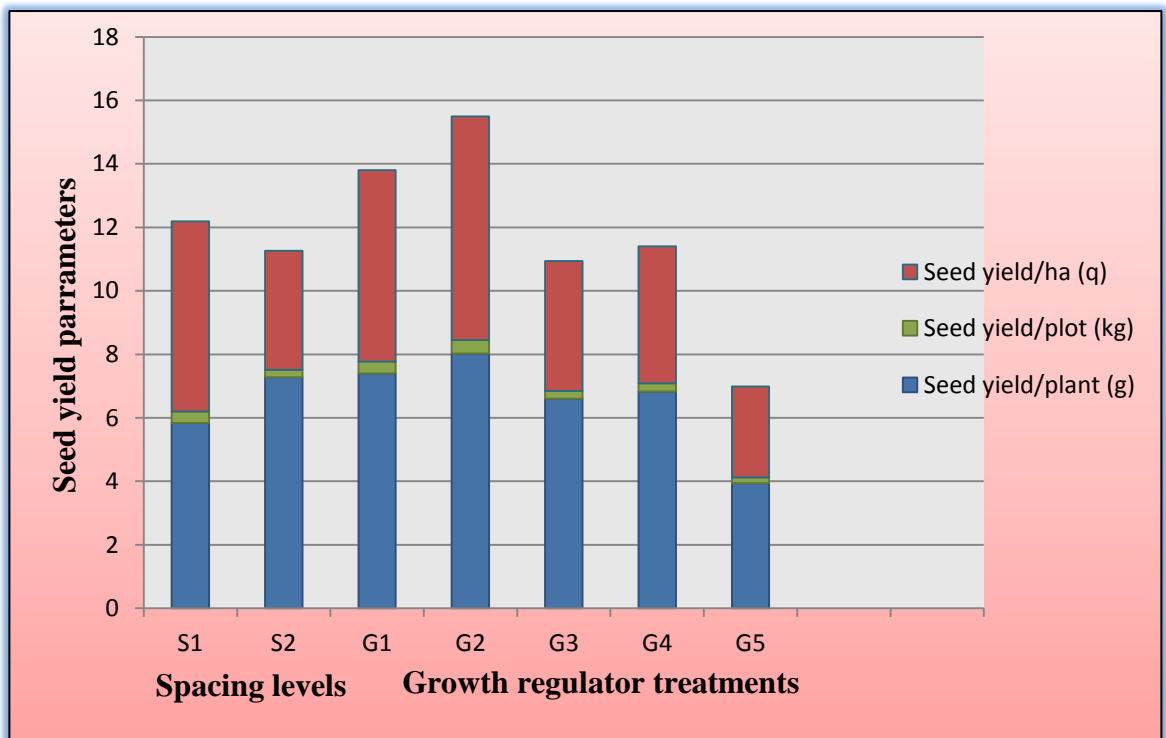


Fig. 9. Seed yield per plant, plot and per ha as influenced by spacing and growth regulators at different intervals after sowing in radish.

spacing (30 × 30 cm). The reason for increased yield components in wider spacing may be attributed to less competition among the plants and translocation of more assimilates to seed development, which ultimately resulted in better nourishment and plant growth. The results are in line with the findings of Sachan and Singh (2005) and Manoj *et al.* (2012) in radish.

5.2 Growth regulators

5.2.1. Morphological parameters

In the present study, the plant height varied significantly among different growth regulator treatments. The results indicated that maximum plant height (79.73 cm) was recorded in GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (76.78 cm) and are statistically on par with each other. While, minimum plant height (63.83 cm) was recorded in control (G₅). The increase in plant height was mainly due to the hormonal action of enhancing cell division and cell elongation. Further GA₃ act at the gene level influencing the translocation and transpiration mechanism of protein bio synthesis (Key, 1969) thus resulting in increased plant height. The similar findings were reported by Ganapathi (2006), Kutijabi (2007) and Abbas (2011) in carrot, Waghmode *et al.* (2010) in onion, Muhammad *et al.* (2013) in bitter gourd and Shirzad *et al.* (2013) in pumpkin.

In the present study, application of growth regulators had a profound and significant effect on production of number of leaves per plant, leaf length and leaf width. The results indicated that maximum number of leaves per plant, leaf length and leaf width (21.35, 39.00 cm and 17.42 cm respectively) was recorded in GA₃ 250 ppm (G₂) followed by GA₃ 200 ppm (G₁). While, minimum number of leaves per plant, leaf length and leaf width (11.58, 26.67 cm and 11.83 cm respectively) was recorded in control (G₅). An increase in these parameters due to the application of growth regulators may increase in leaf area as a result of which photosynthetic activity, efficient translocation and utilization of photosynthates causing rapid cell division and cell elongation in actively growing region of the plant leading to stimulation of growth (Dicks, 1980). These results are in line with the observations made by Mahabir Singh and Rajodia (1989) in radish,

Gavaskar and Anburani (2004) in brinjal, Ganapathi (2006) and Kutijabi (2007) in carrot and Muhammad *et al.* (2013b) in okra.

Spread of the plant and number of branches per plant varied significantly at all the stages of plant growth due to different growth regulator treatments. GA₃ 250ppm (G₂) recorded significantly higher plant spread and number of branches per plant (1182.00 cm² and 14.65) respectively. The least plant spread and number of branches per plant (749.83 cm² and 7.68 respectively) was observed in control (G₅). An increase in plant spread due to the application of GA₃ which enhances rapid cell elongation in actively growing region of the plant leading to stimulation of new growth resulting in the more number of branches and plant spread. These results are in agreement with Malhotra and Chaudhry (2001) in radish, Balaraj *et al.* (2002) in chilli, Panda *et al.* (2007) in coriander, and Abbas (2011) in carrot.

The stem diameter varied significantly among different growth regulators. The result observed that maximum stem diameter (3.00 cm) was recorded in GA₃ 250 ppm. While, minimum stem diameter (2.21 cm) was recorded in control. Foliar application of growth regulators increase in stem diameter might be attributed to increase in cell division and cell elongation in cambium region.

The fresh and dry weight of leaves varied significantly among different growth regulator treatments. The maximum fresh weight and dry weight of leaves (80.47 g and 8.28 g respectively) was recorded in GA₃ 250 ppm (G₂). While, minimum fresh weight and dry weight of leaves (50.62 g and 5.12 g, respectively) was recorded in control (G₅). The increase in the vegetative growth may be due to enhanced cell multiplication, division and cell elongation. The results are in agreement with the findings of Mahabir Singh and Rajodia (1989), Singh and Dohare (1964) and Das and Prusty (1982) in brinjal.

The fresh and dry weight of stem varied significantly among different growth regulator treatments. The results indicated that maximum fresh and dry weight of stem (124.47 g and 26.65 g) was recorded in GA₃ 250 ppm (G₂). While, minimum fresh and dry stem (92.08 g and 19.05 g) was recorded in control (G₅). The higher fresh and dry

weight of stem may be due to better carbon assimilation and distribution of photosynthates in the plants. The results are in agreement with the findings of Mahabir Singh and Rajodia (1989), Singh and Dohare (1964) in radish and Das and Prusty (1982) in brinjal.

5.2.2 Growth parameters

Leaf area fairly gives a good idea of the photosynthetic capacity of the plant. In the present study, the maximum leaf area and leaf area index (530.67 cm^2 and 7.65 respectively) were recorded with the application of GA_3 250 ppm (G_2). While, the minimum leaf area and leaf area index were recorded in control (232.00 cm^2 and 2.04 respectively). This may be due to positive effect of growth regulators on cell division and cell elongation leading to enhanced leaf expansion. Shekhar (1974) also reported that leaf area increased with an increase in time to a maximum coinciding with maximum top growth and steady decline at later stages. Knypl (1979) and Nirmal *et al.* (1994) also reported increased leaf area and leaf area index due to the application of RDF + GA_3 in onion and Deotale *et al.* (1998) in soyabean.

The absolute growth rate and crop growth rate was differed significantly at all the stages of the crop growth. At 40-80 DAS, maximum absolute growth rate and crop growth rate (0.41 g per day and $3.18 \text{ g per m}^2 \text{ per day}$, respectively) were recorded with GA_3 250 ppm (G_2), while least was noticed under control (0.24 g per day and $1.85 \text{ g per m}^2 \text{ per day}$). At 80-120 DAS, maximum absolute growth rate and crop growth rate (0.47 g per day and $3.54 \text{ g per m}^2 \text{ per day}$ respectively) were recorded with GA_3 250 ppm (G_2), which was statistically on par (0.41 g per day and $3.08 \text{ g per m}^2 \text{ per day}$ respectively) with NAA 250 ppm. While, the minimum absolute growth rate and crop growth rate (0.29 g per day and $2.22 \text{ g per m}^2 \text{ per day}$ respectively) were recorded in control.

In the present study, it was found that the absolute growth rate (AGR) and crop growth rate (CGR) increased with increase in the crop duration. Crop growth rate is a widely used character for estimating production efficiency per unit land area and enables to make comparisons between the aspects of study (Watson, 1952). The application of

GA₃ significantly increased the crop growth rate at all the stages compared to other treatments.

Net assimilation rate (NAR), synonymously called as 'Unit leaf rate', expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory area. At 40-80 DAS, maximum net assimilation rate (0.0061 g / dm² / day) was recorded in control, followed by NAA 200 ppm (0.058 g / dm² / day), while the least under GA₃ 250 ppm (0.049 g / dm² / day). At 80-120 DAS, maximum net assimilation rate (0.071 g / dm² / day) was recorded in control, followed by NAA 200 ppm (0.047 g / dm² / day), while the least under GA₃ 250 ppm (0.042 g / dm² / day).

5.2.3 Root parameters

The root length and root girth varied significantly among different growth regulators. The results indicated that maximum root length and root girth (32.40 cm and 15.60 cm) was recorded in GA₃ 250 ppm (G₂). While, minimum root length and root girth (22.40 cm and 10.47 cm) was recorded in control (G₅). The increase in root length and girth might be due to GA stimulates nutrient uptake by inducing rapid cell division and cell elongation. The increase of root size might be also due to application of growth regulators had improved the internal physiology of developing economic parts in terms of better supply of water, nutrients and other compounds vital for their proper growth and development which resulted in improved size as compared to control. Similar results were given by Abdul *et al.* (2002) and Geetharani *et al.* (2008) in onion and Kutijabi (2007) in carrot.

The fresh weight of root varied significantly among different growth regulator treatments. The results indicated that maximum fresh weight of root (420.33 g) was recorded in GA₃ 250 ppm (G₂). While, minimum fresh weight of root (268.67 g) was recorded in control (G₅). The increase in fresh weight of root might be due to foliar application of growth regulators helps to activate polar transport of assimilates, promote cell multiplication and enlargement and more accumulation of food materials like sugars

and water in expanded cells. These results are in conformity with the findings of Abdul *et al.* (2002) in onion.

The data on root dry weight indicated significant differences due to growth regulator treatments at all the stages and it increased drastically from 40 DAS to harvest. The dry weight of root varied significantly among different growth regulator treatments. The results indicated that maximum dry weight of root (21.03 g) was recorded in GA₃ 250 ppm (G₂) While, minimum dry weight of root (13.43 g) was recorded in control (G₅).

The application of GA₃ showed significantly higher root dry weight over others treatments may be due to increased translocation of assimilates from source to the economic part. Similar results of increased bulb dry weight in onion were reported with the application of GA₃ (Padmavathi, 1998 and Singh *et al.*, 1982) in onion.

In the present study, significantly higher root yield per plot and per hectare were recorded with GA₃ application. Among the different growth regulator treatments, GA₃ 250 ppm (G₂) recorded the maximum root yield per plot and per hectare (14.37 kg and 23.98 t, respectively). The lowest root yield per plot and per hectare (10.13 kg and 16.90 t, respectively) were observed in control (G₅). These plant growth regulators are involved in enhancement of photosynthesis and nitrogen metabolism which are major physiological activities in plants. The plant growth substances, either as spray or seed treatment brings about spectacular results both in yield and quality of vegetable crops (Ries and Houtz, 1983). Gibberellic acid was found to be significantly superior compared to other treatments in enhancing the morpho-physiological parameters of the plant. The higher yield may be due to better carbon assimilation and accumulation of carbohydrates in the economic parts. The results are in agreement with the findings of Mahabir Singh and Rajodia (1989) in radish, Abdul *et al.* (2002) in onion and Chauhan and Tandel (2010) in cabbage.

5.2.4 Biochemical parameter

Chlorophyll 'a', chlorophyll 'b' and total chlorophyll content in leaves were significantly influenced by growth regulators. Maximum total chlorophyll content in

leaves (2.43 mg/g fr. wt) was recorded with application of GA₃ 250 ppm (G₂) followed by (2.08 mg/g fr. wt) GA₃ 200 ppm (G₁) while minimum (1.22 mg/g fr. wt) was recorded in control. This might be due to GA₃ may stimulate biosynthetic pathway of chlorophyll. The application of RDF + GA₃ affects carbon assimilation through changes in carbonic anhydrase activity (Khan, 1996 and Khan *et al.*, 1996).

5.2.5 Seed yield parameters

Among different growth regulators, GA₃ (250 ppm) recorded significantly less number of days to 50 per cent flowering. The advanced 50 per cent flowering (78.50 days) was observed at GA₃ 250 ppm followed by GA₃ 200 ppm (85.67 days) and NAA 250 ppm (89.33 days), whereas in control delayed (102.33 days) the days taken for 50 per cent flowering. Early flowering in GA₃ spray may be due to increase in the endogenous gibberellins levels in the plants, as gibberellins are well known for inducing early flowering in several crops. These results are well supported by the previous findings of Bala and Hari (2004) in bhendi, Kutijabi (2007) in carrot, Panda *et al.* (2007) in coriander, Geetharani *et al.* (2008) in onion, and Priya *et al.* (2012) in chilli.

The number of siliqua per plant and number of seeds per pod differed significantly at different concentration of growth regulator treatments. Number of siliqua per plant and number of seeds per pod was found to be maximum (234.07 and 6.33) at GA₃ 250 ppm (G₂). Whereas, minimum number of siliqua per plant and number of seeds per pod (175.00 and 3.17) were recorded at control (G₅). This might be due to the fact that enhanced food material translocated towards the site of production of flower resulted in the higher siliqua and seed set. Similar, results have been quoted by Maske *et al.* (1998) in soyabean, Malhotra and Chaudhry (2001) in radish, Bala and Hari (2004), Patil *et al.* (2008) and Muhammad *et al.* (2013 b) in okra.

The pod weight per plant and length of pod differed significantly with respect to different growth regulator treatments. The pod weight per plant and length of pod were found to be maximum (22.83 g and 7.63 cm) at GA₃ 250 ppm (G₂). While minimum pod weight per plant and length of pod (12.92 g and 4.83 cm) were recorded in control (G₅). This might be due to GA₃ plays an important role in partitioning of more assimilates from

the place of synthesis to the place of consumption. Similar results have been reported by Malhotra and Chaudhry (2001) in radish, Bala and Hari (2004), Patil *et al.* (2008) and Muhammad *et al.* (2013b) in okra.

The seed yield per plant, seed yield per plot seed and seed yield per ha differed significantly with respect to different growth regulator treatments. The maximum (8.03 g, 0.42 kg and 7.05 q respectively) seed yield per plant, seed yield per plot and seed yield per ha was found at GA₃ 250 ppm (G₂). Whereas, minimum seed yield per plant, seed yield per plot and yield per ha (3.94 g, 0.18 kg and 2.87 q) was recorded in control (G₅). The higher seed yield might have happened due to metabolic changes brought out by GA₃ application at flowering. This might be due to the fact that enhanced food material translocated towards the site of production resulted in the high siliqua and seed set. The increase in yield and yield parameters with GA₃ spraying was due to better crop growth, more leaves which increased the number of umbels per plant and ultimately increased the seed yield. The sprayed plants remained physiologically more active and built up sufficient food reserves for developing flowers and seeds. The results are in conformity with the findings of Balaraj *et al.* (2002) in chilli, Goudappalavar (2000) in tomato (Bhat and Singh, 1996) in okra. Similar results were given by Malhotra and Chaudhry (2001) in radish, Natesh *et al.* (2005) in chilli, Panda *et al.* (2007) in coriander, Kutijabi (2007) and Ghoname *et al.* (2011) in carrot and Geetharani *et al.* (2008) in onion.

5.2.6 Seed quality parameters

Germination per cent differed significantly among the different growth regulator treatments. The maximum per cent germination was recorded in G₂ (89.33%), which was statistically on par with G₄ (88.00%), G₁ (87.00%), and G₃ (84.00%). However, the least was recorded in G₅ (76.00 %). Per cent germination was more in GA₃ 250 ppm might be due to gibberellins play a vital role in synthesis of hydrolytic enzymes especially, α – amylase, which in turn convert starch into sugar and is utilized by the growing embryo. Increase in germination percentage may be because of bolder seeds that contain greater metabolites for resumption of embryonic growth during germination. In addition to these metabolites, release of certain enzymes responsible for degradation of macromolecules

into micro molecules within the seed. Similar, result was obtained by Kutijabi (2007) in carrot, Geetharani *et al.* (2008) in onion and Priya *et al.* (2012) in chilli.

The seedling length, seedling dry weight, seedling vigour index and test weight differed significantly among different growth regulator treatments. GA₃ 250 ppm (G₂) recorded significantly higher (15.88 cm, 12.22 mg, 1439 and 9.70 g) seedling length, seedling dry weight, seedling vigour index and test weight respectively, whereas, minimum seedling length, seedling dry weight, seedling vigour index and test weight (10.42 cm, 6.58 mg, 787 and 5.55 g) respectively was recorded in control (G₅). This is mainly due to GA₃ application which brings about metabolic changes that affect the both quality and quantity of the desired product. It also stimulates synthesis of hydrolytic enzymes which are secreted and act as starchy endosperm in turn affecting physiology of seed germination and seedling vigour. Similar effects and GA₃ on seed germination and vigour was also reported by Bhat and Singh (1996) in okra.

The increase in seed quality parameters due to certain changes in metabolism during seed development due to which there would be greater accumulation of food reserves resulting in higher seed quality. These results are in line with the findings of Gowda (2003) in coriander, Kodalli (2006) in chilli, Kutijabi (2007) and Ghoname *et al.* (2011) in carrot, Panda *et al.* (2007) in coriander, Geetharani *et al.* (2008) in onion, Patil *et al.* (2008) in okra, Priya *et al.* (2012) in chilli and Shirzad *et al.* (2013) in pumpkin.

5.3 Interaction

The interaction effect of spacing and growth regulators on morphological parameters were differed significant at different intervals after sowing (DAS). The treatment combination 45 × 45 cm spacing and GA₃ 250 ppm (S₂G₂) recorded maximum (85.53 cm) plant height (fig. 10), number of leaves per plant (24.43) (fig. 11), leaf length (42.67 cm), leaf width (20.33 cm), spread of the plant (1264 cm²), number of branches per plant (18.07), stem diameter (3.70 cm), fresh weight of leaves (86.27 g), dry weight of leaves (8.77 g), fresh weight of stem (129.07 g), dry weight of stem (27.90 g), leaf area (664.33 cm²) and total chlorophyll content in leaves (3.08 mg / g fr.wt). The increase in these parameters under wider spacing with application of GA₃ may be due to the vigorous

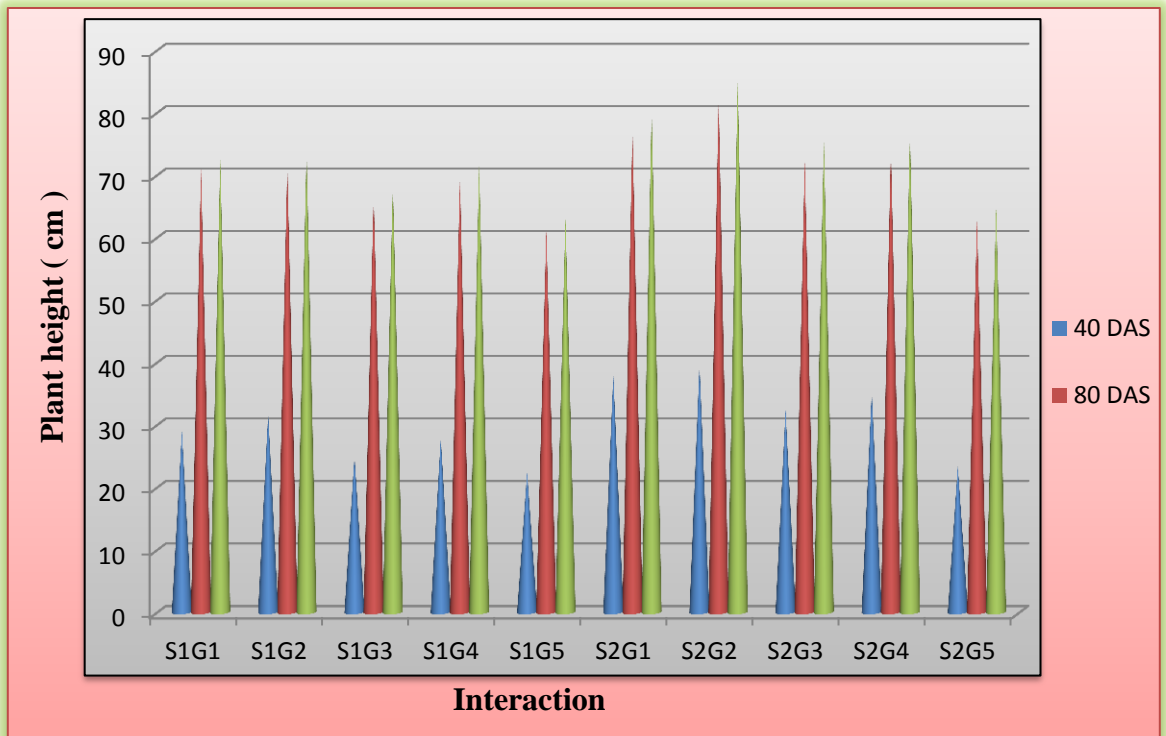


Fig. 10. Plant height as influenced by spacing and growth regulators at different intervals after sowing in radish.

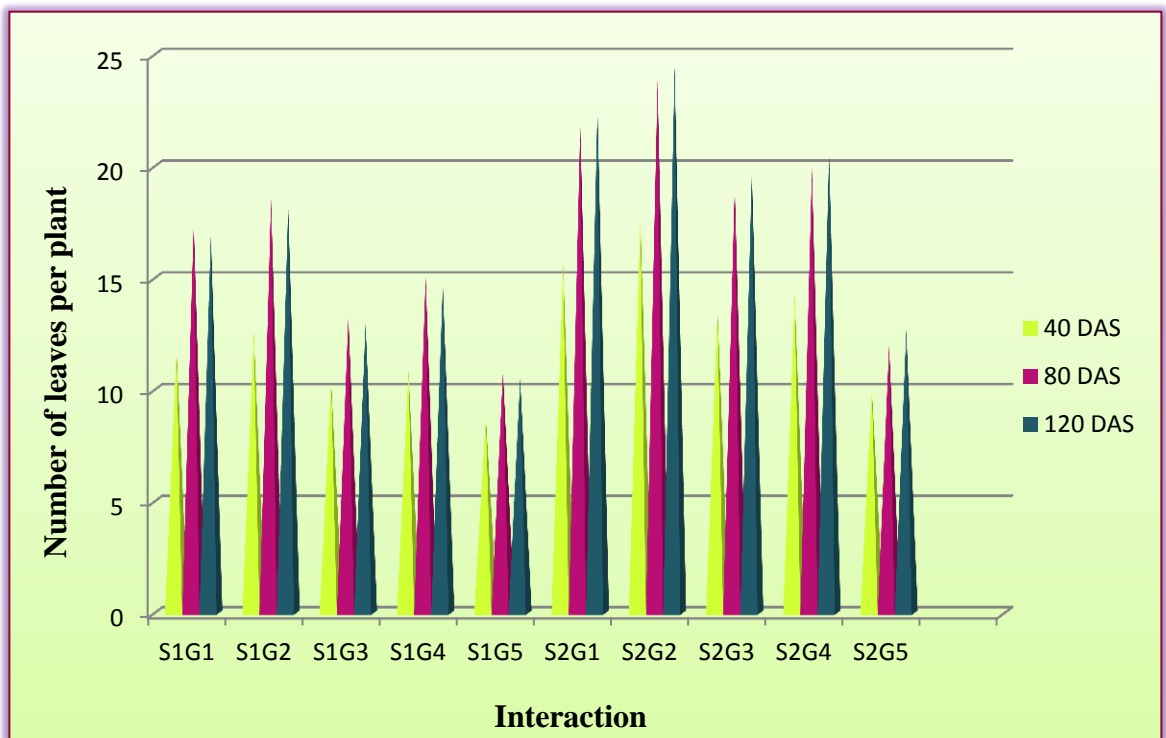


Fig. 11. Number of leaves per plant as influenced by spacing and growth regulators at different intervals after sowing in radish.

growth in wider spacing between the plants as a result of less competition for light, water and nutrition and due to the hormonal action of enhancing cell division and cell elongation. Further GA₃ act at the gene level influencing the translocation and transpiration mechanism of protein bio synthesis thus resulting in increased morphological and growth parameters. The similar findings were reported by Ganapathi (2006), Kutijabi (2007) and Abbas (2011) in carrot, Waghmode *et al.* (2010) in onion, Muhammad *et al.* (2013 a) in bitter gourd, Shirzad *et al.*(2013) in pumpkin Pervez *et al.* (2004), Sachan and Singh (2005) and Manoj *et al.* (2012) in radish.

The interaction of spacing and growth regulators was non significant with respect to leaf area index, absolute growth rate and net assimilation rate.

The interaction effect between spacing and growth regulators was significantly differs with respect to root parameters at different intervals after sowing. The maximum root length (36.80 cm), root girth (17.63 cm), fresh weight of root (480.00 g) and dry weight of root (24.03 g) were observed in S₂G₂ (45 × 45 cm with GA₃ 250 ppm) treatment combinations and the minimum was recorded in S₁G₅ (30 × 30 cm with control) treatment combinations. Which might be due to reduced competition for essential soil nutrients and sunlight which probably promoted the accumulation of photosynthates in roots, the widely spaced plants have accumulated more dry matter through better utilization of light, moisture and space and application of growth regulators had improved the internal physiology of developing economic parts in terms of better supply of water, nutrients and other compounds vital for their proper growth and development which resulted in improved size as compared to control. Similar results were reported by Pervez *et al.* (2004), Lavanya *et al.* (2014) in radish. Kutijabi (2007), Dawuda *et al.* (2011) in carrot, Abdul *et al.* (2002) and Geetharani *et al.* (2008) in onion.

Among the interaction of spacing and growth regulators, significant variation was observed with respect to root yield per plot and per hectare. The maximum root yield per plot and per hectare (15.00 kg and 25.02 t respectively) and minimum (7.63 kg and 12.73 t) was recorded in S₁G₂ (30 × 30 cm with GA₃ 250 ppm) and S₂G₅ (45 × 45 cm with control) treatment combination, respectively. Increment in total yield production due to

increased plant density may be brought about by the higher ground cover of leaf area resulted in higher light interception and hence, higher assimilate production and gibberlic acid growth regulator treatments are involved in enhancement of photosynthesis and nitrogen metabolism which are major physiological activities in plants. Similar results have been reported by Rao and Manohar (1990), Sirkar *et al.* (1998) and El-Desuki *et al.* (2005), Mahabir Singh and Rajodia (1989) in radish, Abdul *et al.* (2002) in onion and Chauhan and Tandel (2010) in cabbage.

Among the interaction of spacing and growth regulators, significant variation was observed with respect to seed yield per plot and per hectare. The maximum seed yield per plot and per hectare (0.55 kg and 9.16 q respectively) and minimum (0.17 kg and 2.79 q respectively) were recorded in S₁G₂ (30 × 30 cm with GA₃ 250 ppm) and S₂G₅ (45 × 45 cm with control) treatment combinations, respectively. This may be because of increased plant population per unit area. The higher seed yield might have happened due to metabolic changes brought out by GA₃ application at flowering. This might be due to the fact that enhanced food material translocated towards the site of production resulted in the high seed yield. These results are in conformity with the findings of Ahmad and Tanki (1997), Kutijabi (2007), Ghoname *et al.* (2011) in carrot. Brar and Kaul (1971), Sharma and Lal (1986), Sharma and Lal (1987), Sharma and Lal (1991), Malik *et al.* (1999), Malhotra and Chaudhry (2001) in radish, Natesh *et al.* (2005) in chilli, Panda *et al.* (2007) in coriander and Geetharani *et al.* (2008) in onion.

Significant differences were recorded for the interaction effect between spacing and growth regulators on seed yield and quality parameters (fig. 12 and 13). The minimum days to 50 per cent flowering (66.00 days), maximum number of siliqua per plant (264.00), number of seeds per pod (7.33), pod weight (25.97 g), length of pod (8.70 cm), seed yield per plant (8.53 g), germination per cent (93.33 %), seedling length (17.83 cm), seedling dry weight (13.13 mg), seedling vigour index (1677) and test weight (12.00 g) was recorded at (45 × 45 cm + GA₃ 250 ppm) S₂G₂ combination. Whereas, minimum was recorded at (30 × 30 cm with control) (plates. 6, 7 and 8). Which seems to be mainly due to more photosynthetic area which was enhanced by more nutrients and light availability to individual plants due to lack of competition and the higher

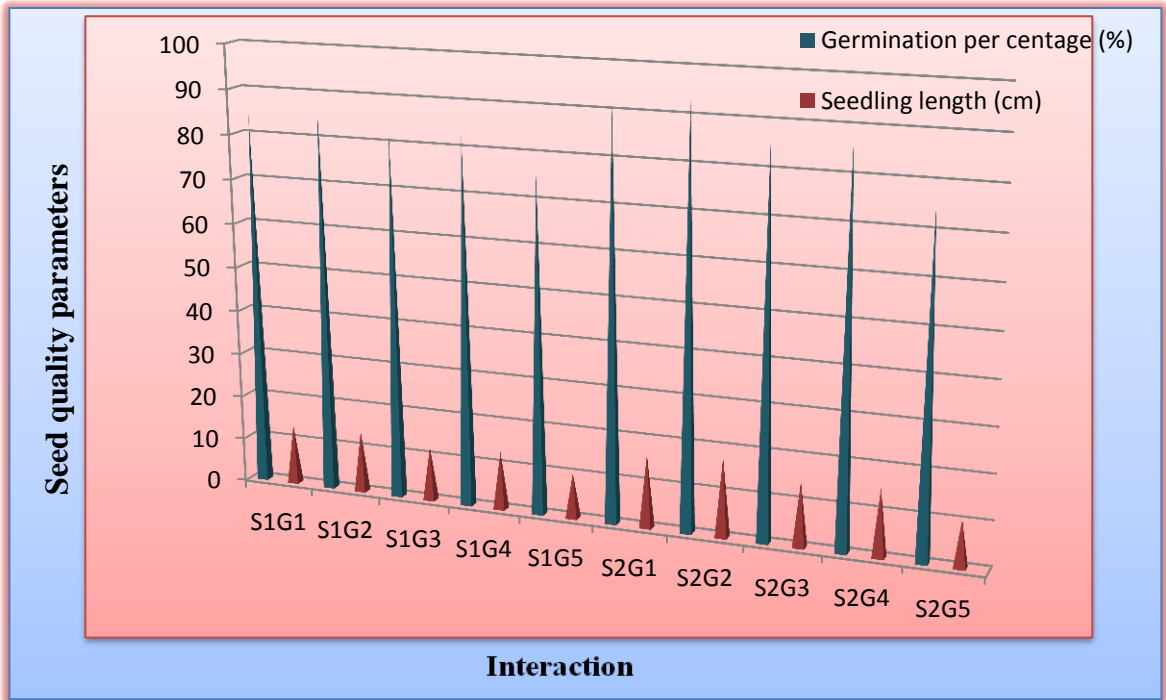


Fig. 12. Seed germination per cent and seedling length as influenced by spacing and growth regulators at different intervals after sowing in radish

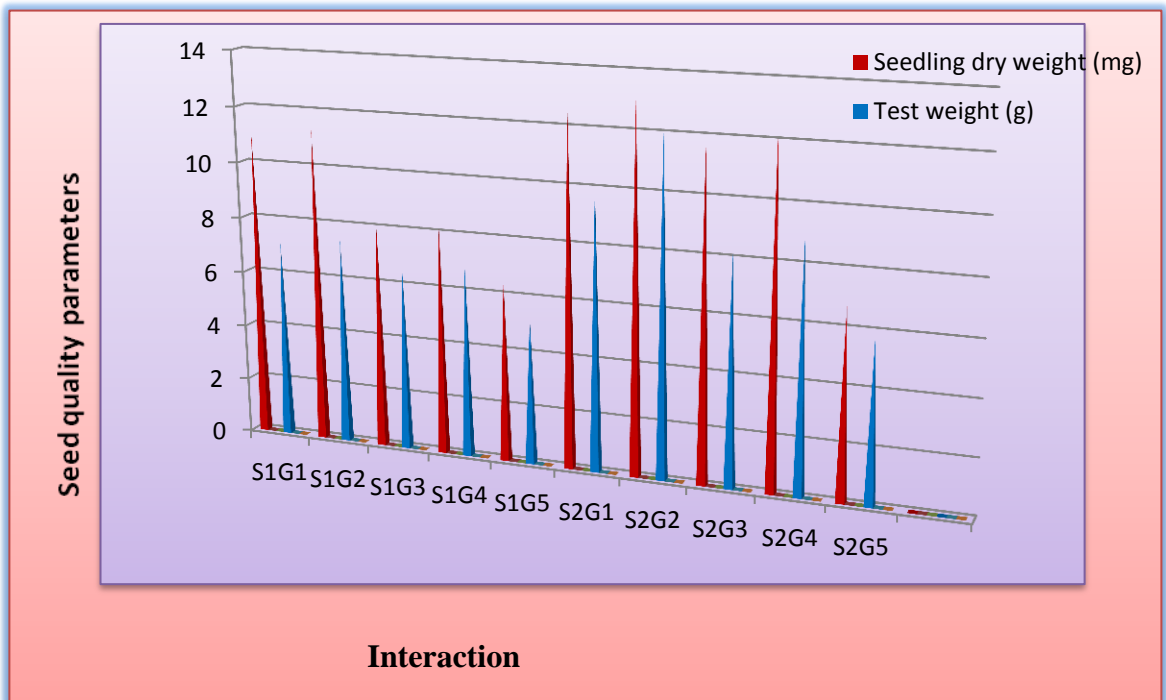


Fig. 13. Seedling dry weight and test weight as influenced by spacing and growth regulators at different intervals after sowing in radish.



45 × 45 cm + GA₃ 250 ppm



45 × 45 cm + GA₃ 200 ppm



30 × 30 cm + NAA 250



30 × 30 cm + control

Plate 6. Influence of spacing and growth regulators on flowering



45 × 45 cm + GA₃ 250 ppm



30 × 30 cm + control

Plate 7. Influence of spacing and growth regulators on size of pod



45 × 45 cm + GA₃ 250 ppm



30 × 30 cm + control

Plate 8. Influence of spacing and growth regulators on seed germination

seed quality attributes at wider spacing might be due to better establishment of plants due to less competition among them for nutrients. Ultimately resulting in proper development of seed reflecting in higher seed quality which in turn might have supplied adequate food reserves during germination. GA₃ application which brings about metabolic changes that affect the both quality and quantity of the desired product. It also stimulates synthesis of hydrolytic enzymes which are secreted and act on starchy endosperm in turn affecting physiology of seed germination and seedling vigour. These results are in agreement with the results of Samnotra *et al.* (1998) and Sachan and Singh (2005) in radish, Kutijabi (2007), Ghoname *et al.* (2011) in carrot, Panda *et al.* (2007) in coriander, Geetharani *et al.* (2008) in onion, Patil *et al.* (2008) in okra, Priya *et al.* (2012) in chilli and Shirzad *et al.* (2013) in pumpkin.

5.4 Economics

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 levels of spacing with growth regulators and their interaction levels. In radish, the maximum benefit cost ratio (1.70) was recorded at (45 × 45 cm + 250 ppm GA₃) S₂G₂ treatment combination followed by (45 × 45 cm + 200 ppm GA₃) S₂G₁ (1.67). The minimum cost benefit ratio (0.19) was recorded in the treatment combination (30 × 30 cm + control) S₁G₅ treatment.

Though the seed yield per ha was higher in closer spacing, but due to smaller seeds, poor quality and low per cent germination hence these seeds have lower market price. Whereas, the seeds obtained with wider spacing was sold at higher price due to bold seeds, good quality and high per cent germination. Hence maximum net return and benefit cost ratio was more in wider spacing.

Silent findings of the study

Among the different spacings, wider (45 × 45 cm) spacing found to be optimum with respect to morphological traits, growth parameters, biochemical constituents, root and seed yield and quality attributes in radish.

Among the different growth regulator treatments, G₂ (GA₃ 250 ppm) found to be optimum with respect to morphological traits, growth parameters, biochemical constituents, root and seed yield and quality attributes in radish. These results confirmed that growth regulators improve the growth, yield and quality of radish.

With respect to interaction levels, application of GA₃ 250 ppm with 45 × 45 cm spacing was found to be optimum for vigorous vegetative growth, higher root and seed yield and quality parameters and the same treatment also obtained highest cost benefit ratio (1.70) in radish.

Future line of work

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

1. Standardization of different growth regulators and their concentrations as seed treatment for seed production.
2. Standardization of seed production methods by using root stecklings under hill zone.
3. Standardization of seed quality enhancement through priming and pelleting.
4. Need to study nutrition with different spacing levels.
5. Standardization of various storage methods to enhance the shelf life of the seeds.

SUMMARY

VI. SUMMARY

The present investigation was carried out on “Effect of plant geometry and growth regulators on growth, root and seed yield of radish (*Raphanus sativus* L.) cv. Pusa Chetki” in an experimental open field, Department of vegetable science, College of Horticulture, Mudigere during the period from November 2014 to March 2015.

In this experiment two spacings (45 × 45 cm and 30 × 30 cm) and two levels of growth regulators (GA₃ and NAA) each at two concentration (200 ppm and 250 ppm) with control, were tried in all possible combinations and assessed for growth, root and seed yield characters. The results obtained from the study are summarized here under.

Increased plant height (75.47 cm), maximum number of leaves per plant (20.05), increased leaf length (36.43 cm) and leaf width (16.03 cm), maximum spread of the plant (1099.07 cm²), more number of branches per plant (13.71) and maximum stem diameter (3.00 cm) were observed at wider spacing (45 × 45 cm) compared to closer spacing (30 × 30 cm). With respect to growth regulator treatments, increased plant height (79.73 cm), maximum number of leaves per plant (21.35), increased leaf length (39.00 cm) and leaf width (17.42 cm), maximum spread of the plant (1182.00 cm²), more number of branches per plant (14.65) and maximum stem diameter (3.00) were observed with the application of GA₃ 250 ppm, while minimum values were recorded at control (water spray).

Fresh weight of leaves and stem as influenced by spacing and plant growth regulators differed significantly. Maximum fresh weight of leaves and stem (73.98 g and 118.51 g respectively), were recorded at wider spacing compared to closer spacing. Among the growth regulators GA₃ 250ppm was significantly differed with respect to fresh weight of leaves and stem. The results revealed that maximum fresh weight of leaves and stem (80.47 g and 124.47 g) were recorded in GA₃ 250 ppm. While, minimum values were recorded in control.

Significantly highest dry matter accumulation in leaves (7.55 g / plant) and stem (24.83 g / plant) were observed at wider spacing (45 × 45 cm). Similarly, highest dry

matter accumulation in leaves (8.28 g / plant) and stem (26.65 g / plant) were observed at GA₃ 250 ppm.

The leaf area and leaf area index increased drastically upto 80 DAS and steadily increased toward harvest. The increased the leaf area (530.67 93 cm²) and leaf area index (7.65) was more pronounced with growth regulators. The higher leaf area (459.93 cm²) was recorded at wider spacing. While, higher leaf area index (5.38) was recorded at closer spacing. Leaf area and leaf area index varied significantly at all the stages of plant growth with respect to spacing and growth regulators.

Maximum absolute growth rate (0.44 g / day) observed at wider spacing (45 × 45 cm). Whereas crop growth rate (3.78 g / m² / day) and net assimilation rate (0.055 g / dm² /day) were observed at closer spacing (30 × 30 cm). In case of growth regulator treatments, increased absolute growth rate (0.47 g /day), crop growth rate (3.54 g/m² /day) and net assimilation rate (0.042 g / dm² /day) was found to be optimum at GA₃ 250 ppm.

Root parameters such as root length, root girth, fresh weight of root, dry weight of root, root yield per plot and per hectare varied significantly by spacing and growth regulators. The maximum root length (30.40 cm), root girth (14.63 cm), fresh weight of root (392.33g) and dry weight of root (19.63g) were recorded in wider spacing (45 × 45 cm) compared to closer spacing (30 × 30 cm). The maximum root yield per plot (14.10 kg) and root yield per ha (23.52 t) were recorded in closer spacing (30 x 30cm). Among the growth regulators GA₃ 250 ppm was significantly differed with respect to root length, root girth, fresh weight of root, dry weight of root of radish. The maximum root length (32.40 cm), root girth (15.60 cm), fresh weight of root (420.33g) and dry weight of root (21.03 g), root yield per plot (14.37 kg) and root yield per ha (23.98 t) were recorded in GA₃ 250 ppm. While, minimum values were recorded in control.

Biochemical parameter studied indicated significant differences due to different spacing levels and growth regulator treatments. Chlorophyll 'a' (2.07 mg / g fr. wt), chlorophyll 'b' (0.36 mg / g fr. wt) and total chlorophyll content (2.43 mg / g fr. wt) were

significantly higher with the application GA₃ 250 ppm followed by GA₃ 200 ppm as compared to control. Among Spacing levels, wider spacing recorded significantly higher values over closer spacing.

The days taken to 50 per cent flowering (78.50 days) was decreased with the foliar application of gibberllic acid 250 ppm at bud initiation stage compare to control (102.33 days). Among the different spacing levels, plants spaced at 45 × 45 cm took less number of days (83.93 days) for 50 per cent flowering. Whereas, plants spaced at 30 × 30 cm took more number of days (95.24 days) for 50 per cent flowering.

Seed yield parameters like number of siliqua per plant (229.54), number of seeds per pod (5.75), pod weight (21.49 g), pod length (7.10 cm) and seed yield per plant (7.28 g) were found to be higher at wider spacing 45 × 45 cm compared to closer spacing (30 × 30 cm). While, maximum seed yield per plot and per hectare (0.36 kg and 5.99 q, respectively), were recorded at closer spacing 30 × 30 cm compared to wider spacing.

Seed yield parameters like number of siliqua per plant (234.07), number of seeds per pod (6.33), pod weight (22.83 g), pod length (7.63 cm), seed yield per plant (8.03 g), seed yield per plot (0.42 kg) and per hectare (7.05 q) were found to be maximum with the foliar application of gibberllic acid at 250 ppm compared to control. With respect to interaction, the treatment combination of 45 × 45 cm and GA₃ 250 ppm was found to be maximum for number of siliqua per plant (264.00), pod weight (25.97 g) and pod length (8.70 cm).

Seed quality attributes were significantly influenced by different levels of spacing and growth regulator treatments. Seed quality parameter *viz.*, germination percentage (86.93 %), test weight (8.96 g), seedling length (14.99 cm), seedling dry weight (11.33 mg) and seedling vigour index (1318) were found to be maximum at wider spacing (45 × 45 cm). While, lowest germination percentage (81.73 %), test weight (6.58 g), seedling length (12.61 cm), seedling dry weight (9.07 mg) and seedling vigour index (1062) were recorded at 30 × 30 cm spacing.

Among different growth regulator concentrations, highest germination percentage, test weight, mean seedling length, seedling dry weight, and seedling vigour index were recorded in gibberlic acid @ 250 ppm (89.33 %), (9.70 g), (15.88 cm), (12.22 cm) and (1439) compared to control (76.00 %), (5.55 g),(10.42 cm),(6.58 g) and (787), respectively.

Foliar application GA₃ @ 250 ppm and wider spacing 45 × 45 cm has resulted in maximum net return (₹. 1,87,102.95 / ha) with a benefit cost ratio of 1.70.

Sowing of radish by 45 × 45 cm spacing was found to be best with respect to growth, root and seed yield of radish. Application of GA₃ 250 ppm recorded maximum growth, root and seed yield of radish.

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VII. REFERENCES

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* *Originals not seen.*

APPENDICES

APPENDIX- I

Monthly meteorological data during the experimental period at the ZAHRS, Mudigere..

Month	Rainfall (mm)	Temperature (⁰ C)		Relative humidity (%)
		Maximum	Minimum	
	2014-2015	2014- 2015	2014- 2015	2014- 2015
January 2014	Nil	26.90	14.62	63.25
February	Nil	27.12	15.16	60.53
March	Nil	32.0	18.5	68
April	188.7	31.41	18.78	78.9
May	265.6	31.53	18.53	74.54
June	306.4	28.25	17.8	73.6
July	1185.4	26.40	17.19	72.38
August	542.6	26.29	17.35	88.22
September	365.4	27.41	18.75	90.63
October	88	26.46	18.01	81.70
November	12	26.96	17.41	73.46
December	19	26.80	14.91	74.29
January 2015	Nil	27.14	14.58	63.58
February	Nil	28.28	15.2	60.46
March	Nil	32.20	18.37	53.12

APPENDIX-II

SOIL PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SITE

Particulars	Values	Method adopted
Physical properties		
Coarse sand (%)	44.3	International pipette method (Piper, 1966)
Fine sand (%)	23.4	
Silt (%)	18.6	
Clay (%)	20.1	
Chemical properties		
Available nitrogen (kg/ha)	149.4	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available phosphorus (kg/ ha)	20.5	Bray's Extractant No-1 method (Jackson,1973)
Available potassium (kg /ha)	131.8	Neutral Normal Ammonium Acetate method by (Jackson, 1973)
Organic carbon (%)	0.92	Walkey and Black's method, 1965
Soil pH	5.39	P ^H meter (Jackson, 1973)
EC ds/m at 25 °C	0.17	Conductivity bridge (Jackson, 1973)

APPENDIX – III

Per ha cost structure in radish seed production.

No.	Materials/works	Cost (₹)
I.	Variable cost	
1	Fertilizers (75: 38: 38 kg NPK/ha)	
	a. Urea @ ₹ 5.52/kg	894.24
	b. Rock phosphate @ ₹ 8.4/kg	1995.00
	c. MOP @ ₹ 19.6/kg	1243.81
2	FYM	40000
3	Seeds	
	a. Spacing (S ₁)	4160
	b. Spacing (S ₂)	3120
4.	Plant protection chemicals	2700
4	Labour charge	180/day
5	Tractor charge, Land preparation	4000
6	Seed sowing	900
7	Earthing up + fertilizer application	1800
8	Weeding	2700
9	Irrigation	2700
10	Harvesting	1800
11	Threshing of pods	900
12	Winnowing and cleaning of seeds	1800
II	Fixed cost	
1	Rental value of farm, Land revenue etc	6000
III.	Total cost (A)	
	a. S ₁	73593.05
	b. S ₂	72553.05

Note : Seed price (₹) = 520 per kg.

APPENDIX-IV

Cost of cultivation (₹. per ha) in seed production of radish using different spacing and growth regulators.

Treatments	Cost of the treatments (₹)				
	GA ₃	NAA	Labour	Total cost (B)	Total cost (₹) (A +B)
S ₁ G ₁ - 30 × 30cm + GA ₃ 200 ppm	28005.6	-	1800	29805.6	103398.65
S ₁ G ₂ - 30 × 30cm + GA ₃ 250 ppm	34944	-	1800	36744	110337.05
S ₁ G ₃ - 30 × 30cm + NAA 200 ppm	-	1116.9	1800	2916.9	76509.95
S ₁ G ₄ - 30 × 30cm + NAA 250 ppm	-	1458.31	1800	3258.31	76851.36
S ₁ G ₅ - 30 × 30cm + control	-	-	-	-	73593.05
S ₂ G ₁ - 45 × 45cm + GA ₃ 200 ppm	28005.6	-	1800	29805.6	102358.65
S ₂ G ₂ - 45 × 45cm + GA ₃ 250 ppm	34944	-	1800	36744	109297.05
S ₂ G ₃ - 45 × 45cm + NAA 200 ppm	-	1116.9	1800	2916.9	75469.95
S ₂ G ₄ - 45 × 45cm + NAA 250 ppm	-	1458.31	1800	3258.31	75811.36
S ₂ G ₅ - 45 × 45cm + control	-	-	-	-	72553.05

Seed price (₹) = 520 per kg

APPENDIX- V

LIST OF SYMBOLS AND ABBREVIATIONS

Symbols	Abbreviations
%	Per cent
@	At
⁰ C	Degree centigrade
CD	Critical difference
cm	Centimeter
cm ²	Centimeter square
cv.	Cultivar
<i>et al.</i>	Et alii (and other)
g	Gram
hr	Hour
<i>i.e.</i>	That is
Kg	Kilogram
m ²	Meter square
mg	Milligram
ml	Milliliter
mm	Millimeter
ppm	Parts per million
S.Em.	Standard Error of Mean
q	quintals
<i>viz.</i>	As follows
GA ₃	Gibberellic acid
NAA	Naphthalene acetic acid
AGR	Absolute growth rate
CGR	Crop growth rate
NAR	Net assimilation rate