“EFFECT OF INORGANIC NUTRIENTS AND BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*) Cv. PUSA BHARATI”

S. HIMA BINDU

B. Sc (Hons.) Horticulture

MASTER OF SCIENCE IN HORTICULTURE

(VEGETABLE SCIENCE)

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF HORTICULTURE, RAJENDRANAGR,

HYDERABAD- 500030.

SRI KONDA LAXMAN TELANGANA STATE HORTICULTURAL UNIVERSITY

MULUGU (VIL & MNDL), SIDDIPET (DIST), TELANGANA-502279

NOVEMBER, 2021

"EFFECT OF INORGANIC NUTRIENTS AND BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*) Cv. PUSA BHARATI"

By

S. HIMA BINDU

B. Sc (Hons.) Horticulture

THISES SUBMITTED TO SRI KONDA LAXMAN TELANGANA STATE HORTICULTURAL UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT

FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN HORTICULTURE

(VEGETABLE SCIENCE)

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF HORTICULTURE, RAJENDRANAGAR-500030.

SRI KONDA LAXMAN TELANGANA STATE

HORTICULTURAL UNIVERSITY

NOVEMBER, 2021

CERTIFICATE

Ms. **S. HIMA BINDU** has satisfactorily prosecuted the course of research and that the thesis entitled **"EFFECT OF INORGANIC NUTRIENTS AND BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*) Cv. PUSA BHARATI"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any University.

Place: Rajendranagar, Hyderabad **Dr. M. HANUMAN NAYAK**

Date: 24-07-2021 **Chairman**

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF INORGANIC NUTRIENTS AND BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF SPINACH BEET (*Beta vulgaris* var *bengalensis*) Cv. PUSA BHARATI"** submitted in partial fulfilment of the requirements for the degree of Master of Science in Horticulture (Vegetable Science) of Sri Konda Laxman Telangana State Horticulture University, Mulugu, Siddipet is a record of bonafide research work carried out by **Ms. S. HIMA BINDU** under our guidance and supervision.

No part of thesis has been submitted by the student of any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

Thesis approved by the Student Advisory Committee

Chairman: **Dr. M. HANUMAN NAYAK**
Senior Scientist, (Hort.) & Head,
Vegetable Research Station,
Rajendranagar, Hyderabad-500030. ____________________

Member: **Dr. P. PRASANTH**
Senior Scientist (Hort.) & Head,
Floricultural Research Station,
Rajendranagar, Hyderabad-500030. ____________________

Member: **A. MAMATHA**
Scientist, (Hort.)
Vegetable Research Station,
Rajendranagar, Hyderabad-500030. ________________

Member: **Dr. S. PRANEETH KUMAR**
Scientist, (Crop Physiology)
Floricultural Research Station,
Rajendranagar, Hyderabad-500030. __________________

Date of final viva-voice: 10-11-2021

DECLARATION

I, Ms. **S. HIMA BINDU** hereby declare that the thesis entitled **"EFFECT OF INORGANIC NUTRIENTS AND BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*) Cv. PUSA BHARATI"** submitted to Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, for the degree of Master of Science in Horticulture (Vegetable Science) is the result of original work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

Place: Rajendranagar　　　　　　　　Name: S. Hima bindu

Date: 24-07-2021　　　　　　　　I.D.No : RHM/2019-19

ACKNOWLEDGEMENTS

I would like to commence my acknowledgement with the name of God Almighty for his boundless blessings which accompanied me in all endeavours.

I am grateful and privileged to have worked under the esteemed guidance of the chairman of my Advisory committee ***Dr. M. Hanuman Nayak****, Senior scientist (Hort.) & Head, Vegetable Research Station, ARI, Rajendranagar, Hyderabad for his co-operation, affectionate guidance and extending all possible help and valuable suggestions.*

I am grateful and privileged to convey my fidelity to the member of my Advisory committee, ***Dr. P. Prasanth,*** *Senior scientist (Hort.) & Head, Floricultural Research Station, ARI, Rajendranagar, Hyderabad for his co-operation and encouragement given, which entitled in me the spirit of confidence to successfully complete this task.*

I sincerely extend my profound gratitude to the member of my Advisory Committee, ***Smt. Mamatha****, scientist (Hort.), Vegetable Research Station, Rajendranagar, for her kind co-operation, valuable suggestions and timely assistance.*

I sincerely extened my thanks to the member of my advisory committee ***Dr. S. Praneeth Kumar,*** *Scientist, Crop Physiology, Floriculture Research Station, Rajendranagar for his valuable suggestions during the course of my research work.*

It is also a pleasure in expressing my thankfulness to ***Smt. A.V.N. Lavanya,*** *scientist (Hort.), Vegetable Research Station, Rajendranagar, Hyderabad, for her guidance, constant encouragement from starting to end of the task.*

I want to express my heartfelt gratitude and thanks to ***Dr. M. Padma*** *(Dean of PG studies),* ***Dr. A. Kiran Kumar****, Comptroller and Director of Extension, SKLTSHU, Mulugu, Siddipet, for their motivation and assistance to carry out the work in pandemic situation.*

With a profound and unfailing sense of obligation I express my heartily thanks to ***Dr. A. Girwani,*** *Associate Dean,* ***Dr. D. Laxminarayana,*** *Associate Professor,* ***Dr. K. Venkata laxmi,*** *Assistant Professor, P.G. Incharge,* ***Dr. S. Mallesh,*** *Assistant Professor,* ***Smt. K. Nirosha,*** *Assistant Professor and* ***Dr. D. Naga Harshitha,*** *Assistant Professor College of Horticulture, Rajendranagar, for their support.*

This thesis would be incomplete if I do not reckon the sacrifice, love, affection, and support of my father ***Mr. S. Solomon raj****, mother* ***Mrs. S. Manjula****, brother* ***S. Nihal raj.*** *Without their efforts and blessings, it was not possible to complete my degree programme. I express my gratitude to my dear relatives* ***Samson,*** *Babai-****Daniel,*** *Pinni-****Swarupa rani, Neela, Praneeth, Pranay, Parishudh*** *and* ***Hymavathi*** *for their best wishes, help and encouragment during the course of work.*

My deepest sense of love and indebtedness to my beloved ***Sunitha, Sowjanya, Santhosha*** *and* ***Tejeswini*** *for their selfless support, meticulous affection and constant encouragement.*

I specially thankful to my friends and batchmates ***Sripriya, Swarna, Gayathri, Sruthi, Prashanthi, Akhila, Sneha, Suchitha, Swathi, Shivateja, Akash, Prashanth, Mahesh, Srikanth, Sai Krishna, Irfan*** *and lovely juniors* ***Mounika, Merin, Amulya, Alekya, Queeny, Madhusri, Ruth, Junisha, Saranya, Diana*** *and* ***Sushma.***

I would like to offer my special thanks to ***Sai baba*** *(PG academic section),* ***Vinod, Vanitha, Naveen, Narasimha*** *and also for giving earnest suggestions and opportunity to continue my departmental study and necessary facilities.*

Finally, I am thankful to the Sri Konda Laxman Telangana State Horticultural University for giving this opportunity and to the Government of Telangana for providing the financial assistance during the course of my study.

(*S. HIMA BINDU*)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF ILLUSTRATIONS

12.	Effect of inorganic nutrients and biofertilizers on leaf yield plant^{-1} (g) in spinach beet Cv. Pusa Bharati	
13.	Effect of inorganic nutrients and biofertilizers on leaf yield ha^{-1} (q) in spinach beet Cv. Pusa Bharati	
14.	Effect of inorganic nutrients and biofertilizers on Moisture (%) in spinach beet Cv. Pusa Bharati	
15.	Effect of inorganic nutrients and biofertilizers on Shelf life (No. of days) in spinach beet Cv. Pusa Bharati	
16.	Effect of inorganic nutrients and biofertilizers on vitamin-C (mg 100 g^{-1}) in spinach beet Cv. Pusa Bharati	
17.	Effect of inorganic nutrients and biofertilizers on carotene content (mg 100 g^{-1}) in spinach beet Cv. Pusa Bharati	
18.	Effect of inorganic nutrients and biofertilizers on Chlorophyll (SPAD units) in spinach beet Cv. Pusa Bharati	
19.	Effect of inorganic nutrients and biofertilizers on Physiological loss in weight (%) in spinach beet Cv. Pusa Bharati	
20.	Effect of inorganic nutrients and biofertilizers on macronutrients (kg ha^{-1}) in soil after harvest of the crop	
21.	Effect of inorganic nutrients and biofertilizers on micronutrients (mg 100 g^{-1}) in soil after harvest of the crop	
22.	Benefit cost ratio as influenced by inorganic nutrients and biofertilizers in spinach beet Cv. Pusa Bharati	

APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Percentage
&	:	and
/	:	Per
@	:	at the rate
₹	:	Rupee
^{0}C	:	degree Celsius
1N	:	1 Normality
AMC	:	Arka Microbial Consortium
B	:	Boron
C/N ratio	:	Carbon to Nitrogen ratio
Ca	:	Calcium
CD @ 5%	:	Critical Difference at 5% level of Significance
Cl	:	Chlorine
cm	:	Centimeter
cm^2	:	Centimeter square
Co_4	:	Carbon tetroxide
Cu	:	Copper
Cv	:	Cultivar
d^{-1}	:	per day
DAS	:	Days after sowing
DTPA	:	Diethylenetriaminepentaacetic acid
E	:	East
EC	:	Electric conductivity
et. al	:	and others
Etc	:	and so on
Fe	:	Iron
Fed	:	Federal reserve system
$FeSo_4$	:	Ferrous sulphate

Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram
g-1	:	per gram
ha	:	Hectare
ha^{-1}	:	per hectare
Hcl	:	Hydrochloric acid
HPO_3	:	Meta phosphoric acid
i.e	:	in other words
IIHR	:	Indian Institute of Horticulture institute
INM	:	Integrated nutrient management
IU	:	International unit
K	:	Potassium
K_2O	:	Potassium oxide
Kg	:	Kilogram
$KMnO_4$	:	Potassium permanganate
KSB	:	Potassium solubilizing bacteria
L	:	Litre
L-1	:	per litre
LAD	:	Leaf area duration
LAI	:	Leaf area index
m^{-2}	:	Meter square
Mg	:	Magnesium
mg	:	milligram
ml	:	millilitre
mm	:	millimeter
Mn	:	Manganese
Mo	:	Molybdenum
MT	:	Metric tonne
N	:	North
N_2	:	Nitrogen
$NaHCO_3$	:	Sodium bicarbonate

NaOH	:	Sodium hydroxide
NFB	:	Nitrogen Fixing Bacteria
nm	:	nano meter
No.	:	Number
No_3	:	Nitrate
NPs	:	Nano particles
P	:	Phosphorous
P. G	:	Post graduate
P^H	:	power of hydrogen
PJTSAU	:	Professor Jayashanker Telangana state Agricultural university
$Plant^{-1}$	:	per plant
$plot^{-1}$	:	per plot
PLW	:	Physiological loss weight
ppm	:	parts per million
PSB	:	Phosphorous solubilizing bacteria
q	:	Quintal
RBD	:	Randomized Block Design
RD	:	Recommended dose
RDF	:	Recommended dose of fertilizers
RDN	:	Recommended dose of Nitrogen
RR	:	Recommended rate
S	:	South
S	:	Sulphur
SEm ±	:	Standard error mean ±
SKLTSHU	:	Sri Konda Laxman Telangana State Horticultural university
SLA	:	Specific leaf area
SLW	:	Specific leaf weight
sp.	:	species
SPAD	:	Soil Plant Analytical Development
ssp.	:	Sub species

t	:	tonnes
TSS	:	Total soluble solids
VAM	:	Vesicular arbuscular mycorrhizae
Var.	:	Variety
VC	:	Vermicompost
viz.,	:	namely
W	:	West
Zn	:	Zinc
ZnO	:	Zinc oxide
$ZnSo_4$	:	Zinc sulphate

Name of the author : **S. HIMA BINDU**

I.D. No. : **RHM/2019-19**

Title of the thesis : **"EFFECT OF INORGANIC NUTRIENTS AND BIOFERTILIZERS ON GROWTH, YIELD AND QUALITY OF SPINACH BEET (*Beta vulgaris* var. *bengalensis*) Cv. PUSA BHARATI"**

Degree to which it is submitted : **MASTER OF SCIENCE IN HORTICULTURE**

Faculty : **HORTICULTURE**

Major Field : **VEGETABLE SCIENCE**

Major advisor : **Dr. M. HANUMAN NAYAK**

University : **SRI KONDA LAXMAN TELANGANA STATE HORTICULTURAL UNIVERSITY**

Year of submission : **2021**

ABSTRACT

The present investigation entitled **"Effect of inorganic nutrients and biofertilizers on growth, yield and quality of spinach beet (*Beta vulgaris* var *bengalensis*) Cv. Pusa Bharati"** was carried out during rabi season of the year 2020-21 at PG research farm, College of Horticulture, Rajendranagar, Hyderabad.

A total of ten treatments with three replications were carried out to know the effective combination of nutrient application on morphological parameters like plant height (cm), leaf length (cm), leaf width (cm) and length of leaf petiole (cm). Growth parameters like leaf area (cm^2), leaf area index, specific leaf area (cm^2 g^{-1}), specific leaf weight (g cm^{-2}) and leaf area duration (cm^2 d^{-1}). Yield parameters like number of leaves, leaf weight (g), leaf yield per plant (g) and leaf yield (q ha^{-1}). Quality parameters like moisture content (%), shelf life (No. of days), vitamin-C (mg 100 g^{-1}), carotene content (mg 100 g^{-1}), physiological loss in weight (%) and economics were worked out.

The results related to morphological parameters revealed that, among different treatment combinations, T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) registered significantly higher plant height (14.94, 26.84 and 35.80 cm), maximum leaf length (10.94, 18.38 and 23.32 cm), maximum leaf width (4.16, 12.45 and 13.52 cm) and length of leaf petiole (7.79, 10.00 and 14.94 cm) at 15, 30 and 45 DAS respectively.

The results pertaining to growth parameters reported that, among the treatment combinations, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1})

recorded significantly maximum leaf area (120.83, 353.56 and 401.88 cm^2), highest leaf area index (0.402, 1.178 and 1.339) at 15, 30 and 45 DAS. Specific leaf area was recorded minimum values (8.91, 12.57 and 6.96 cm^2 g^{-1}) in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) whereas, maximum values (15.07, 25.57 and 14.64 cm^2 g^{-1}) was recorded in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) at 15, 30 and 45 DAS. Highest Specific leaf weight (0.112, 0.079 and 0.143 g cm^{-2}) at 15, 30 and 45 DAS and highest leaf area duration between 15 to 30 DAS and 30 to 45 DAS (11.79 and 18.75 cm^2 d^{-1}) were recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}).

The data pertaining to yield parameters, highest number of leaves (13.16, 16.56 and 19.91), maximum leaf weight (19.38, 38.76 and 36.44 g) highest leaf yield per plant (41.53, 47.65 and 98.11 g) and highest leaf yield per hectare (412.75 q ha^{-1}) were recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) at 30, 45 and 60 DAS respectively.

The results pertaining to quality parameters indicated that maximum Vitamin-C (65.70 mg 100 g^{-1}), Carotene content (10.59 mg 100 g^{-1}) and Chlorophyll (41.63 SPAD units) were recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}). Lowest moisture content (84.46 %) with minimum PLW (47.24 %) which ultimately increases the shelf life (2.99 days) was obtained in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}).

The data on economics of treatment combinations showed that, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded higher gross returns (₹ 199375/-), net returns (₹ 103214/-) and benefit cost ratio (6.00) Whereas, the minimum benefic cost ratio (3.50) recorded in treatment T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75kg ha^{-1})

It can be concluded from present study that, T_9 (T_6+ Arka vegetable special @ 5 g L^{-1}) treatment was the effective combination of nutrient application on growth, yield and quality of spinach beet.

Chapter-I

INTRODUCTION

Chapter I

INTRODUCTION

Spinach beet (*Beta vulgaris* var. *bengalensis*; 2n=2x=18) is the most popular vegetable crop grown in India and other parts of the world as leafy vegetable. It belongs to the family Chenopodiaceae. It is also known as Indian spinach, Beet leaf in English and Palak in Hindi and is originated from Indo-Chinese region. (Nath, 1976)

Indian Council of Medical Research, New Delhi recommends 325 g of vegetables per person per day. Among these leafy vegetables contributes 50 g, tuber crops contribute 50 g and other vegetables including onion contributes 225 g per day per person for balanced diet. But, as per PJTSAU, actual consumption of leafy vegetables is 24 g per day per person in Telangana state. In India, spinach beet mostly grown for its nutritive, tender and soft succulent leaves and it plays a vital role in daily diet of humans with high nutritional values.

Spinach beet is rich in vitamins especially vitamin A (97701 IU) and other vitamins like Ascorbic acid (70 mg 100 g^{-1}), Riboflavin, Thiamine. Minerals like Iron and Calcium (380 mg 100 g^{-1}), Folic acid and some amounts of Nicotinic acid, Pyridoxine, Antioxidants as Carotene, Flavones, Indoles and Isothiocyanates, essential amino acids *etc.* Hence, it is called “Mines of Minerals” (Thamburaj and Singh, 2015).

India is blessed with diverse agro-climatic zones with distinct seasons, making it possible to grow wide range of vegetables and is second largest producer of vegetables next to China in the world. As per National Horticulture Database published by National Horticulture Board, during 2018-19, area under cultivation of vegetable crops is 10.1 million hectares with Production of 185.8 million Metric tonnes and Productivity of 18.4 MT ha^{-1}. According to National Horticulture Board, during 2018-19 in Telangana state, area under cultivation of Vegetable crops is 140.31 thousand hectares with production of 2548.69 lakh MT. Present area under cultivation of leafy vegetables in Telangana state is 21,208 acres with production of 89,577 MT.

In recent years, as the consumers are becoming more aware about the use of chemical free vegetables particularly leafy vegetables. Hence, it becomes the need to sustain the production level with minimum or no use of chemicals. Continuous application of chemicals deteriorates the soil and cause soil problems. Now-a-days, the producers are taking more interest in the nutritional harvest *i.e.,* quality of the produce in terms of its food value rather than its quantity per hectare. Ignorance of organic manures and random use of chemical fertilizers, soil becomes vulnerable that leads to nutrient imbalance and threat to ecological sustainability. It is also well understood that the ideal soil condition can be created through combination of organic manures for maximum crop yield.

In this modernization, consumption of chemicals like fertilizers, pesticides, growth regulators *etc.,* have been utilized in the production system. Farmers use huge amount of nitrogenous fertilizers for efficient growth leads to deterioration of quality, shelf-life and presence of chemical residue in leaves which causes harm to consumers.

Biofertilizer is a wide term applied to a diverse category of bio-inoculants such as nitrogen fixers Azotobacter, phosphate solubilizing Bacteria like *Pseudomonas*, *Bacillus*, *Rhizobium*, *Agrobacterium etc.,* and Potassium solubilizing bacteria like *Acidothiobacillus*, *Ferrooxians* and *Bacillus* spp. like *B. circulans, B. edaphicus and B.mucilagenous*. They are efficient, eco-friendly, cost effective, economically viable apart from meeting the crop nutrient requirements. They also play a significant role in improving nutrient availability in the soil for crop plants. Among various bio-inoculants Azotobacter, a nonsymbiotic, free-living, aerobic nitrogen fixing bacteria, can substitute part of inorganic fertilizers. Azotobacter inoculation saves nitrogenous fertilizers by 10-20 per cent (Mohandas, 1999). Phosphate Solubulizing bacteria (PSB) was reported to play a significant role in solubilizing the inorganic phosphates which are largely unavailable to plants and making it available to crop use (Tilak and Singh, 1994). Potassium solubilizing bacteria (KSB) can solubilize K-bearing minerals and convert the insoluble K to soluble forms of K available to plant uptake (Etesami *et al*., 2017).

Arka Microbial Consortium (AMC) is a carrier-based product which contains N Fixing, P and Zn solubilizing and plant growth promoting microbes as a single formulation. Besides, the synergistic effects of the formulated microbes can help in sustainable vegetable production.

Arka vegetable special is a micronutrient formulation contains most of the micronutrients such as Zn, B, Fe, Cu, Mn, Mo and Cl and also contains most of the secondary nutrients such as Ca, Mg, S and K which enhances fruit quality in terms of fruit appearance, fruit keeping quality and taste. It can be mixed with any fungicide or insecticide, recommended for all vegetable crops at different doses.

Most of the farmers use only urea as a fertilizer which is sometimes above recommended dose. They are not sufficiently aware of management practices and use of other fertilizers and bio fertilizer. Possibly these are the main causes of poor yield and soil health deterioration. Also, increase in N fertilizer led to increase in nitrate content of the crop tissues without significant increase in yield (Custic *et al.,* 1994). Increasing the use of chemical fertilizer led to high cost in vegetable production and creates pollution of their agricultural environment as well as affects the soil fertility; therefore, it has become essential to use untraditional fertilizers as supplements or substitutes for chemical fertilizers. In the same respect, (Ahmadi *et al.,* 2010) reported that, total yield, number of leaves/plant and nitrate content in leaves were increased by increasing chemical fertilizer NPK, while different fertilizer levels had no significant effect on petiole length.

To maintain and sustain a higher level of soil fertility and crop productivity, by reducing the levels of inorganic nutrients are very important in the crop production system. In addition, it minimizes the soil water pollution to greater extent. Therefore, it has become essential to use untraditional fertilizers as supplements or substitutes for chemical fertilizers. Keeping the facts in view, the study was carried out to examine the best inorganic nutrients and its combination with biofertilizers for better growth, yield and also nutrient availability for crop and soil with the following objectives.

OBJECTIVES

- To study the influence of inorganic nutrients and biofertilizers on growth and yield of Palak.
- To study the influence of inorganic nutrients and biofertilizers on quality of Palak.
- To find out the effective combination of nutrient application on growth and yield of Palak.

Chapter-II

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Commercialization of inorganic fertilizers had led to a major shift from organic manures to chemical fertilizers. But the continuous and haphazard uses of chemical fertilizers make the soil more problematic and threat to ecological sustainability. In recent years, as the consumers are more aware about the use of chemical free vegetables particularly leafy vegetables. Hence, there is need to reduce the levels of inorganic nutrients and it is essential to use untraditional fertilizers as supplements or substitutes for chemical fertilizers.

Balanced use of inorganic fertilizers and organic sources of nutrients such as organic manures and biofertilizers aims at maximizing yields, maintaining soil productivity, proper environment and ecological balance. This information on leafy vegetables is very scanty. Therefore, literature pertaining to leafy vegetables along with other vegetable crops also has been reviewed and presented in this chapter under the following sub-headings.

2.1. Effect of biofertilizers on growth and yield attributes

2.2. Effect of biofertilizers on quality attributes

2.3. Effect of inorganic and organic sources on growth and yield attributes

2.4. Effect of inorganic and organic sources on quality attributes

2.5. Effect of micronutrients on growth and yield attributes

2.6. Effect of micronutrients on quality attributes

2.1. Effect of biofertilizers on growth and yield attributes

Aishwath *et al.* (2012) studied the effect of PSB, Azotobacter and their combination on growth characters and yield attributes of coriander. Splitted seeds of coriander were inoculated with Azotobacter and PSB alone and their combinations. Results revealed that plant height at various stages and number of primary, secondary branches, numbers of umbellates/ umbel, seed, straw and biological yields were highest with combine use of PSB and Azotobacter.

Chamangasht *et al.* (2012) studied the effect of Azotobacter, Azospirillum, Pseudomonas (strain 187) and their mixture on lettuce growth and yield. Results indicated that inoculating seeds with the biofertilizers significantly increased plant height, the number of leaves, biomass, leaf area index and plant yield, compared with the control (no biofertilizer).

Choudhary *et al*. (2017) conducted an experiment consist of 16 treatment combinations *viz.*, four levels of fertility (control, 50 %, 75 % and 100 % recommended dose of NPK) and four different biofertilizer inoculations (control, Azotobactor, Azospirillum and PSB) in knol-khol. Among different bio-fertilizers the inoculation of PSB leads to maximum plant height, number of leaves per plant, knob diameter, biological yield per plant, average weight of knob, volume of knob, yield of knob per hectare but at par with Azospirillum.

Meena *et al.* (2017) evaluated on effect of organic manures and biofertilizers on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica* Plenck.) Cv. KTS-1 and recorded highest plant height (52.67 cm), number of leaves per plant (22.13), leaf length (43.07 cm), leaf width (35.20 cm), stem diameter (5.00 cm), days to curd (65.13), days to 50 % curd initiation (75.23 days), days taken to 50 % curd maturity (96.13 days), curd diameter (10.52 cm), curd weight (305.33 g), yield (125.20 q/ha)

Chaudhary *et al.* (2018) examined the response of three levels of biofertilizers *viz.* (Azotobactor, PSB, Azotobactor + PSB) and five different sources of organic manures *viz.* FYM, Vermicompost, Castor cake, Poultry manure, Neem cake in amaranthus. The results revealed that among different biofertilizers, minimum days taken for first cutting, second cutting, third cutting and fourth cutting at 20 cm height, maximum yield of first cutting, second cutting, third cutting and fourth cutting subsequently cutting at 20 cm height (g), yield per plot (kg) and yield per ha (q/ha) were recorded with treatment b_3 (Azotobactor + PSB) and treatment f_2 (Vermicompost).

Shinde *et al*. (2018) investigated on effect of biofertilizers on growth and yield of Spinach by using different combination treatments of biofertilizers. It was found that, the application of Azotobacter + PSB each @ 2 lit/ha were recorded maximum values of growth attributes like plant height (26.6 cm), number of leaves per plant (19.33), number of branches per plant (1.32) and yield attributes like fresh weight of whole plant (98.11 g), Yield per plot (3.8 kg), yield per hectare (63.34 q).

Gayathri and Malathi (2019) studied the effect of different biofertilizers on the growth of *Amaranthus viridis* L. recorded that the growth parameters such as root length, shoot length, fresh weight and dry weight was estimated to be higher in plants treated with Azospirillum on the 30th day. On the 45th day, the root length and shoot length was found to be higher in Azospirillum treated plants, but the fresh weight and dry weight were found to be more in plants treated with Phosphobacteria and concluded that bio-fertilizers are a suitable supplement to chemical fertilizers to meet the integrated nutrient demand of the crops.

Hndersah *et al*. (2019) assesed whether mixed biofertilizer could decrease inorganic fertilizers dosage and maintain population of Phosphate solubilizing bacteria (PSB) and Nitrogen fixing bacteria (NFB) in the rhizosphere and to verify the difference yield of leafy vegetable grown with and without biofertilizer. Experiment has been conducted in vegetable farming area and set up by used of three leafy vegetables; caysim (*Brassica rapa* L), amaranth (*Amaranthus* sp.) and water spinach (*Ipomoea aquatica Forssk*.). Results verified that biofertilizer inoculation increased crops productivity and population of PSB and NFB in rhizosphere of the three vegetables, and decreased NPK fertilizer dosage up to 25 % and suggested that microbial inoculation practice can support local vegetables production as well as environmental health, and farmers might receive additional income.

Sharma and Divakara (2019) studied application of the fungicide along with or without co-application of a bio fertilizer *viz*., Arka microbial consortium. Increase in biomass by 11 to 15 per cent in spinach and green onions resulting from application of the bio fertilizer seemed to have resulted in faster dissipation of chlorothalonil in the produce and concluded that the bio fertilizer used in this study increased the yield without harming the environment, thereby, also, accelerating the reduction in chlorothalonil residues in the produce.

2.2. Effect of biofertilizers on quality attributes

Raut *et al.* (2006) evaluated on soil microbial population and tomato yield as influenced by plant nutrient sources and determined that maximum ascorbic acid content was observed in the treatment 30 t FYM + 5 kg Azospirillum which confirm that quality of the agricultural produce improved through organic manures and plant growth promoting rhizobacteria. Among the different treatments, addition of organic manure further improves the status significantly over control.

Sonali *et al.* (2012) studied the effect of different biofertilizers on quality of fenugreek and reported that, the quality parameters *viz.*, chlorophyll content, leaf moisture content, leaf protein content were found to be significantly maximum with seed treatment and soil application of rhizobium plus PSB.

Maheswari and Kalaiyarasi (2015) made trails on the survival of bacteria Azotobacter on liquid and carrier using pot culture in amaranth. Results revealed that T3 combined inoculation liquid biofertilizer and carrier based biofertilizer such as Azotobacter could enhance the morphological parameters and biochemical constituents such as chlorophyll, carotenoids, compared to individual inoculation and control.

Choudhary *et al*. (2017) conducted an experiment consisting of 16 treatment combinations *viz.*, four levels of fertility (control, 50 %, 75 % and 100 % recommended dose of NPK) and four different biofertilizer inoculations (control, *Azotobactor*, *Azospirillum* and PSB) in knol-khol. Among different bio-fertilizers the inoculation of PSB leads to maximum NPK content in Knob, protein content, ascorbic acid and chlorophyll content over rest of Biofertilizers but at par with *Azospirillum.*

Meena *et al.* (2017) evaluated on effect of organic manures and biofertilizers on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica* Plenck.) Cv. KTS-1 and recorded maximum vitamin C contain (90.50 mg/100), T.S.S contain (8.80 ^{0}Brix) and reducing sugar (3.25 %) , non-reducing sugar (0.79 %), Total sugars (3.97 %) was recorded in T_8 (RDF 25 % + Vermicompost 50 % + Azotobacter 50 % + Azotobacter 25 % except acidity.

Chaudhary *et al.* (2018) examined the response of three levels of biofertilizers *viz.* (Azotobactor, PSB, Azotobactor + PSB) and five different sources of organic manures *viz.* FYM, Vermicompost, Caster cake, Poultry manure, Neem cake in amaranthus. Among different sources of organic sources, chlorophyll a, chlorophyll b, total chlorophyll, carotenoid content, protein Content and iron content were recorded with treatment b_3 (Azotobactor + PSB) and treatment f_2 (Vermicompost).

2.3. Effect of inorganic and organic sources on growth and yield attributes

Raut *et al.* (2006) evaluated on soil microbial population and tomato yield as influenced by plant nutrient sources and determined that the recommended NPK along with FYM gave the maximum plant height (95.67 cm), fruit weight (591.0 g plant^{-1}) and fruit yield (196.43 q ha^{-1}) which shows promise on inorganic fertilizers.

Shukla *et al.* (2006) found that application of recommended dose of N, P and K (100, 75 and 55 kg ha^{-1}) with farm yard manure and vermicompost (250 and 12.5 q ha^{-1}) regularly was better in increasing yield per plant, yield ha^{-1}, number of fruits per plant, number of fruits per cluster and average fruit weight in tomato.

Phandis *et al.* (2007) reported that application of NPK at 150:80:80 kg ha^{-1} + vermicompost increased the yield by 33 % over the recommended NPK ha^{-1}+ FYM. Vermicompost, FYM and control (no fertilizers) reduced the yield by 31, 35 and 40 % relative to the recommended treatment in spinach Cv. All Green.

Patel *et al.* (2010) studied the effect of of integrated nutrient management (INM) practices in fenugreek (*Trigonella foenum-graecum*) and reported that the application of recommended dose through inorganic form with PSB @ 5 kg ha^{-1} gave higher growth and yield attributes and was at par with recommended dose of fertilizer + Azotobacter sp. @ 5 kg ha^{-1} + 5 t farm yard manure ha^{-1} and recommended dose of nitrogen + PSB @ 5 kg ha^{-1} which were significantly superior to other treatments except test weight.The maximum net realization and benefit:cost ratio was obtained when the crop was fertilized with full dose of nitrogen and phosphorus with PSB @ 5 kg ha^{-1}.

Godara *et al.* (2012) conducted an experiment on effect of different combinations of organic and inorganic nutrient sources on productivity and profitability of fenugreek (*Trigonella-foenium-graecum*) and inferred that application of 50 % RDF along with 50 % vermicompost and poultry manure is better for realizing good soil health and sustainable higher yield levels.

Aisha *et al.* (2013) investigated the effect of bio and chemical fertilizer (NPK) at different rates for influence plant growth, total yield and chemical properties of spinach plants. Results revealed that the interaction treatments showed that using high rate of bio fertilizer (2 kg/fed.) with the 70% of (RR) of chemical fertilizer resulted the superiority in plant growth characters as well as the best total yield (ton/fed.) and its content of protein, P, K and No_3.

Pathak *et al.* (2018) made studies on the effect of source of nutrient on growth, yield and quality in radish – coriander cropping sequence and results revealed that (Recommended FYM @ 20 t ha^{-1} + fertilizer @ 80:60:80 NPK kg ha^{-1} + PP with organic methods) + IIHR microbial consortium @ 12.5 kg ha^{-1} recorded significantly highest days to seed germination (4 days), plant height (33.50 cm), number of leaves plant^{-1} (10.47), leaf area (293.46 cm^2), length of leaves (26.69 cm), length of root (15.24 cm), root circumference (10.23 cm), Average root weight (160.26 g), Days taken to harvest of roots (54 days), fresh weight of radish root (72.33 g), dry weight of radish root (3.60 g), root yield (296.28 q ha^{-1}).

Malav *et al*. (2018) laid out an experiment on the standardization of organic module for production of fenugreek (*Trigonella foenum graecum* L.) and revealed that the seed and straw yield of fenugreek was found significant due to different treatments, wherein integrated use of organic sources of nitrogen (50 % RDN through castor cake + Rhizobium + PSB) recorded significantly higher seed and straw yield of fenugreek as compared to their individual use and concluded that it is better for realizing good soil health and sustainable higher yield levels.

Rather *et al.* (2018) conducted an experiment to find out the effect of organic manures and bio-fertilizers on growth and yield of Lettuce Cv. LS-2 constituting 13 treatments combinations in all. The investigation revealed that the Treatment T9, (60 kg N ha^{-1} + 45 kg P ha^{-1}+ 30 kg K ha^{-1}+ Vermicompost (4 t ha^{-1}) + Biofertilizers @ 7.5 l ha^{-1}) recorded higher values for plant height (37.84 cm), plant spread (39.91 cm), minimum no. of days to first harvest (40), leaf area (280.42 cm^2), no. of leaves $plant^{-1}$ (48.15), average leaf weight (13.95 g), leaf weight $plant^{-1}$ (518.25 g), leaf yield $plot^{-1}$ (9.81 kg) and leaf yield ha^{-1} (23.83 t).

Yadav *et al.* (2019) investigated on effect of integrated nutrient management on growth, leaf yield and economics of spinach (*Beta vulgaris* L.) var. Pusa Jyothi. Results revealed that the application of 75% RDF + 10 t Vermicompost ha^{-1} + 5 kg PSB ha^{-1} + 5 kg Azotobacter ha^{-1} (T_8) was recorded significantly maximum plant height, number of leaves $plant^{-1}$, fresh and dry weight of leaves $plant^{-1}$ and leaves yield ha^{-1} at first year, second year and pooled as compared to control.

Khadse *et al*. (2021) laid out an experiment with nine treatment combinations and four replications. Treatments consist of three nitrogen sources *viz.*, 100% N through urea, 50 % N through FYM + 50 % N through urea and 50 % N through FYM + 50 % N through Vermicompost + Biofertilizers and three vegetables *viz.*, Coriander, Fenugreek and Spinach. The growth characters of all vegetables and maximum green biomass yield were significantly higher with the application of 50 % N through FYM + 50 % N through urea followed by 50 % N through FYM + 50 % N through Vermicompost + Biofertilizers.

Babaleshawar *et al.* (2020) conducted an experiment to study the effect of integrated nutrient management on yield and quality of kasuri methi (*Trigonella corniculata* L.) under hill zone of Karnataka and reported that the yield attributes like dry herb yield (1.88 t/ha), fresh herb yield (8.02 t/ha), No. of pods plant^{-1} (620.17), Pod length (2.14) was recorded in the treatment supplied with 75% N+ RD PK +FYM (7.5 t ha^{-1}) + Rhizobium (1.5t ha^{-1}) + Azospirillum (5 kg ha^{-1}) + PSB (5 kg ha^{-1}). While it was found statistically at par with application of 50% N+ RD PK + FYM (7.5 t ha^{-1}) + Rhizobium (1.5 kg ha^{-1}) + Azospirillum (5 kg ha^{-1}) + PSB (5 kg ha^{-1}).

Sahu *et al.* (2020) investigation entitled Study the effect of integrated nutrient management on vegetative growth of fenugreek (*Trigonella foenum graecum* L.) and concluded that the treatment (T_{11}) *i.e.*, 50% RDF + Neem cake @ 1 ton ha^{-1} + Rhizobium + PSB was best at all the stages of growth and yield parameters showed better performance from other treatments of organic, inorganic and biofertilizer applications.

2.4. Effect of inorganic and organic sources on quality attributes

Rafi *et al.* (2002) revealed that application of 50 % recommended dose of FYM @ 12.5 t ha^{-1} along with reduced levels of recommended doses of fertilizers (50 % RDF @ 100:50:50 NPK kg ha^{-1}) resulted in the highest yield with high quality and also revealed that the readymade organic manures of commercial companies used in this study were inferior to traditional organic manures *viz.,* FYM and Vermicompost.

Patil *et al.* (2004) made studies on effect of inorganic and organic fertilizers on growth, fruit yield and quality of tomato and observed that highest number of leaves per plant, TSS and shelf life was obtained with RDF (NPK @ 50:25:25 kg ha^{-1}) +FYM @ 12 t ha^{-1}) and RDF (NPK @ 50:25:25 kg ha^{-1}) +Vermicompost @ 12 t ha^{-1})

Kadlag *et al.* (2007) conducted an experiment on yield and quality of tomato fruit as influenced by organic manures and biofertilizers and found that highest fruit yield and fruit quality of tomato was observed with the application of recommended dose of fertilizer (NPK @ 100:50:50 kg ha^{-1}) + PSB and RDF + Azospirillum + PSB respectively.

Kumar and Sharma (2007) investigated the effect of different methods of biofertilizer application in tomato seed production carried out and significantly highest plant height, minimum spoilage of fruits, maximum shelf life of fruits and highest fruit yield was observed when biofertilizers applied alone, in combination with 75 % @ 75, 56.25 and 41.25 kg ha^{-1} and 100 % @ 100, 75 and 55 kg ha^{-1} NPK + full dose of FYM @ 25 t ha^{-1} on tomato production.

Phandis *et al.* (2007) reported that application of NPK at 150:80:80 kg ha^{-1} + vermicompost in spinach Cv. All green recorded the highest values for dry matter and ascorbic acid contents, followed by NPK at 150:80:80 kg ha^{-1} + FYM. The latter treatment gave the highest values for chlorophyll and crude protein contents.

Padmanabha *et al.* (2008) evaluated that the effects of organic and inorganic fertilizers on the content and uptake of nutrients (N, P and K) in roots and haulms of palak (*Beta vulgaris* var *bengalensis*). The application of N P K (150:100:100) + Agrimagic equivalent to FYM on N basis (8.87 t ha^{-1}) recorded the highest content and uptake of N, P and K in palak.

Rodge and Yadlod (2009) reported that the increased height of plant, number of primary branches, number of leaves, maximum number of fruits per plant, heaviest fruit, fruit yield per plant, per plot, highest fruit juice and TSS in tomato, was observed with the application of 50 % RDF + 50 % FYM which was followed by 50 % RDF + 50 % Vermicompost.

Kanaujia *et al.* (2010) conducted integrated nutrient studies in radish at Nagland revealed that integrated application of chemical fertilizers, organic manures and biofertilizers alone or in combination significantly increased the growth, yield and quality characters compared to control. Maximum root yield (534.66 q ha^{-1}), TSS (4.33^{0} Brix) and vitamin C content (24.93 mg 100 g^{-1}) were recorded with 50 % FYM + Biofertilizers compared to 100 % NPK. These results suggested that optimum quality production of radish can be obtained through organic manures under the treatment T_7 (50 % NPK + 50 % FYM + Biofertilizers).

Kumar *et al.* (2010) conducted an experiment on the response of integrated nutrient management (INM) on growth, yield and quality of tomato and found that the maximum growth, yield and TSS content in tomato with the application of RDF (NPK @ 90:60:60 kg ha^{-1}) + organic manure (FYM @ 15 t ha^{-1}, Vermicompost @ 10 t ha^{-1} and poultry manure @ 3 q ha^{-1}) + biofertilizers (VAM 2 kg ha^{-1}, PSB 2 kg ha^{-1} and Azospirillum 2 kg ha^{-1}).

Sharma *et al.* (2010) studied the effect of integrated nutrient management on growth, yield and quality parameters of tomato and observed that the combined application of Azotobacter @ 2 kg ha^{-1} + 75 % N_2 + full dose of P_2O_5 and K_2O + full dose of FYM, treatment combination significantly increased growth, yield and quality characters over RDF or organic manures alone.

Chumyani *et al.* (2012) evaluated on effect of integrated nutrient management on growth, yield and quality of tomato and observed that the maximum fruit yield, vitamin C, TSS and produced the highest net return with cost-benefit ratio of 1:3.1 and also buildup of organic carbon in the soil after harvest of tomato Cv. Punjab chhuhara, were recorded with the application of NPK @ 60:30:30 kg ha^{-1}+ FYM @ 10 t ha^{-1}+ Vermicompost @ 5 t ha^{-1} + biofertilizers.

Yeptho *et al.* (2012) made studies on effect of integrated nutrient management on growth, yield and quality of tomato under polyhouse condition and noticed that higher plant height, number of branches plant per plant, fruit length, fruit diameter, fresh weight of fruit, yield, TSS and vitamin C content in tomato on application of recommended dose of fertilizer (NPK @ 60:30:30 kg ha^{-1}) + Vermicompost @ 5 t ha^{-1}) + biofertilizers.

Pathak *et al.* (2018) were made studies on the effect of source of nutrient on growth, yield and quality in radish – coriander cropping sequence and results revealed that (Recommended FYM @ 20 t ha-1 + fertilizer @ 80:60:80 NPK kg ha^{-1} + PP with organic methods) + IIHR microbial consortium @ 12.5 kg ha^{-1} record significantly highest vitamin C (15.44 mg/ 100 g), reducing sugar (2.97 %), non-reducing sugar (16.78 %), total sugar (18.95 %) and T.S.S. (5.45 ^{o} Brix).

Raturi *et al.* (2018) investigated entitled "Effect of organic and inorganic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annuum* L.) Grown under polyhouse condition" and reported that shelf life, ascorbic acid, TSS were recorded maximum with the conjoint application of 50 % NPK + Azotobacter + vermicompost.

Babaleshawar *et al.* (2020) conducted an experiment to study the effect of integrated nutrient management on yield and quality of kasuri methi (*Trigonella corniculata* L.) under hill zone of Karnataka and reported that quality attributes like crude protein in herb (13.31 %) and in seed (21.33 %) was recorded in the treatment supplied with 75% N+ RD PK +FYM (7.5 t ha^{-1}) + Rhizobium (1.5t ha^{-1}) + Azospirillum (5 kg ha^{-1}) + PSB (5 kg ha^{-1}). While it was found statistically at par with application of 50% N+ RD PK + FYM (7.5 t ha^{-1}) + Rhizobium (1.5 kg ha^{-1}) + Azospirillum (5 kg ha^{-1}) + PSB (5 kg ha^{-1}).

Nisar *et al.* (2020) made studies on the effect of integrated nutrient management on quality attributes of black carrot with different combinations of inorganic fertilizers, organic manures and biofertilizers. Results revealed that among the different treatment combinations, treatment with 50 % N + 25 % P & K + PSB + KSB 50 % VC) recorded the higher values for dry matter content (14.40%), total sugars (8.19 %), total carotenoids (3.90 mg^{-1} 100 g), total phenolic content (251.83 mg^{-1} 100 g), anthocyanin content (49.66 mg^{-1} 100 g).

2.5. Effect of micronutrients on growth and yield attributes

Diana and Nehru (2014) conducted an experiment to find out the role of micronutrients on growth, seed yield and quality in coriander Cv. CO-4. Results indicated that foliar spray of 0.5 % $FeSO_4$ induced the highest growth rates in terms of net assimilation rate (0.085 mg g^{-1} day^{-1} in rabi and 0.063 mg g^{-1} day^{-1} in kharif) and crop growth rate (7.52 mg m^{-2} day^{-1} in rabi and 7.78 mg m^{-2} day^{-1} in kharif). Maximum number of umbels per plant (33.7 in rabi and 13.8 in kharif) and highest seed yield per hectare (623.3 kg in rabi and 599.9 kg in kharif).

Kisan *et al.* (2015) laid out an experiment on the effect of nano-zinc oxide particles on the leaf physical and nutritional traits of spinach. The spinach plants were sprayed with graded concentration of zinc oxide nanoparticles (ZnO NPs) after 14 days of sowing and showed that the plants sprayed with ZnO NPs at the concentration of 500 and 1000 ppm showed the increased leaf length, width, surface area and colour of leaf samples when compared to control leaf samples.

Mounika *et al.* (2017) studied the effect of different biofertilizers and micronutrients on growth, leaf yield and quality of coriander Cv. Sadhana. Among the treatments, seed inoculation with Azospirillum + PSB+ foliar spray of zinc sulphate @ 0.5 % recorded maximum plant height, number of primary branches, leaf area, fresh leaf yield per plant, leaf yield per plot, leaf yield per hectare, dry matter production.

Sarkar *et al.* (2017) conducted experiment on the effect of boron and zinc application on growth, seed yield and its quality of water spinach (*Ipomoea reptans* Poir.). Results revealed that soil application of borax @ 25 kg ha^{-1} and $ZnSo_4$ @ 15 kg ha^{-1} alone and as combination recorded maximum number of flowers/hill (282.6, 275.1 & 311.5), number of capsules/hill (238.2, 220.7 & 257.8), seed yield (1.22, 1.21 & 1.32 t ha^{-1}), shelling percentage (67.14, 67.06 & 68.76 %), 1000 seed weight (38.05, 38.25 & 41.16 g), germination percentage (86.6, 86.3 & 90.0 %), seedling vigour index (6.20, 6.26 & 6.63) and seedling growth rate (0.123, 0.123 and 0.127 g $plant^{-1}$ day^{-1}), respectively over control.

Tania *et al*. (2018) assessed the influence of micronutrients on growth and yield of coriander. Spraying with B-0.05 %+ Zn-0.1 %, also proved to be effective with respect to growth characters namely root length (9.65 cm), number of primary (7.73) and secondary (17.87) branches, number of umbellets/umbel (5.66), number of seeds/umbel (28.20), and various yield components namely seed weight per umbellet (0.063 g) and seed weight/umbel (0.35 g) and concluded that Boron and Zinc may be sprayed 45 days after sowing in coriander for better vegetative growth and yield at Gangetic plains of West Bengal.

2.6. Effect of micronutrients on quality attributes

Kisan *et al.* (2015) laid out an experiment on the effect of nano-zinc oxide particles on the leaf physical and nutritional traits of spinach. The spinach plants were sprayed with graded concentration of zinc oxide nanoparticles (ZnO NPs) after 14 days of sowing and showed that the plants sprayed with ZnO NPs at the concentration of 500 and 1000 ppm showed the higher values of protein and dietary fibre content in comparison to control leaf samples of spinach.

Mounika *et al.* (2017) studied the effect of different biofertilizers and micronutrients on growth, leaf yield and quality of coriander Cv. Sadhana. Among the treatments, seed inoculation with Azospirillum + PSB + foliar spray of zinc sulphate @ 0.5 % recorded maximum protein content, ascorbic acid content and moisture content.

Prasad *et al.* (2017) studied the effect of zinc and iron on quality of Amaranth (*Amaranthus* spp.) Cv. Pusa Kiran and reported that chlorophyll a, chlorophyll b, total chlorophyll, and protein content were significantly increased by individual application of zinc @ 0.45 % and iron @ 0.30 % concentration and combined application of zinc and iron @ 0.45 % increased almost all quality parameters though carotenoid content was maximum in treatment without application of any treatment.

Sarkar *et al.* (2017) conducted experiment on the effect of boron and zinc application on growth, seed yield and its quality of water spinach (*Ipomoea reptans* Poir.). Results revealed that maximum vine length, number of nodes per plant, average internode length and chlorophyll content of leaf were found in twice foliar sprays of borax @ 1.5 g/litre (B_2) and twice foliar sprays of $ZnSO_4$ @ 1.5 g/litre (Zn_2) individually as well as their combination (B_2Zn_2).

Sidhu *et al.* (2019) were focused on the on role of micronutrients in vegetable production and also gave a brief overview of recent research findings related to role of micronutrients on vegetable production, which can contribute to a better understanding of the role of micronutrients in vegetable plants. They concluded that application of micronutrients to sustain soil health and crop productivity besides maintaining the quality of vegetables is of profound importance. Micronutrients are beneficial to improve yield, quality, earliness, fruit setting, increases post-harvest life, and develop resistance to biotic and a biotic stress.

Chapter-III

MATERIAL AND METHODS

Chapter III

MATERIAL AND METHODS

This chapter comprises the details about materials used and the method adopted during the course of present investigation entitled **“Effect of inorganic nutrients and biofertilizers on growth, yield and quality of Spinach beet (*Beta vulgaris* var. *bengalensis*) Cv. Pusa Bharati”** carried out during *Rabi* season in the year 2020-21 at Student research farm, College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad. The details of the location, the material used and the techniques adopted during the period of experimentation are presented in this chapter in the following headings and sub headings.

3.1 GEOGRAPHICAL LOCATION AND WEATHER CONDITIONS OF THE EXPERIMENTAL SITE

The experimental site is situated at an altitude of 542.3 m above mean sea level on 79°.23' East longitude and 17°.19' North latitude. The climate of Rajendranagar is semi-arid. Data on weather parameters during the period of investigation recorded at the Agriculture Research Institute, Rajendranagar, Hyderabad is presented in appendix I.

3.2 SOIL

3.2.1. COLLECTION OF SAMPLES

A composite soil sample (0-15 cm depth) was collected from research plot of student research farm, College of Horticulture, Rajendranagar, Hyderabad. Soil sample was collected from research plot before application of fertilizers. The soil sample was air dried, crushed with hammer and passed through 2 mm sieve and preserve for physical and chemical analysis and are presented in Table 3.1

3.3 Materials

3.3.1 Layout of experimental site

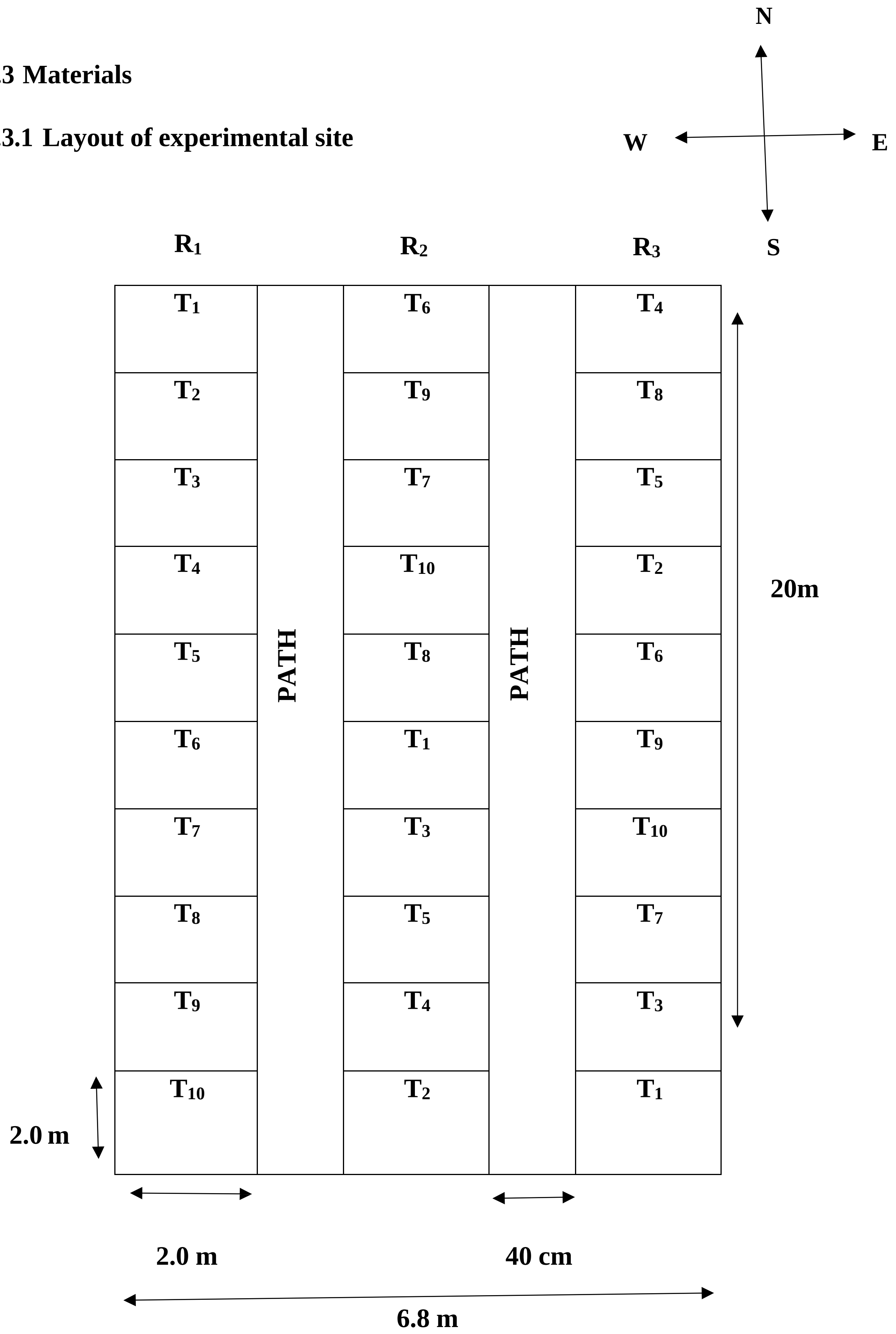

Plate 1. General view of experiment

3.3.2 Experimental details

1. Name of the crop	:	Spinach beet
2. Family	:	Chenopodiaceae
3. Variety	:	Pusa Bharati
4. Experimental design	:	Randomized Block Design
5. Number of replication	:	3
6. Number of treatments	:	10
7. Total number of plots	:	30
8. Spacing	:	30 x 10 cm^2
9. Plot size	:	2 x 2 m^2
10. Total experimental area	:	120 m^2
11. Research work	:	College of Horticulture, Rajendranagar, Hyderabad
12. Season year experiment	:	Rabi season 2020 – 2021

TREATMENT DETAILS:

T_1 - 100 % RDF @ 100:25:50 kg/ha

T_2 - 75 % RDF + Biofertilizers [Azotobacter + Phosphorous Solubulizing Bacteria (PSB) + Potassium Solubulizing Bacteria (KSB)] (Each @ 1.25 kg/ha)

T_3 - 50 % RDF + Biofertilizers [Azotobacter + Phosphorous Solubulizing Bacteria (PSB) + Potassium Solubulizing Bacteria (KSB)] (Each @ 2.5 kg/ha)

T_4 - 25 % RDF + Biofertilizers [Azotobacter + Phosphorous Solubulizing Bacteria (PSB) + Potassium Solubulizing Bacteria (KSB)] (Each @ 3.75 kg/ha)

T_5 - 75 % RDF + Arka Microbial Consortium (AMC) @ 2.5 kg/ha + Potassium Solubulizing Bacteria (KSB) @ 1.25 kg/ha

T_6 - 50 % RDF + Arka Microbial Consortium (AMC) @ 5 kg/ha + Potassium Solubulizing Bacteria (KSB) @ 2.5 kg/ha

T_7 - 25 % RDF + Arka Microbial Consortium (AMC) @ 7.5 kg/ha + Potassium Solubulizing Bacteria (KSB) @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 gm/litre

T_9 - T_6 + Arka vegetable special @ 5 gm/litre

T_{10} - T_7 + Arka vegetable special @ 5 gm/litre

NOTE: Foliar application of Arka vegetable special was done for 3 times *i.e.*, at 15 DAS, 30 DAS and 45 DAS

Table 3.1. Salient soil characteristics of experimental site

Physico-chemical properties	
pH	8.65
Electric conductivity (EC) ds m^{-1}	0.16
Chemical properties	
Available nitrogen (kg ha^{-1})	142.50
Available phosphorous (kg ha^{-1})	36.00
Available potassium (kg ha^{-1})	192.00
Zinc (mg kg^{-1})	0.323
Iron (mg kg^{-1})	1.127
Manganese (mg kg^{-1})	5.739
Copper (mg kg^{-1})	0.392

Azotobacter

Phosphorous Solubilizing Bacteria (PSB)

Potassium Solubilizing bacteria (KSB)

Arka Microbial Consortium (AMC)

Arka vegetable special

Plate 2. Different Treatments used in the Experiment

3.4 Cultivation details

3.4.1 Field preparation

The experiment plot was ploughed, harrowed with disc to bring it to fine tilth and perfectly levelled before being divided into sub plots as per the layout of experiment.

3.4.2 Sowing

The seeds were sown at a spacing of 30 cm between rows and 10 cm within the row. The field was irrigated immediately after sowing and thinning was done at 15 days after sowing of the crop.

3.4.3 Method of application

Before sowing, farm yard manure along with biofertilizers were applied to the soil as a basal dose as per the treatments. Dosage of different biofertilizers were fixed to meet the recommended dose of nitrogen as per the available nitrogen content in the respective biofertilizers.

Inorganic fertilizers were applied as per treatment in the form of urea, single super phosphate and murate of potash to supplement the nitrogen, phosphorous and potassium nutrients respectively. Nitrogen was applied in 3 split doses in the form of urea. As a basal dose 1/4th of the total nitrogen was applied at the time of last ploughing and remaining 2 splits were applied after each cutting. Phosphorous and potassium were applied as a basal dose only in the form of single super phosphate and murate of potash respectively.

3.4.4 Irrigation

The crop was irrigated immediately after sowing. Subsequently, the irrigations were given at 7 days interval to maintain uniform soil moisture throughout the crop growth period.

3.4.5 Intercultural operations

The experiment plot was kept free of weeds throughout the crop growth period. A total of 3 weedings were done at 15, 30 and 45 days after sowing.

Layout of Experimental site

After application of inorganic nutrients and Biofertilizers in field

After Installation of drip

At the time of germination

Plate 3. Field preparation

3.4.6 Plant protection

The crop was not affected with any insect pest or disease. Hence, no insecticides and fungicides were applied.

3.4.7 Harvesting

A total of three cuttings were taken. The first cutting was done at 30 days after sowing and the subsequent cuttings were made at 15 days interval.

3.5 Observations recorded

Five plants in each treatment and replications were randomly selected and tagged of each replication in each treatment for recording the observations.

3.5.1 Morphological parameters

3.5.1.1 Plant height (cm)

Plant height from base of plant to the tip of the longest leaf was measured with scale from five tagged plants per replication per treatment at 15, 30 and 45 days after sowing and their mean was worked out.

3.5.1.2 Leaf length (cm)

Leaf length from tip of the leaf to petiole base was measured with scale from five tagged plants per replication per treatment at 15, 30 and 45 days after sowing and their mean was worked out.

3.5.1.3 Leaf width (cm)

Leaf width was measured with scale from five tagged plants per replication per treatment at 15, 30 and 45 days after sowing and their mean was worked out.

3.5.1.4 Length of leaf petiole (cm)

Length of leaf petiole was measured with scale from five tagged plants per replication per treatment at 15, 30 and 45 days after sowing and their mean was worked out.

3.5.2 Growth parameters

3.5.2.1 Leaf area (cm^2)

Leaf area was recorded with leaf area meter model number CI 202 portable area meter at 15,30 and 45 days after sowing from five plants per treatment per replication and their mean was worked out.

3.5.2.2 Leaf area index

Leaf area index was calculated as suggested by Watson, (1952)

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Area occupied by each plant } (cm^2)}$$

3.5.2.3 Specific leaf area ($cm^2\ g^{-1}$)

Specific leaf area was calculated by formula given below

$$SLA = \frac{\text{Leaf area } (cm^2)}{\text{Leaf weight (g)}}$$

3.5.2.4 Specific leaf weight ($g\ cm^{-1}$)

Specific leaf weight was calculated by formula given below

$$SLW = \frac{\text{Leaf weight (g)}}{\text{Leaf area } (cm^2)}$$

3.5.2.5 Leaf area duration (LAD) ($cm^2\ d^{-1}$)

Leaf area duration is the integral of leaf area index over the growth period and was worked out as per the formula suggested by Power *et al*. (1967)

$$LAD\ (cm^2\ d^{-1}) = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Whereas, LAI_1 = Leaf area index at time t_1

LAI_2 = Leaf area index at time t_2

3.5.3 Yield parameters

3.5.3.1 Number of leaves per plant

The leaves per plant were counted from the labelled plants. The average number of leaves per plant was worked out.

3.5.3.2 Leaf weight (g)

Leaf weight was recorded at each stage of cutting from the five plants and their mean was worked out.

3.5.3.3 Leaf yield per plant (g)

The leaves were separated from each tagged plant and weighed individually and their mean was worked out.

3.5.3.4 Leaf yield (ha^{-1})

The total yields were computed by adding the weights recorded at all cuttings and were expressed as kg $plot^{-1}$ and q ha^{-1} by taking standard population count in the plot on per plant basis.

3.5.4 Quality parameters

3.5.4.1 Moisture content (%)

Moisture percentage was estimated by taking 100 g sample of palak leaves collected from each treatment by recording fresh weight and oven dry weight at 65 ^{0}C for 48 hours at 3rd cutting (60 DAS). It was calculated by

$$\text{Moisture \%} = \frac{\text{Fresh weight- Dry weight}}{\text{Fresh weight}} \times 100$$

3.5.4.2 Shelf life (No. of days)

Shelf life of the spinach beet crop was assessed after harvesting, which were kept at ambient temperature.

3.5.4.3 Carotene content (mg/100g)

Carotene content was estimated by the method of Ranganna (1986)

Procedure

10 g of the spinach beet sample was ground in a mortar and pestle, then 1 g of the above ground sample was taken for estimation and again ground with acetone and filtered through a filter paper into a conical flask. Extraction was continued till the residue was colourless.

Filtrate was transferred into a separating funnel and 10-15ml of petroleum ether was added. The pigments were transferred into the petroleum ether by diluting the acetone with water. The extraction of the acetone phase was repeated with small volumes of petroleum ether. The volume of the petroleum ether extract was noted and read the colour intensity at 452 nm. The carotene content was expressed in mg 100 g^{-1}.

3.5.4.4 Vitamin C or Ascorbic Acid content (mg 100 g^{-1})

Assay method was followed given by Ranganna (1986).

(a) Preparation of 3 percent Meta phosphoric acid (HPO_3):

For preparing the 3 % Meta phosphoric acid (HPO_3) solution, dissolve the 3 gm sticks or pellets of HPO_3 in 100 ml distilled water.

(b) Preparation of standard ascorbic acid solution:

100 mg of l-Ascorbic acid was weighed and made up to 100 ml with 3 % (HPO_3). one ml of this solution was diluted to 10 ml by adding 3 % HPO_3 (1ml = 0.1 mg ascorbic acid).

(c) Preparation of dye solution:

52 mg of sodium salt of 2,6-di chlorophenol indophenol was dissolved in 150 ml of hot distilled water containing 42 mg sodium bicarbonate after cooling and it was diluted with 200 ml distilled water and stored in refrigerator and standardized every day.

(d) Standardization of dye:

In 5 ml of standard ascorbic acid solution 5 ml of HPO_3 micro burette was filled with dye solution. standard ascorbic acid was filled against dye solution to a pink colour, which persisted for 15 seconds. One milligram of ascorbic acid was used per ml of dye to determine the dye factor as follows:

$$\text{dye factor} = 0.5 / \text{Titre value}$$

(e) Preparation of sample:

10 grams of sample was blended with 100 ml of 3 % HPO_3 after that it was filtered.

(f) Assay of ascorbic acid:

An aliquot (10 ml) of the sample was taken and titrated against the standard dye to a pink colour end point, which persisted for 15 seconds. The ascorbic acid content of the sample was calculated using the following formula:

$$\text{Ascorbic acid} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up} \times 100 \ (\text{mg } 100 \text{ g}^{-1} \text{ pulp})}{\text{Aliquot extract taken for estimation} \times \text{Weight of sample taken for estimation}}$$

3.5.4.5 SPAD units

The SPAD meter (Soil Plant Analytical Development) is a simple handheld and portable instrument which provides information on relative amount of leaf chlorophyll. Observations were recorded from 5 randomly selected plants with SPAD chlorophyll meter and their mean were worked out.

3.5.4.6 Physiological loss in weight (%)

Five plants of each treatment after weighing were kept in at room temperature condition. The weights were recorded at every day up to 3 days of storage. The percent weight loss was calculated by using following formula

$$PLW\ \% = \frac{P_0 \text{ or } P_1 \text{ or } P_2 \text{ or } P_3}{P_0} \times 100$$

Where, P_0 = Initial weight

P_1 = Weight after 1st day

P_2 = Weight after 2nd day

P_3 = Weight after 3rd day

3.6 SOIL ANALYSIS (BEFORE PLANTING AND AFTER HARVEST)

Soil sample were collected randomly from plough layer depth with the help of soil sampling tube before sowing and after harvesting of crops from each plot and mixed thoroughly, dried to air crushed sieved through 2 mm sieves. The soil sampled prepared was subjected to chemical analysis for evaluating soil fertility status by following procedures are presented in Table 3.6.

3.6.1. Available nitrogen (kg ha^{-1})

Determination of available nitrogen was done by alkaline permanganate method suggested by Subbiah and Asija (1956), which is based on extraction of inorganic and readily oxidizable nitrogen from inorganic compounds. The nitrogen was extracted with 0.32 per cent $KMNO_4$, ammonia distilled by adding 2.5 per cent NaOH and absorbed in 2 per cent boric acid solution containing indicator. The ammonia absorbed was estimated titrimetrically using standard hydrochloric acid (0.02 HCL) (Tandon, 1995)

3.6.2 Available phosphorus (kg ha^{-1})

Available phosphorous was determined by Olsens mehod (Olsen *et al.*, 1954) using 0.5N $NaHCO_3$ as an extractant and develop blue colour using ascorbic acid (Murphy and Riley, 1962). The intensity of blue colour was recorded on ‘Spectronic’- 20 spectrophotometer 108 at 730 nm.

3.6.3 Available potassium (kg ha^{-1})

The available amount of potassium was determined by extraction with Neutral 1N ammonium acetate. The soil (5 g) was taken in 100 ml conical flask. then 25 ml of neutral 1N ammonium acetate was added and shaked for 5 min and after that the contents were filtered through filter paper (Whatmann no.1). The concentration of K was determined by Systronic -128 type flame photometer.

3.6.4 Available micronutrients

The available cationic micronutrients (Fe, Mn, Zn and Cu) were extracted from soil by using DTPA extractant in 1: 2 ratio, as per the procedure given by Lindsay and Norvell (1978), and were determined by using atomic absorption spectrophotometer (Model varian spectra AA20) the contents of these micronutrients were expressed in mg kg^{-1} of soil.

Table 3.6. Reference and method of analysis

S. No.	**Parameters**	**Reference and method of Analysis**
1.	Available nitrogen (kg ha^{-1})	Alkaline permangate method (Subbiah and Asija, 1956)
2.	Available phosphorous (kg ha^{-1})	Olsen’s method (Olsen *et al.*, 1954)
3.	Available potassium (kg ha^{-1})	Flame photometer method (Metson, 1956)

3.7 Economics

Details on cost of cultivation, gross and net returns and benefit cost ratio of spinach beet for different treatments were calculated.

3.7.1 Net returns

Net returns were arrived after deducting the cost of cultivation from the gross returns of the marketable produce on hectare basis and expressed in rupees ha^{-1}.

3.7.2 Benefit cost ratio

This was obtained by dividing gross returns with cost of cultivation ha^{-1}.

3.7.3 Statistical analysis

The data were analyzed statiscally applying the analysis of variance procedures for randomized block design (Panse and Sukhatne, 1967)

Chapter-IV

RESULTS AND DISCUSSION

Chapter IV

RESULTS AND DISCUSSION

The present studies entitled that **"Effect of inorganic nutrients and biofertilizers on growth, yield and quality of spinach beet (*Beta vulgaris* var *bengalensis*) Cv. Pusa Bharati"** was carried out during *Rabi* season of 2020-2021. The data of the morphological, growth, yield, quality, soil nutrient analysis and economics were statistically analyzed and the results obtained are discussed in this chapter in the following paragraphs.

4.1 Morphological Parameters

4.2 Growth Parameters

4.3 Yield Parameters

4.4 Quality Parameters

4.5 Soil nutrient analysis

4.6 Economics

4.1. Morphological Parameters

4.1.1. Plant height (cm):

The effect of different treatments on plant height recorded at 15, 30 and 45 days after sowing is presented in Table 4.1 and depicted in Fig.1

AT 15 DAS

The highest plant height at 15 DAS was recorded in the treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (14.94 cm) which was followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (12.98 cm). The lowest plant height was recorded in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) (7.45 cm).

AT 30 DAS

Highest plant height at 30 DAS was recorded in the treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (26.84 cm) which was followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (25.57 cm). Lowest plant height was recorded in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) (16.35 cm).

AT 45 DAS

The results showed that highest plant height at 45 DAS was recorded in the treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (35.80 cm) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (34.10 cm). While, T_6 statistically at par with treatment T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (33.02 cm). Lowest plant height was recorded in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) (23.88 cm).

The increase in plant height might be due to the presence of readily available nitrogen through inorganic nutrients and biofertilizers. This could be attributed to feasibility of nitrogen fixing and phosphorous as a result of microbial inoculation, have led to better root and shoot development. The positive influence of foliar application of Arka vegetable special on crop growth may be due to the improved ability of the crop to absorb nutrients, photosynthesis and better sink source relationship as this play vital role in various biochemical processes. Similar results were reported by Mounika *et al.* (2017) in coriander.

4.1.2. Leaf length (cm):

The data pertaining to leaf length at 15, 30 and 45 days after sowing as effected by the inorganic nutrients and biofertilizers is presented in the Table 4.2 and illustrated in Fig.2

AT 15 DAS

There was significant difference observed among the treatments for leaf length at 15 DAS. The highest leaf length (10.94 cm) was found significantly

Table 4.1. Effect of inorganic nutrients and biofertilizers on plant height (cm) in spinach beet Cv. Pusa Bharati

Treatments	**Plant height (cm)**		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	9.21	20.01	28.70
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)	9.74	21.93	30.56
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	9.54	21.14	30.12
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	7.45	16.35	23.88
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	10.29	23.21	31.91
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	12.98	25.57	34.10
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	8.12	17.77	24.85
T_8 – T_5 + Arka vegetable special @ 5 g/litre	11.54	24.28	33.02
T_9 – T_6 + Arka vegetable special @ 5 g/litre	14.94	26.84	35.80
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	8.67	18.91	26.52
S.E (m) ±	**0.352**	**0.364**	**0.499**
CD at 5 %	**1.04**	**1.08**	**1.48**

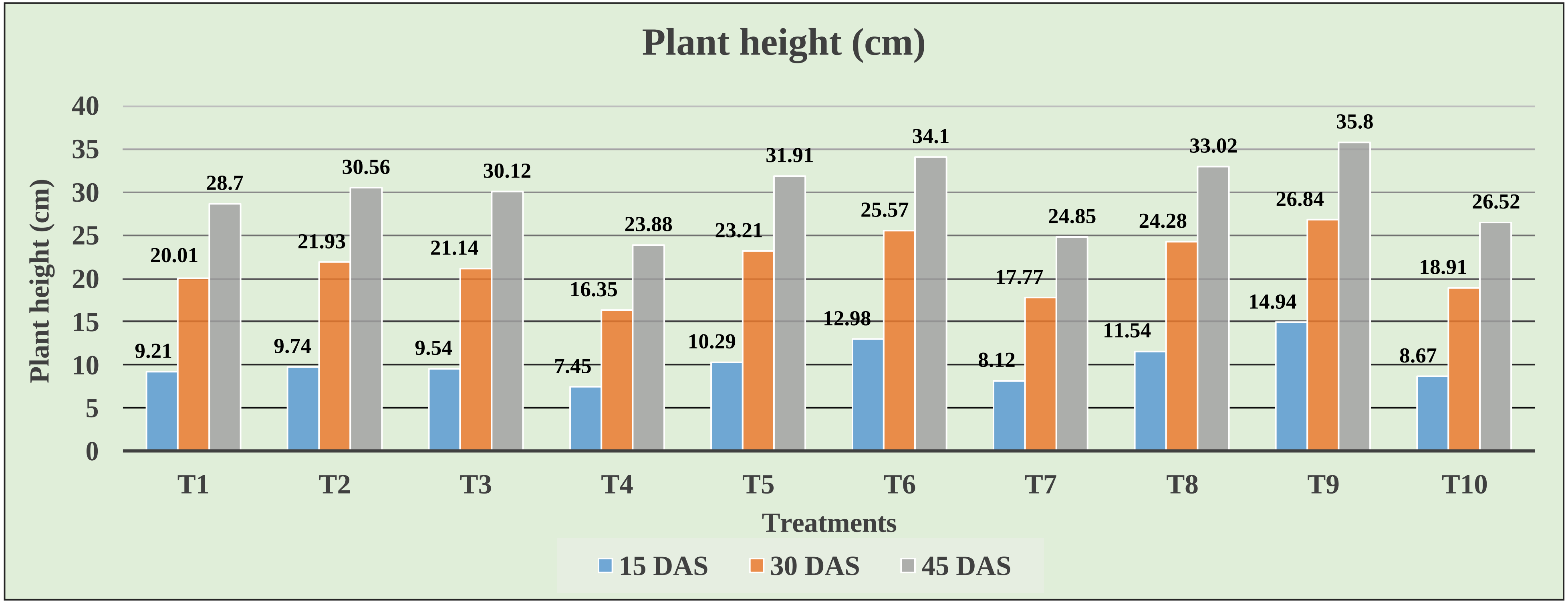

Fig.1 Effect of inorganic nutrients and biofertilizers on plant height (cm) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

$T_9 - T_6$ + Arka Vegetable Special @ 5 g/litre

T_4 - 25% RDF + Azotobacter + PSB + KSB (Each 3.75 kg/ha)

Plate 4. Comparision of plant height in best and least treatments

maximum at treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (8.78 cm). The minimum leaf length (4.06 cm) was observed in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}).

AT 30 DAS

The maximum leaf length was recorded under treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (18.38 cm) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (17.14 cm). The minimum leaf length (10.59 cm) was observed in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) which was statistically at par with treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (11.15 cm).

AT 45 DAS

Significantly maximum leaf length was recorded under treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (23.32 cm) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (21.59 cm). The minimum leaf length (12.01 cm) was observed in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1}) which was statistically at par with treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (13.15 cm).

Highest leaf length may be due to impact of combined application of inorganic nutrients and biofertilizers on growth cell division, cell elongation, cell enlargement and formation of more tissues and vigor of plant. Khadse *et al.* (2021) reported that influence of inorganic fertilizers in combination with biofertilizers might be due to optimum supply of nutrients particularly nitrogen.

4.1.3. Leaf width (cm):

Leaf width was effected by the inorganic nutrients and biofertilizers is presented in the Table 4.3 and Fig.3.

AT 15 DAS

Significantly maximum value (4.16 cm) recorded under the treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) which was followed by treatment T_6 (50

Table 4.2. Effect of inorganic nutrients and biofertilizers on leaf length (cm) in spinach beet Cv. Pusa Bharati

Treatments	Leaf length (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	5.21	13.09	15.88
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)	6.46	14.76	17.32
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	6.03	14.02	17.01
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	4.06	10.59	12.01
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	7.10	15.06	18.26
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	8.78	17.14	21.59
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	4.26	11.15	13.15
T_8 – T_5 + Arka vegetable special @ 5 g/litre	7.50	15.91	19.76
T_9 – T_6 + Arka vegetable special @ 5 g/litre	10.94	18.38	23.32
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	4.62	12.00	14.94
S.E (m) ±	**0.37**	**0.36**	**0.45**
CD at 5 %	**1.12**	**1.08**	**1.36**

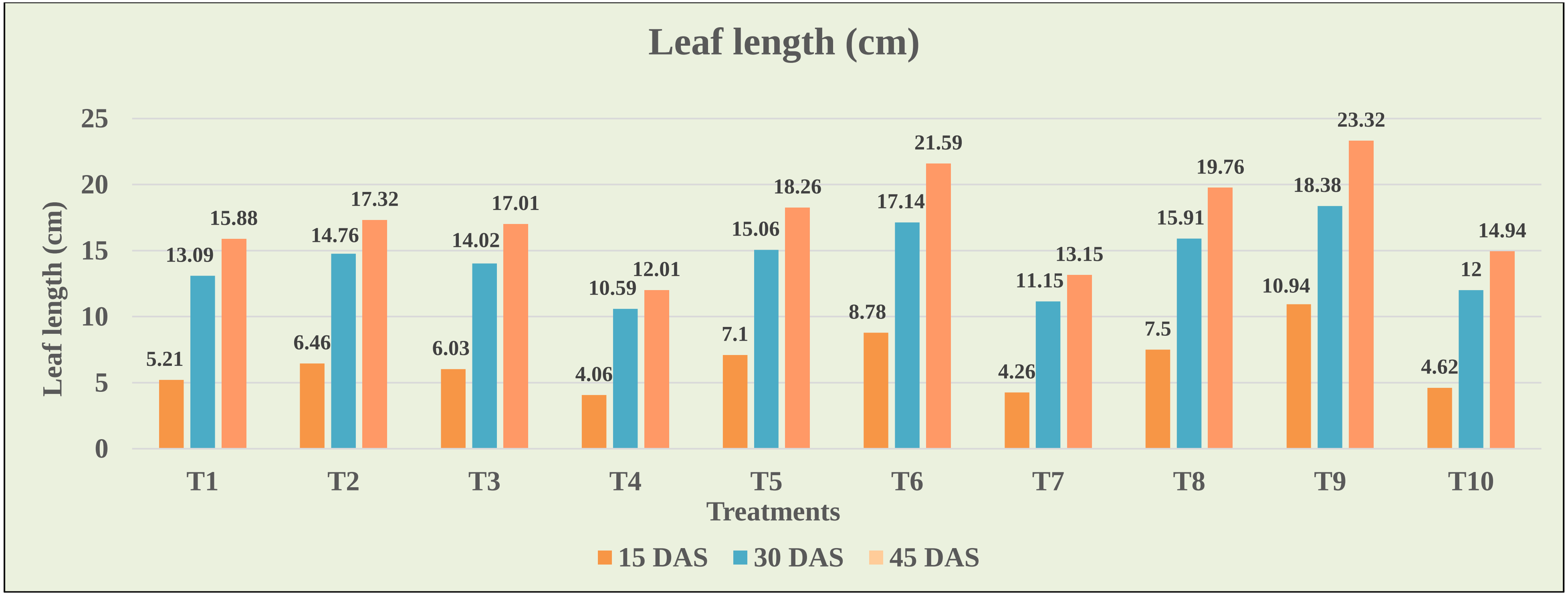

Fig.2 Effect of inorganic nutrients and biofertilizers on leaf length (cm) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

% RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (3.95 cm). However, the minimum value (2.41 cm) was observed in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

AT 30 DAS

Highest leaf width was recorded at 30 DAS in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (12.45 cm) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (12.01 cm). However, the lowest value was observed in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @3.75 kg ha^{-1}) (9.02 cm).

AT 45 DAS

The maximum leaf width was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (13.52 cm) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (12.67 cm) was statistically at par with the treatment T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (12.15 cm) However, the lowest value was observed in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (9.49 cm).

The increase in morphological parameters may be attributed to the meristematic activity for producing more tissues and organs, since nitrogen plays a major role in cell division, cell elongation, cell enlargement (Morschmer, 1986) This may increase the proportion of the protoplasm to cell size (Russel, 1973). This will led to high yield because the vegetative growth in spinach was considered as a parameter for yield.

4.1.4. Length of leaf petiole (cm):

The data on length of leaf petiole as influenced by various treatments are presented in Table 4.4 and depicted in Fig.4

AT 15 DAS

The maximum length of leaf petiole was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (7.79 cm) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (6.84 cm) and was statistically at

Table 4.3. Effect of inorganic nutrients and biofertilizers on leaf width (cm) in spinach beet Cv. Pusa Bharati

Treatments	**Leaf width (cm)**		
	15 DAS	**30 DAS**	**45 DAS**
$\mathbf{T_1}$ – 100 % RDF @ 100:25:50 Kg/ha	2.98	10.55	10.87
$\mathbf{T_2}$ – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)	3.19	10.99	11.63
$\mathbf{T_3}$ – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	3.06	10.70	11.27
$\mathbf{T_4}$ – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	2.41	9.02	9.49
$\mathbf{T_5}$ – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	3.30	11.36	12.00
$\mathbf{T_6}$ – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	3.95	12.01	12.67
$\mathbf{T_7}$ – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	2.63	9.98	10.15
$\mathbf{T_8}$ – T_5 + Arka vegetable special @ 5 g/litre	3.65	11.74	12.15
$\mathbf{T_9}$ – T_6 + Arka vegetable special @ 5 g/litre	4.16	12.45	13.52
$\mathbf{T_{10}}$ – T_7 + Arka vegetable special @ 5 g/litre	2.83	10.15	10.51
S.E (m) ±	**0.06**	**0.11**	**0.20**
CD at 5 %	**0.20**	**0.33**	**0.61**

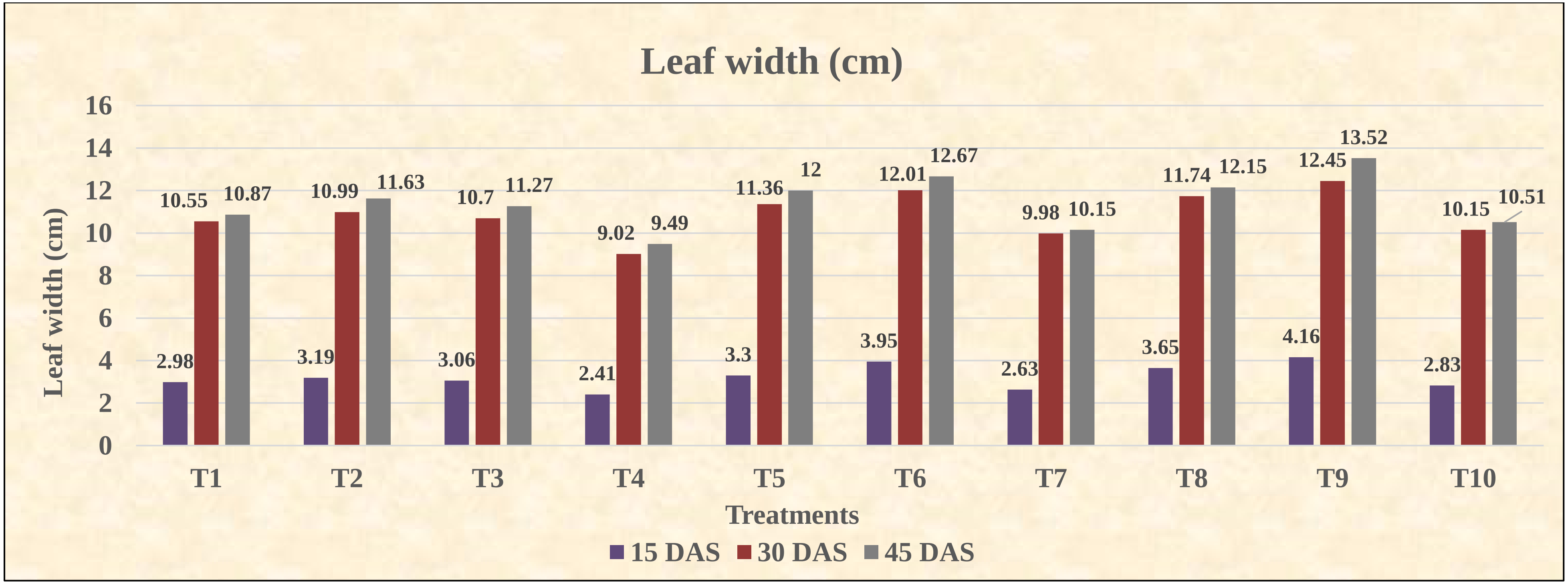

Fig.3 Effect of inorganic nutrients and biofertilizers on leaf width (cm) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

par with T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (6.11 cm) and treatment T_5 (75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg ha^{-1}) (5.77 cm) whereas treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) recorded significantly lower value (3.09 cm).

AT 30 DAS

Among all the treatments, T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded significantly the highest length of leaf petiole (10.00 cm) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (9.11 cm) and it was statistically at par with T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (8.60 cm) whereas T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) recorded lowest value (6.00 cm) statistically at par with treatment T_{10} (T_7 + Arka vegetable special @ 5 g L^{-1}) (6.17 cm) and T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB) @ 3.75 kg ha^{-1}) (6.05 cm)

AT 45 DAS

Significant differences in length of leaf petiole were observed due to integrated source of nutrients at 45 DAS. Among all the treatments, T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (14.94 cm) recorded significantly maximum length of leaf petiole followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (14.30 cm) while it was significantly minimum in T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (8.16 cm)

Increasing in petiole length might be due to the presence of plant growth promoting substance present in Arka microbial consortium and nitrogen through inorganic nutrients and biofertilizers, where in inorganic source could have exerted positive influence on extended nutrient availability to match the physiological needs of the crop which triggered to produce elevated stature of the growth components.

Table 4.4. Effect of inorganic nutrients and biofertilizers on length of leaf petiole (cm) in spinach beet Cv. Pusa Bharati

Treatments	Length of leaf petiole (cm)		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 Kg/ha	4.26	6.87	10.01
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)	5.28	7.68	11.16
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	5.08	7.07	10.59
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	3.09	6.00	8.16
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	5.77	8.37	12.00
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	6.84	9.11	14.30
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	3.59	6.05	8.68
T_8 – T_5 + Arka vegetable special @ 5 g/litre	6.11	8.60	13.01
T_9 – T_6 + Arka vegetable special @ 5 g/litre	7.79	10.00	14.94
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	4.00	6.17	9.52
S.E (m) ±	**0.36**	**0.24**	**0.14**
CD at 5 %	**1.08**	**0.72**	**0.42**

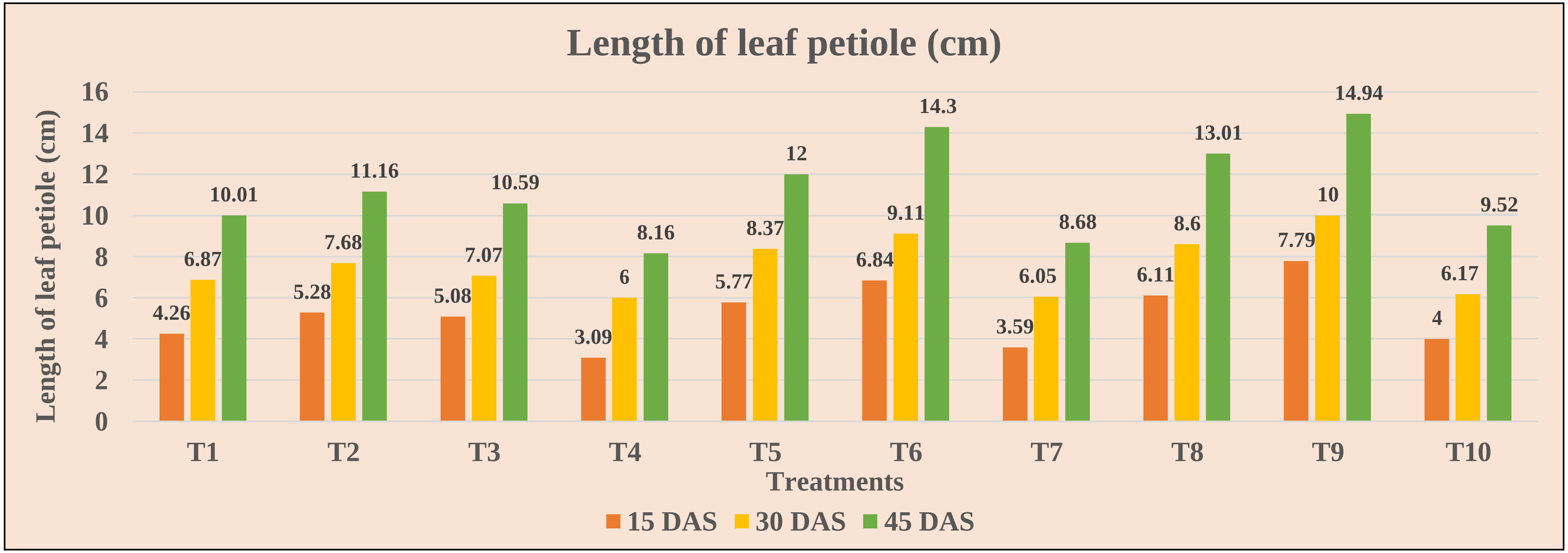

Fig.4 Effect of inorganic nutrients and biofertilizers on length of leaf petiole (cm) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

4.2 Growth parameters

4.2.1. Leaf area (cm^2)

The data pertaining to leaf area were recorded at 15, 30 and 45 DAS which are presented in Table 4.5 and illustrated in Fig.5

AT 15 DAS

The highest leaf area (120.83 cm^2) was found significantly maximum at 15 DAS in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (117.53 cm^2). The minimum leaf area (88.32 cm^2) was observed in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

AT 30 DAS

There was significant difference observed among the integrated source of nutrients with respect to leaf area at 30 DAS. Among all the treatments, T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded maximum leaf area (353.56 cm^2) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (347.24 cm^2), whereas minimum leaf area was registered in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (302.84 cm^2).

AT 45 DAS

All treatments had significant influence on leaf area at 45 DAS. Among the different nutrient source, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded maximum leaf area (401.88 cm^2) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (396.44 cm^2) while, it was significantly minimum in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (354.11 cm^2).

The increase in leaf area might be due to application of integrated nutrient combination which enhances availability of nutrients in soil, reflected in increase of leaf area. These results are in accordance with Sunanda *et al.* (2014) in Kasurimethi.

Table 4.5. Effect of inorganic nutrients and biofertilizers on leaf area (cm^2) in spinach beet Cv. Pusa Bharati

Treatments	**Leaf area (cm^2)**		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	95.88	317.59	369.66
T_2 – 75 % RDF + Azotobacter + PSB +KSB (Each @ 1.25 kg/ha)	101.33	324.14	376.33
T_3- 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	99.44	320.84	374.88
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	88.32	302.84	354.11
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	110.37	338.66	389.18
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	117.53	347.24	396.44
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	90.95	306.37	359.34
T_8 – T_5 + Arka vegetable special @ 5 g/litre	114.53	344.88	393.18
T_9 – T_6 + Arka vegetable special @ 5 g/litre	120.83	353.56	401.88
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	92.59	308.37	360.77
S.E (m) ±	**0.72**	**0.82**	**1.09**
CD at 5 %	**2.16**	**2.45**	**3.23**

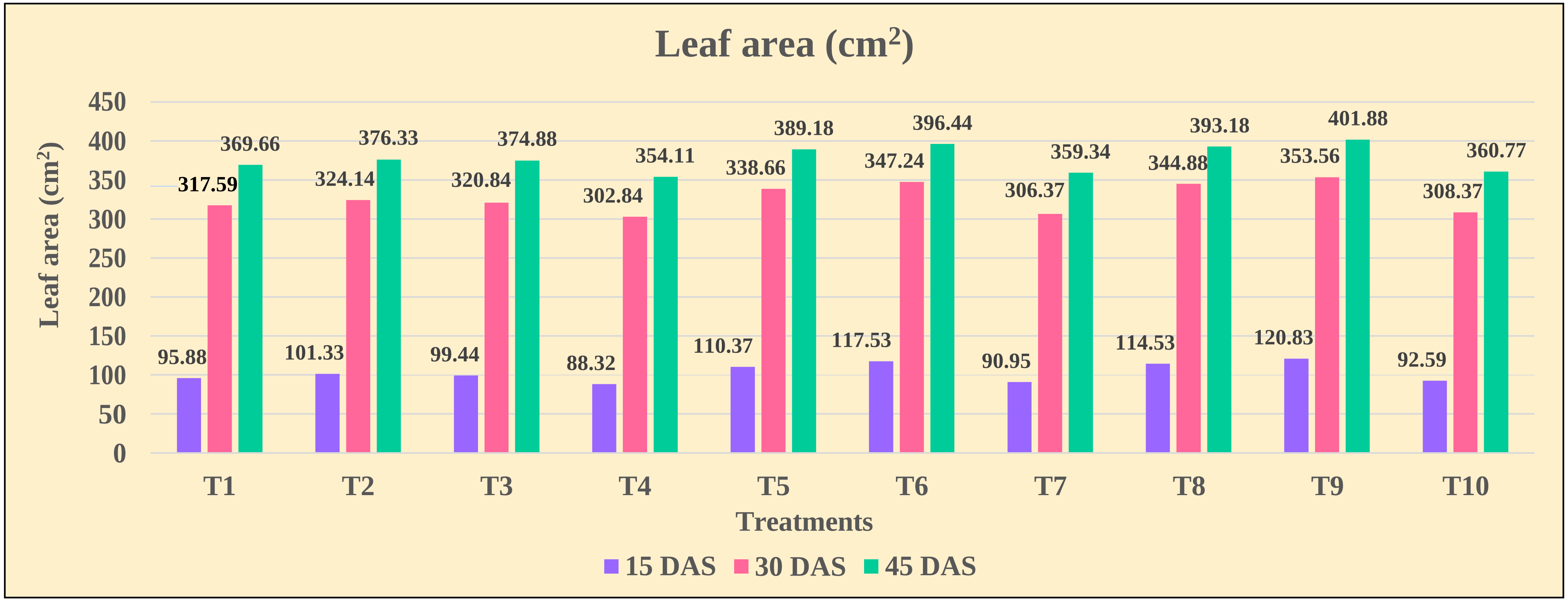

Fig.5 Effect of inorganic nutrients and biofertilizers on leaf area (cm^2) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

4.2.2 Leaf area index

Leaf area index of various treatments of spinach beet is given in Table 4.6 at 15, 30 and 45 days after sowing. Its graphical presentation has been shown in Fig. 6

AT 15 DAS

Highest Leaf area index at 15 DAS was recorded in the treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (0.402) which was followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (0.391) whereas T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) recorded lowest value (0.294) and it was statistically at par with treatment T_7 (25% RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (0.303)

AT 30 DAS

The maximum leaf area index was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (1.178) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (1.157) and it was statistically at par with the treatment T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (1.149) However, the lowest value was observed in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (1.007).

AT 45 DAS

Among the different nutrient source, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (1.339) recorded maximum leaf area index which was followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (1.321) whereas minimum leaf area index (1.180) was registered in T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

Table 4.6. Effect of inorganic nutrients and biofertilizers on leaf area index in spinach beet Cv. Pusa Bharati

Treatments	Leaf area index		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	0.319	1.058	1.232
T_2 – 75 % RDF + Azotobacter + PSB +KSB (Each @ 1.25 kg/ha)	0.337	1.080	1.254
T_3- 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	0.331	1.069	1.249
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	0.294	1.007	1.180
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	0.367	1.128	1.297
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	0.391	1.157	1.321
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	0.303	1.021	1.197
T_8 – T_5 + Arka vegetable special @ 5 g/litre	0.381	1.149	1.310
T_9 – T_6 + Arka vegetable special @ 5 g/litre	0.402	1.178	1.339
T_{10}– T_7 + Arka vegetable special @ 5 g/litre	0.308	1.027	1.202
S.E (m) ±	**0.003**	**0.006**	**0.005**
CD at 5 %	**0.009**	**0.01**	**0.01**

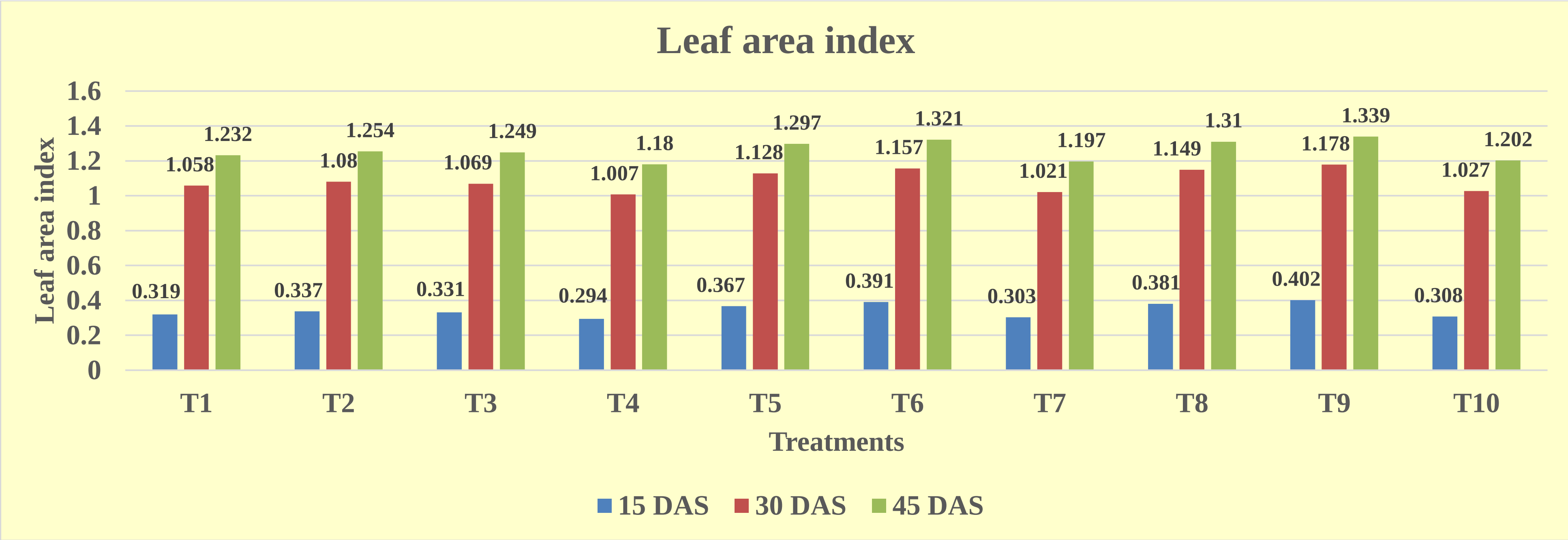

Fig.6 Effect of inorganic nutrients and biofertilizers on leaf area index in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

The increase in leaf area index was due to increase number of leaves per plant and leaf area the results are in agreement with findings of Ramachandra and Thimmaraju (1983) in amaranthus.

4.2.3 Specific leaf area (cm^2 g^{-1})

Specific leaf area was effected by the inorganic nutrients and biofertilizers is presented in the Table 4.7 and Fig.7.

AT 15 DAS

From the data (Table 4.7) can be concluded that, the highest specific leaf area was recorded (15.07 cm^2 g^{-1}) in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) significantly followed by treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (14.41 cm^2 g^{-1}). However, lowest specific leaf area (8.91 cm^2 g^{-1}) was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) significantly followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (9.68 cm^2 g^{-1}).

AT 30 DAS

Highest specific leaf area (25.57 cm^2 g^{-1}) was recorded in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @3.75 kg ha^{-1}) significantly followed by treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (23.35 cm^2 g^{-1}). However, lowest specific leaf area (12.57 cm^2 g^{-1}) was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) and it was significantly followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (14.31 cm^2 g^{-1}).

AT 45 DAS

Highest specific leaf area was recorded (14.64 cm^2 g^{-1}) in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) significantly followed by treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (13.19 cm^2 g^{-1}). However, lowest specific leaf area (6.96 cm^2 g^{-1}) was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) which was

Table 4.7. Effect of inorganic nutrients and biofertilizers on specific leaf area (cm^2 g^{-1}) in spinach beet Cv. Pusa Bharati

Treatments	**Specific leaf area (cm^2 g^{-1})**		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	13.46	22.30	12.62
T_2 – 75 % RDF + Azotobacter + PSB +KSB (Each @ 1.25 kg/ha)	11.97	19.04	10.74
T_3- 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	12.55	20.25	11.57
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	15.07	25.57	14.64
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	10.83	16.61	9.50
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	9.68	14.31	8.03
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	14.41	23.35	13.19
T_8 – T_5 + Arka vegetable special @ 5 g/litre	10.32	15.54	8.82
T_9 – T_6 + Arka vegetable special @ 5 g/litre	8.91	12.57	6.96
T_{10}– T_7 + Arka vegetable special @ 5 g/litre	13.57	21.06	11.87
S.E (m) ±	**0.18**	**0.34**	**0.17**
CD at 5 %	**0.53**	**1.03**	**0.51**

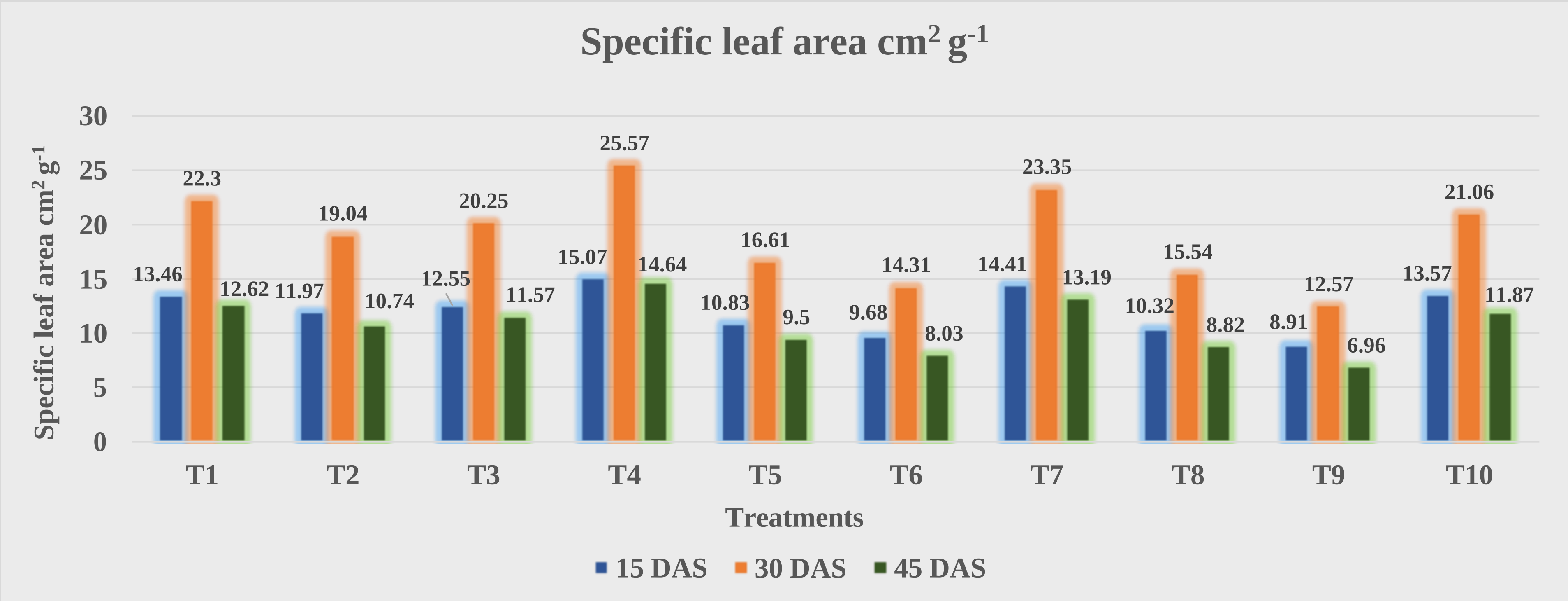

Fig.7 Effect of inorganic nutrients and biofertilizers on specific leaf area (cm^2 g^{-1}) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

significantly followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (8.03 cm^2 g^{-1}) and statistically at par with treatment T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (8.82 cm^2 g^{-1}).

Specific leaf area is the ratio of assimilating area to its dry weight. Highest leaf area was observed in T_4 treatment which might have led to more assimilation of photosynthates and contributed to highest specific leaf area. SLA is maximum in open area crops because of high photosynthetic surface area (Radford, 1967).

4.2.4 Specific leaf weight (g cm^{-2})

The data pertaining to specific leaf weight was found to be non-significant at 15, 30 and 45 DAS presented in Table 4.8 and depicted in Fig.8

15 DAS

Highest specific leaf weight was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (0.112 g cm^{-2}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (0.103 g cm^{-2}). Lowest specific leaf weight was obtained in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (0.053 g cm^{-2}).

30 DAS

Highest specific leaf weight was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (0.079 g cm^{-2}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (0.069 g cm^{-2}). Lowest specific leaf weight was obtained in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (0.039 g cm^{-2}).

45 DAS

Highest specific leaf weight was obtained in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (0.143 g cm^{-2}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (0.124 g cm^{-2}). Lowest specific leaf weight was obtained in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (0.068 g cm^{-2}).

Table 4.8. Effect of inorganic nutrients and biofertilizers on specific leaf weight (g cm^{-2}) in spinach beet Cv. Pusa Bharati

Treatments	Specific leaf weight (g cm^{-2})		
	15 DAS	**30 DAS**	**45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	0.074	0.047	0.079
T_2 – 75 % RDF + Azotobacter + PSB +KSB (Each @ 1.25 kg/ha)	0.083	0.052	0.093
T_3- 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	0.079	0.049	0.086
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	0.053	0.039	0.068
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	0.092	0.060	0.105
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	0.103	0.069	0.124
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	0.069	0.042	0.075
T_8 – T_5 + Arka vegetable special @ 5 g/litre	0.096	0.064	0.113
T_9 – T_6 + Arka vegetable special @ 5 g/litre	0.112	0.079	0.143
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	0.073	0.044	0.084
S.E (m) ±	**0.002**	**0.001**	**0.003**
CD at 5 %	**0.007**	**0.004**	**0.009**

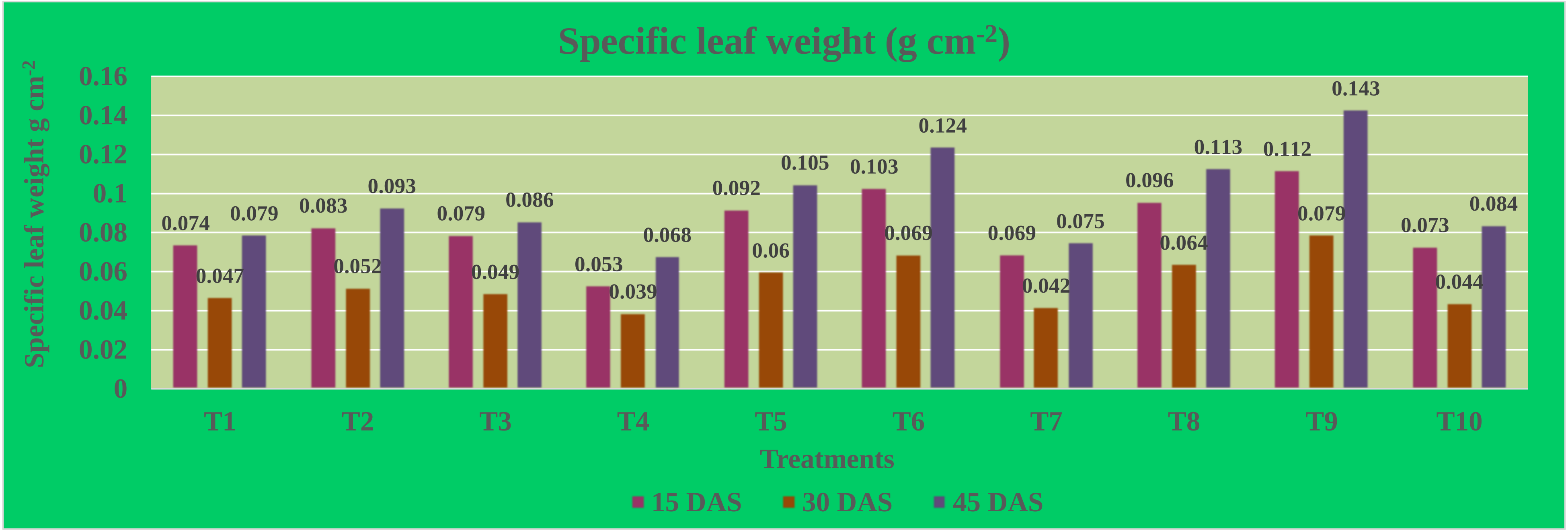

Fig.8 Effect of inorganic nutrients and biofertilizers on specific leaf weight (g cm^{-2}) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

Specific leaf weight is the reverse condition of the Specific leaf area which indicates leaf thickness. Therefore, highest SLW might be due to presence of high leaf thickness that leads to increase in dry leaf weight.

4.2.5 Leaf area Duration (cm^2 d^{-1})

The data on leaf area duration as influenced by various treatments are presented in Table 4.9 and illustrated in Fig.9

Between 15 to 30 days

Leaf area duration was highest in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (11.79 cm^2 d^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (11.55 cm^2 d^{-1}) and it was at par with treatment T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (11.40 cm^2 d^{-1}) whereas, lowest values were recorded in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (9.70 cm^2 d^{-1}).

Between 30 to 45 days

Leaf area duration was highest in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (18.75 cm^2 d^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (18.52 cm^2 d^{-1}) whereas, lowest values were recorded in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) (16.35 cm^2 d^{-1})

Higher leaf area duration may be due to the higher leaf area index. The results are confirmation with findings of Ramachandra and Thimmaraju (1983) in amaranthus.

4.3 Yield parameters

4.3.1 Number of leaves per plant

The data enunciated on number of leaves per plant as affected by the inorganic nutrients and biofertilizers at 30, 45 and 60 days after sowing are presented in the Table 4.10 and Fig.10

Table. 4.9. Effect of inorganic nutrients and biofertilizers on leaf area duration ($cm^2\ d^{-1}$) in spinach beet Cv. Pusa Bharati

Treatments	Leaf area duration ($cm^2\ d^{-1}$)	
	15 to 30 DAS	**30 to 45 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	10.26	17.10
T_2 – 75 % RDF + Azotobacter + PSB +KSB (Each @ 1.25 kg/ha)	10.62	17.47
T_3- 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	10.43	17.25
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	9.70	16.35
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	11.15	18.07
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	11.55	18.52
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	9.92	16.57
T_8 – T_5 + Arka vegetable special @ 5 g/litre	11.40	18.37
T_9 – T_6 + Arka vegetable special @ 5 g/litre	11.79	18.75
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	9.96	16.65
S.E (m) ±	**0.06**	**0.04**
CD at 5 %	**0.19**	**0.14**

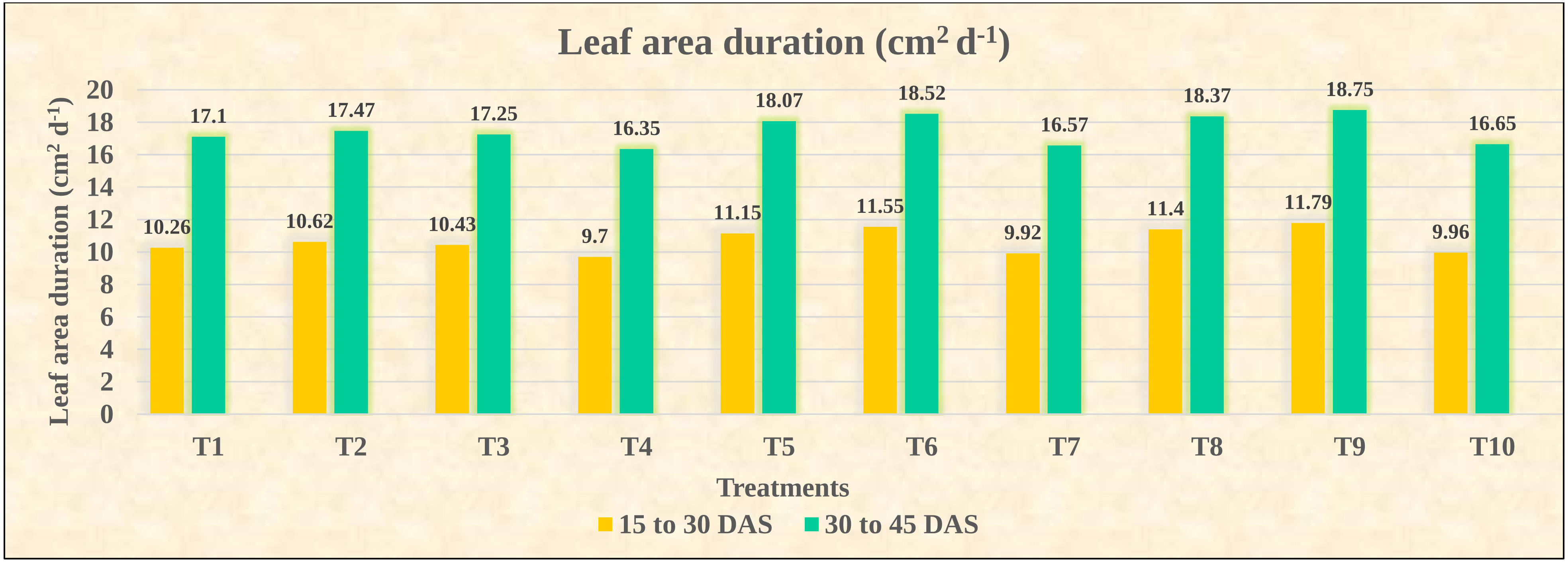

Fig.9 Effect of inorganic nutrients and biofertilizers on leaf area duration ($cm^2 d^{-1}$) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

AT 30 DAS

The maximum number of leaves per plant was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (13.16) which was statistically at par with the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (12.58) while it was minimum in treatment T_4 **(**25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75kg ha^{-1}) (6.11) which was at par with treatments T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (6.36), T_{10} (T_7 + Arka vegetable special @ 5 g L^{-1}) (6.94) and T_1 (100 % RDF @ 100:25:50 kg ha^{-1}) (7.01).

AT 45 DAS

Significantly highest number of leaves per plant was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (16.56) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (15.05). Lowest number of leaves were obtained in T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75kg ha^{-1}) (6.44) and statistically at par with the treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (7.54)

AT 60 DAS

Significantly maximum number of leaves per plant was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (19.91) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1})(18.17) statistically at par with T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (17.02) while, minimum number of leaves (9.32) was recorded in treatment T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75kg ha^{-1}) and it was statistically at par with treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (10.06)

The production of maximum number of leaves might be due to higher metabolic activity because of optimum N supply resulting in higher production of carbohydrates and phytohormones. These results are in line with Sentiyangla *et al.* (2010) who reported significant increase in number of leaves in radish.

3.2 Leaf weight (g)

The data pertaining to leaf weight of spinach beet as effected by the inorganic and biofertilizers are presented in the Table 4.11 and Fig. 11

Table 4.10. Effect of inorganic nutrients and biofertilizers on number of leaves per plant in spinach beet Cv. Pusa Bharati

Treatments	Number of leaves per plant		
	30 DAS	**45 DAS**	**60 DAS**
T_1 – 100 % RDF @ 100:25:50 Kg/ha	7.01	9.06	12.42
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 Kg/ha)	9.11	11.02	14.92
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 Kg/ha)	8.06	10.39	14.02
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75Kg/ha)	6.11	6.44	9.32
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	10.59	12.64	16.00
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	12.58	15.05	18.17
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	6.36	7.54	10.06
T_8 – T_5 + Arka vegetable special @ 5 g/litre	11.02	13.82	17.02
T_9 – T_6 + Arka vegetable special @ 5 g/litre	13.16	16.56	19.91
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	6.94	8.23	11.14
S.E (m) ±	**0.36**	**0.39**	**0.42**
CD at 5 %	**1.08**	**1.18**	**1.25**

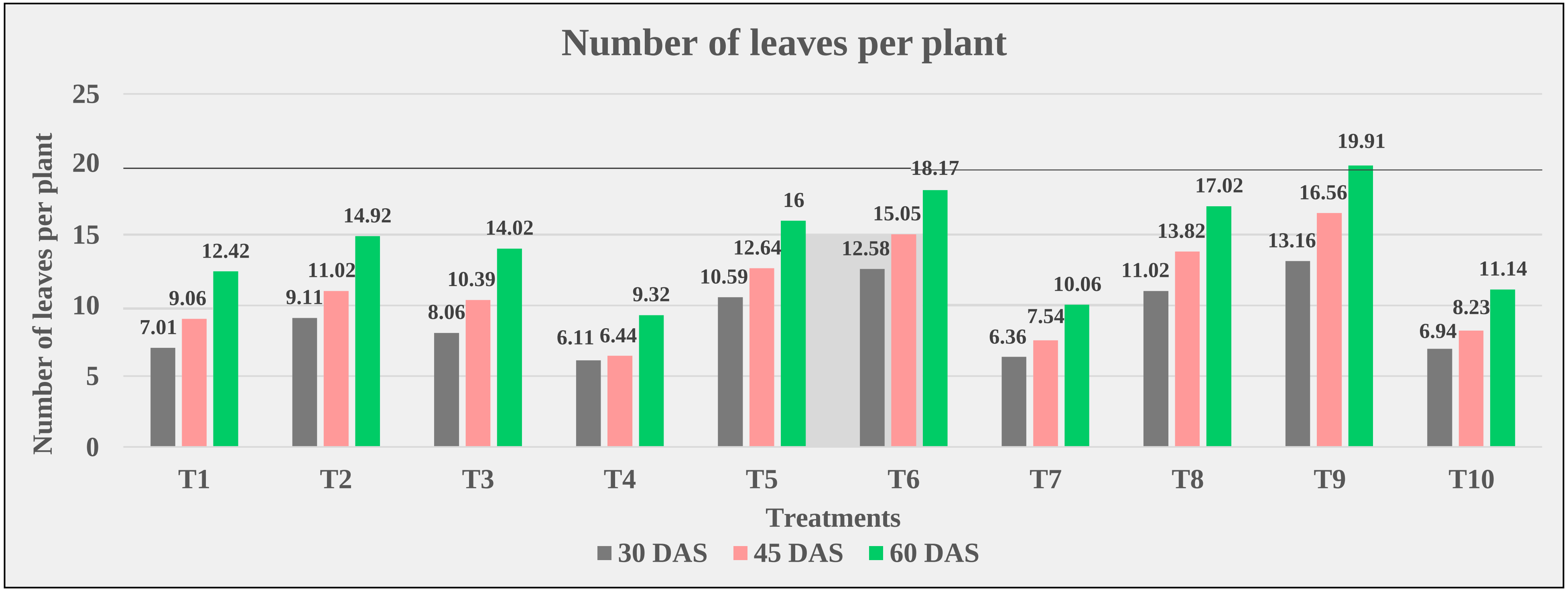

Fig.10 Effect of inorganic nutrients and biofertilizers on number of leaves per plant in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

AT 30 DAS

Among all the treatments, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (19.38 g) recorded maximum leaf weight and was statistically at par with the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (18.97 g) while, T_6 was at par with T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (18.77 g) whereas minimum leaf weight (14.69 g) was observed in T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

AT 45 DAS

Highest leaf weight (38.76 g) was recorded under treatment T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (37.94 g) and it was at par with T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (37.55 g). Lowest leaf weight (29.38 g) was observed in T_4 (25% RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

AT 60 DAS

The maximum leaf weight (36.44 g) was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (35.24 g) whereas minimum leaf weight (25.32 g) was recorded in T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) statistically at par with treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (26.13 g).

Maximum leaf weight by T_9 at 30, 45 and 60 DAS might be due to availability of nutrients from inorganic N and biofertilizers in adequate quantities which are essential for growth and development. Nitrogen being a constituent of protoplasm and its favourable effect on chlorophyll content of leaves might have resulted in increased synthesis of carbohydrates (Tisdale *et al*., 1993)

4.3.3 Leaf yield plant^{-1} (g)

The data pertaining to the leaf yield per plant at 30, 45 and 60 days after sowing were recorded and presented in Table 4.12 and Fig.12

Table 4.11. Effect of inorganic nutrients and biofertilizers on leaf weight (g) in spinach beet Cv. Pusa Bharati

Treatments	Leaf weight (g)		
	30 DAS	**45 DAS**	**60 DAS**
T_1 – 100 % RDF @ 100:25:50 Kg/ha	16.59	33.15	28.40
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 Kg/ha)	17.61	35.23	31.09
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 Kg/ha)	17.43	34.86	29.59
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75Kg/ha)	14.69	29.38	25.32
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	18.30	36.61	32.14
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	18.97	37.94	35.24
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	15.74	31.48	26.13
T_8 – T_5 + Arka vegetable special @ 5 g/litre	18.77	37.55	33.69
T_9 – T_6 + Arka vegetable special @ 5 g/litre	19.38	38.76	36.44
T_{10}– T_7 + Arka vegetable Special @ 5 g/litre	16.29	32.59	27.26
S.E (m) ±	**0.17**	**0.18**	**0.38**
CD at 5 %	**0.51**	**0.54**	**1.13**

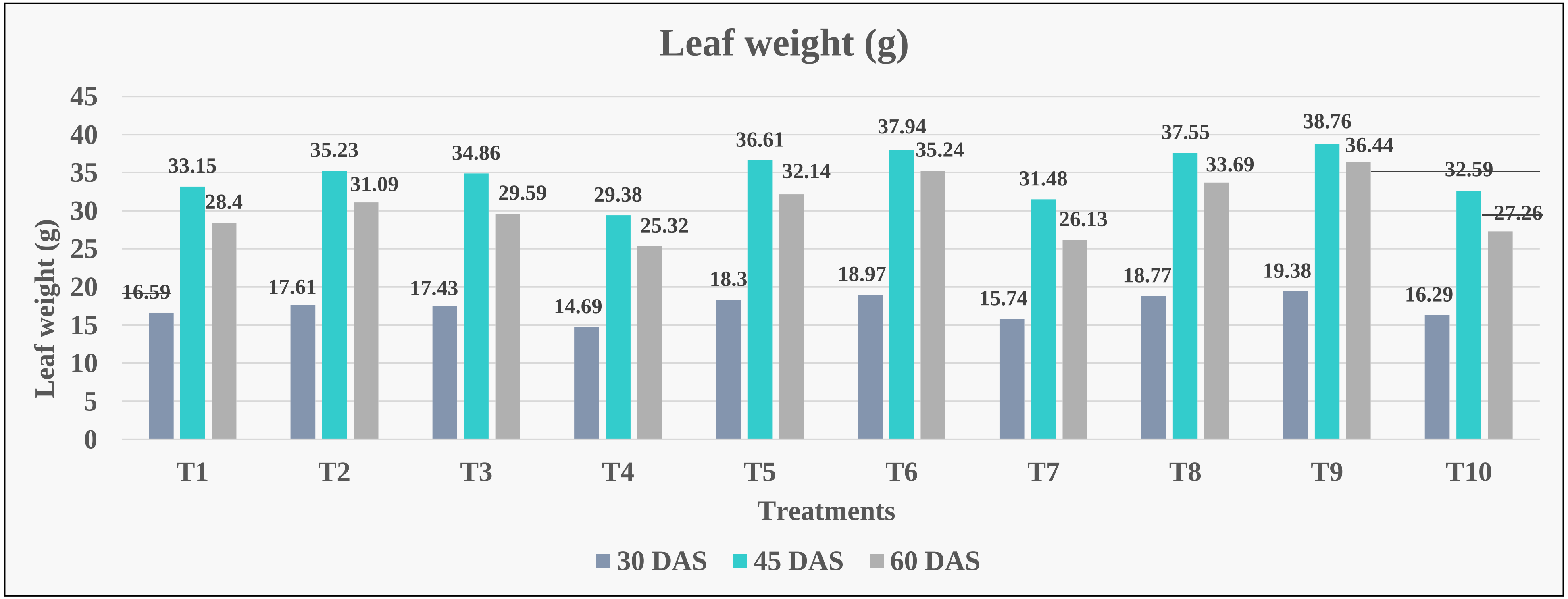

Fig.11 Effect of inorganic nutrients and biofertilizers on leaf weight (g) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

AT 30 DAS

Significantly maximum leaf yield plant^{-1} (41.53 g) was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (38.90 g) whereas, the minimum value (28.00 g) was recorded in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}) statistically at par with treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (29.06 g).

AT 45 DAS

Significantly maximum leaf yield plant^{-1} was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (47.65 g) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (44.21 g) and it was statistically at par with T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (43.65 g). However minimum value was recorded in treatment T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @3.75 kg ha^{-1}) (35.00 g) statistically at par with the treatment T_7 (25 % RDF + AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}) (36.02 g).

AT 60 DAS

Among all the treatments T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (98.11 g) significantly recorded highest value which was at par with the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (97.01 g) While, the lowest value (82.32 g) was registered in T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

Highest yield in T_9 treatment might be due to increased vegetative growth, balanced C/N ratio and role of co-enzymes directly or indirectly in regulating various physiological processes within plant, which could have ultimately led to greater yield. All these properties in inorganic nutrients, biofertilizers and micronutrient spray might have led to better root proliferation, better translocation of plant nutrients and accelerated carbohydrate synthesis, finally leading to better leaf yield. Similar results were reported by Stancheva and Mithova (2002) and Tosic *et al*. (2016).

Table 4.12. Effect of inorganic nutrients and biofertilizers on leaf yield Plant^{-1} (g) in spinach beet Cv. Pusa Bharati

Treatments	Leaf yield plant^{-1} (g)		
	30 DAS	**45 DAS**	**60 DAS**
T_1 – 100 % RDF @ 100:25:50 kg/ha	31.19	38.36	88.23
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)	33.76	41.11	91.62
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	32.26	40.02	89.59
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	28.00	35.00	82.32
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	35.50	42.51	93.15
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	38.90	44.21	97.01
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	29.06	36.02	84.83
T_8 – T_5 + Arka vegetable special @ 5 g/litre	36.84	43.65	94.30
T_9 – T_6 + Arka vegetable special @ 5 g/litre	41.53	47.65	98.11
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	30.14	37.12	86.13
S.E (m) ±	**0.52**	**0.36**	**0.37**
CD at 5 %	**1.56**	**1.08**	**1.12**

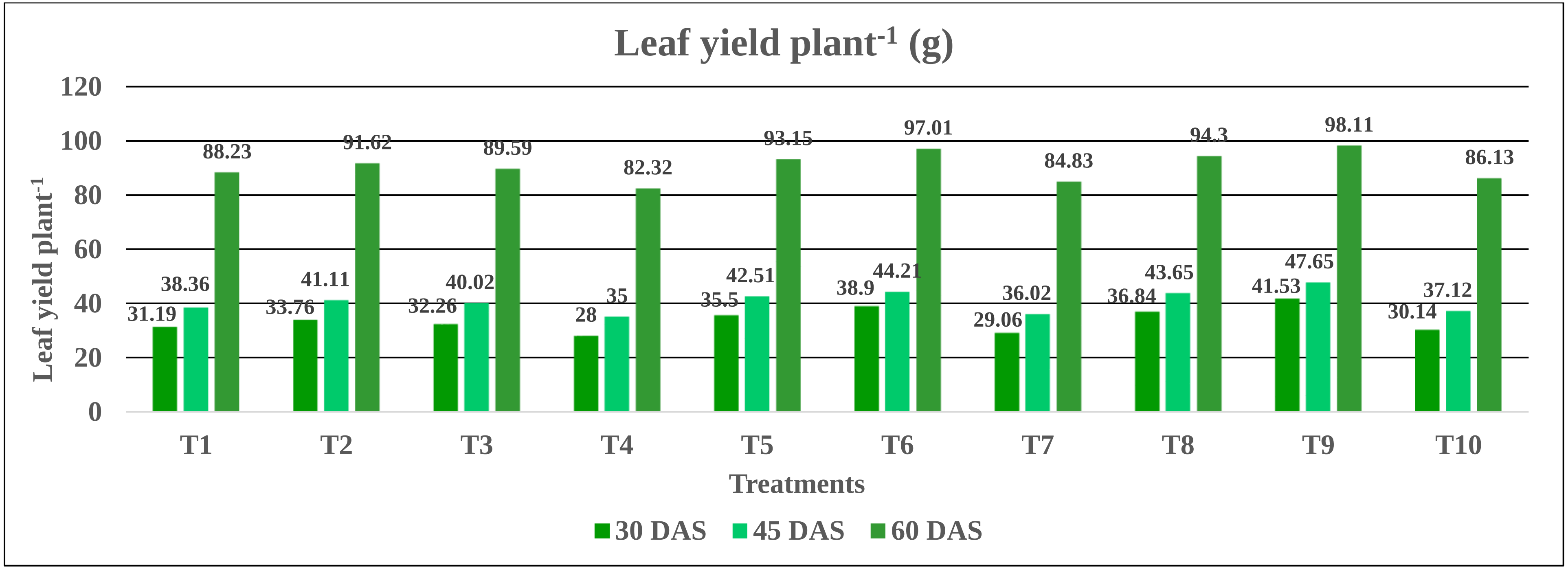

Fig.12 Effect of inorganic nutrients and biofertilizers on leaf yield plant^{-1} (g) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

4.3.4 Leaf yield ha^{-1} (q)

Effect of inorganic nutrients and biofertilizers on Leaf yield q ha^{-1} is presented in the Table 4.13 and depicted in Fig.13

All the treatments differed significantly with respect to leaf yield per hectare. It was observed that, significantly highest yield was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) (412.75 q ha^{-1}) followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (388.25 q ha^{-1}) While, the lowest yield (235.88 q ha^{-1}) was registered in T_4 (25 % RDF + Biofertilizers [Azotobacter + PSB + KSB] (Each @ 3.75 kg ha^{-1}).

The increment of yield might be due to application of inorganic nutrients and biofertilizers *i.e.,* Azotobacter, PSB, KSB and AMC which have enhanced the availability of N and P in soil as major plant nutrients. The yield improvement may be attributed to higher yield attributing components such as increased vegetative and yield parameters which were positively affected by the foliar application of micronutrients as reported by Diana and Nehru (2014).

4.4 Quality parameters

4.4.1 Moisture content (%)

Data in respect of moisture content of leaves is presented in Table 4.14 and illustrated in Fig.14

Highest moisture content was recorded in T_1 treatment (100 % RDF @ 100:25:50 kg ha^{-1}) (92.54 %). Lowest moisture (84.46 %) was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}).

However, vegetables with high moisture deteriorate faster. Pertaining to data presented in Table 4.14 indicated that the treatment receiving 50 % RDF through inorganic nutrients and 50 % biofertilizers *i.e.* Arka microbial consortium (AMC) and Potassium solubilizing bacteria (KSB) recorded significantly less moisture content after harvest and in 100 % RDF it was high. Lower moisture might be due to higher dry matter accumulation, as a result of increased photosynthetic activity and availability of macro and micro elements. These results are in similar lines with the findings of Karadkhelkar (1985) in spinach.

Table 4.13. Effect of inorganic nutrients and biofertilizers on leaf yield ha^{-1} (q) in spinach beet Cv. Pusa Bharati

Treatments	1st cut (kg/plot)	2nd cut (kg/plot)	3rd cut (kg/plot)	Total yield (kg/plot)	Total yield (q/ha)
T_1 – 100 % RDF @ 100:25:50 kg/ha	4.14	3.94	3.74	11.84	296.19
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)	4.57	4.43	4.23	13.23	330.75
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	4.53	4.17	4.03	12.73	318.25
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	3.28	3.14	3.00	9.43	235.88
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	5.07	4.53	4.30	13.90	347.50
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	5.43	5.07	5.03	15.53	388.25
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	3.74	3.54	3.34	10.62	265.57
T_8 – T_5 + Arka vegetable special @ 5 g/litre	5.23	4.63	4.67	14.53	363.25
T_9 – T_6 + Arka vegetable special @ 5 g/litre	5.77	5.47	5.27	16.51	412.75
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	3.99	3.79	3.59	11.37	284.26
S.E (m) ±	**0.07**	**0.15**	**0.15**	**0.28**	**1.03**
CD at 5 %	**0.20**	**0.46**	**0.46**	**0.89**	**3.08**

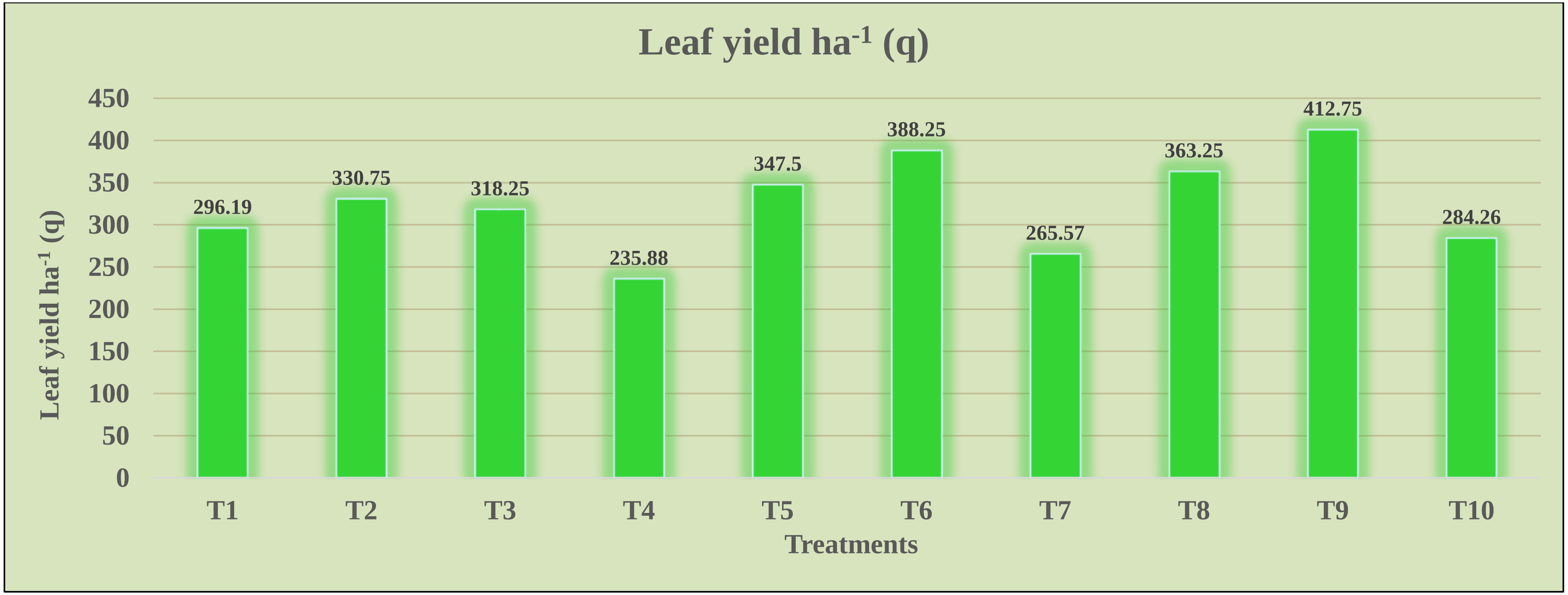

Fig.13 Effect of inorganic nutrients and biofertilizers on leaf yield ha^{-1} (q) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

4.4.2 Shelf life (No.of days)

The data pertaining to shelf life was found significant and is presented in Table 4.14 and furnished in Fig.15

The maximum shelf life of spinach was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (2.99 days) followed by T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (2.74 days). The minimum (1.20 days) was observed in the T_1 treatment (100 % RDF @ 100:25:50 kg ha^{-1}).

The increased shelf life due to combined application of inorganic nutrients, biofertilizers and Arka vegetable special micronutrient spray could be due to better nutrient supply helping to maintain equilibrium in metabolism even after harvest. Healthy plant with moderate moisture and less loss of carbohydrates from the produce of this treatment might have helped in increasing the shelf life.

4.4.3 Carotene content (mg 100g^{-1})

The carotene content of spinach was observed at all the three cutting stages of the crop, and the data is reported as mean in Table 4.15 and illustrated in Fig.16

Significantly maximum carotene content (10.59 mg 100 g^{-1}) was observed in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (10.19 mg 100 g^{-1}). The minimum carotene content (5.66 mg 100 g^{-1}) was observed in T_1 (100 % RDF @ 100: 25: 50 kg ha^{-1}).

A mean carotene of 10.59 mg 100 g^{-1} was obtained and it ranged from 5.66 to 10.59 mg 100 g^{-1} among treatments. Application of recommended fertilizer dose had significantly enhanced the carotene content (10.59 mg 100 g^{-1}). Maurya and Goswami (1985) also reported such highest carotene content with balanced NPK application.

4.4.4 Vitamin-C (mg/100g)

Significant differences were observed in respect of Vitamin-C content among different treatment combinations of inorganic nutrients and biofertilizers and data mean values are presented in Table 4.15 and Fig. 17

The maximum Vitamin-C content in palak leaves (65.70 mg 100g^{-1}) was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by

Table 4.14. Effect of inorganic nutrients and biofertilizers on Moisture content (%) and Shelf life (No. of days) in spinach beet Cv. Pusa Bharati

Treatments	Moisture content (%)	Shelf life (No. of days)
T_1 – 100 % RDF @ 100:25:50 Kg/ha	92.54	1.20
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 Kg/ha)	88.38	2.51
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	89.67	2.35
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	91.95	1.41
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB 1.25 kg/ha	90.86	2.12
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	91.25	1.86
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	91.46	1.50
T_8 – T_5 + Arka vegetable special @ 5 g/litre	87.39	2.74
T_9 – T_6 + Arka vegetable special @ 5 g/litre	84.46	2.99
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	91.38	1.63
S.E (m) ±	**0.10**	**0.06**
CD at 5 %	**0.31**	**0.17**

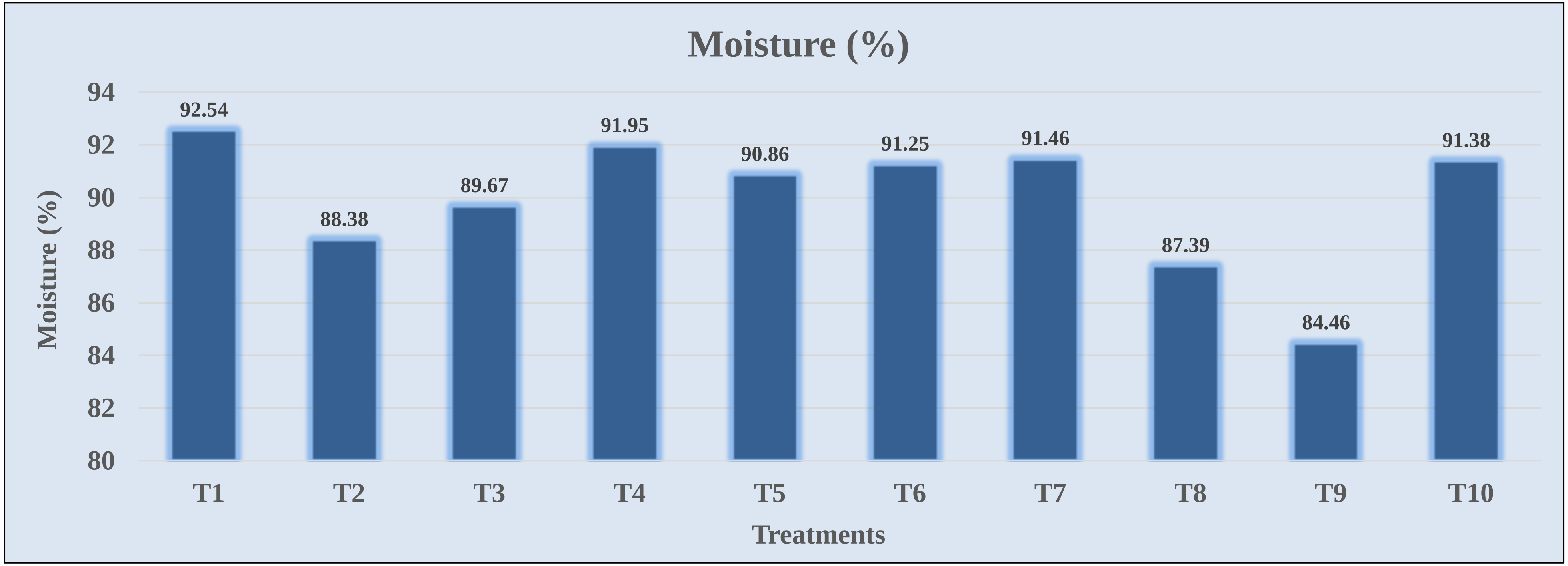

Fig.14 Effect of inorganic nutrients and biofertilizers on Moisture (%) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

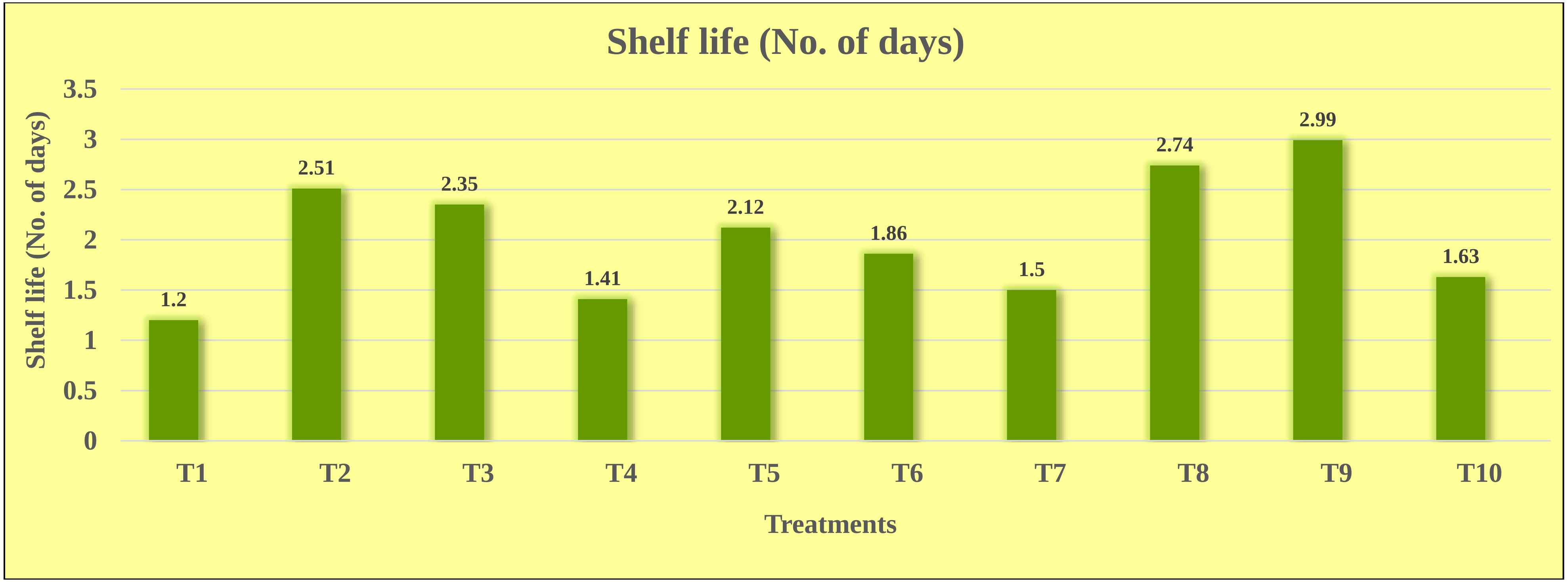

Fig.15 Effect of inorganic nutrients and biofertilizers on Shelf life (No. of days) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 - 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

treatment T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (64.60 mg $100g^{-1}$). The lowest Vitamin-C content (43.18 mg $100g^{-1}$) was observed in the treatment T_1 (100 % RDF @ 100:25:50 kg ha^{-1}).

The ascorbic acid (Vitamin-C) content in spinach leaves ranged from 43.18 to 65.70 mg $100g^{-1.}$ The highest ascorbic acid content was recorded with the treatment 50 % RDF through inorganic fertilizers with integration of 50 % biofertilizers could be enhanced the growth promoting substances which accelerates the physiological process like synthesis of carbohydrates. The results unison with the findings of Kalyani *et al*. (1996) in cauliflower, Balakrishnan (1988) in chillies.

4.4.5 SPAD units

The chlorophyll content of spinach was measured with a spadmeter at all the three cutting stages of the crop, and the data is reported as mean spadmeter readings in Table 4.15 and Fig 18.

The chlorophyll content was the highest (41.63 SPAD units) when the crop received all the three major nutrients in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (40.41 SPAD units). The lowest value recorded in treatment T_1 (100 % RDF @ 100:25:50 kg ha^{-1}) (29.25 SPAD units).

Higher chlorophyll content in treatment T_9 might be due to the application of 50 % RDF where maximum nitrogen is available and Arka microbial consortium contains N fixing, P and Zn solubilizing microbes' involvement in protein synthesis could have resulted more chlorophyll synthesis in spinach beet. These results are in agreement with the findings of Paithankar and Gore (2018).

4.4.6 Physiological loss in weight (PLW%)

The data regarding physiological loss in weight of spinach influenced due to different treatments of inorganic and biofertilizers presented in Table 4.16 and depicted in Fig. 19

The data clearly revealed that there was increase in weight loss of spinach as per the storage period. The minimum physiological loss in weight was recorded

Table 4.15. Effect of inorganic nutrients and biofertilizers on vitamin-C, carotene content and chlorophyll (SPAD units) in spinach beet Cv. Pusa Bharati

Treatments	Vitamin-C (mg 100 g^{-1})	Carotene content (mg 100 g^{-1})	Chlorophyll (SPAD units)
T_1 – 100 % RDF @ 100:25:50 kg/ha	43.18	5.66	29.25
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)	62.56	9.52	39.05
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	56.80	9.32	37.94
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	51.63	8.25	34.13
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	52.15	8.43	35.31
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	54.35	8.97	36.78
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	48.88	7.67	32.97
T_8 – T_5 + Arka vegetable special @ 5 g/litre	64.60	10.19	40.41
T_9 – T_6 + Arka vegetable special @ 5 g/litre	65.70	10.59	41.63
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	45.98	6.46	31.36
S.E (m) ±	**0.349**	**0.117**	**0.326**
CD at 5%	**1.03**	**0.342**	**0.968**

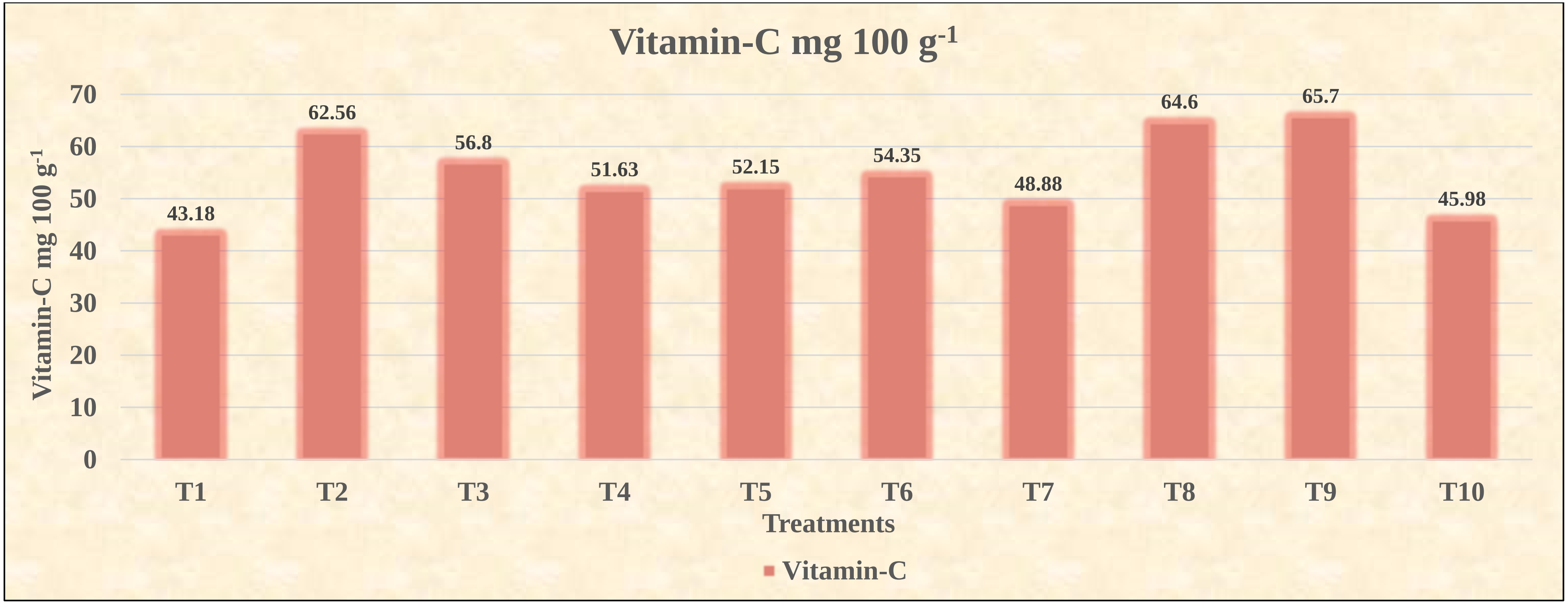

Fig.16 Effect of inorganic nutrients and biofertilizers on Vitamin – C (mg 100 g^{-1}) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

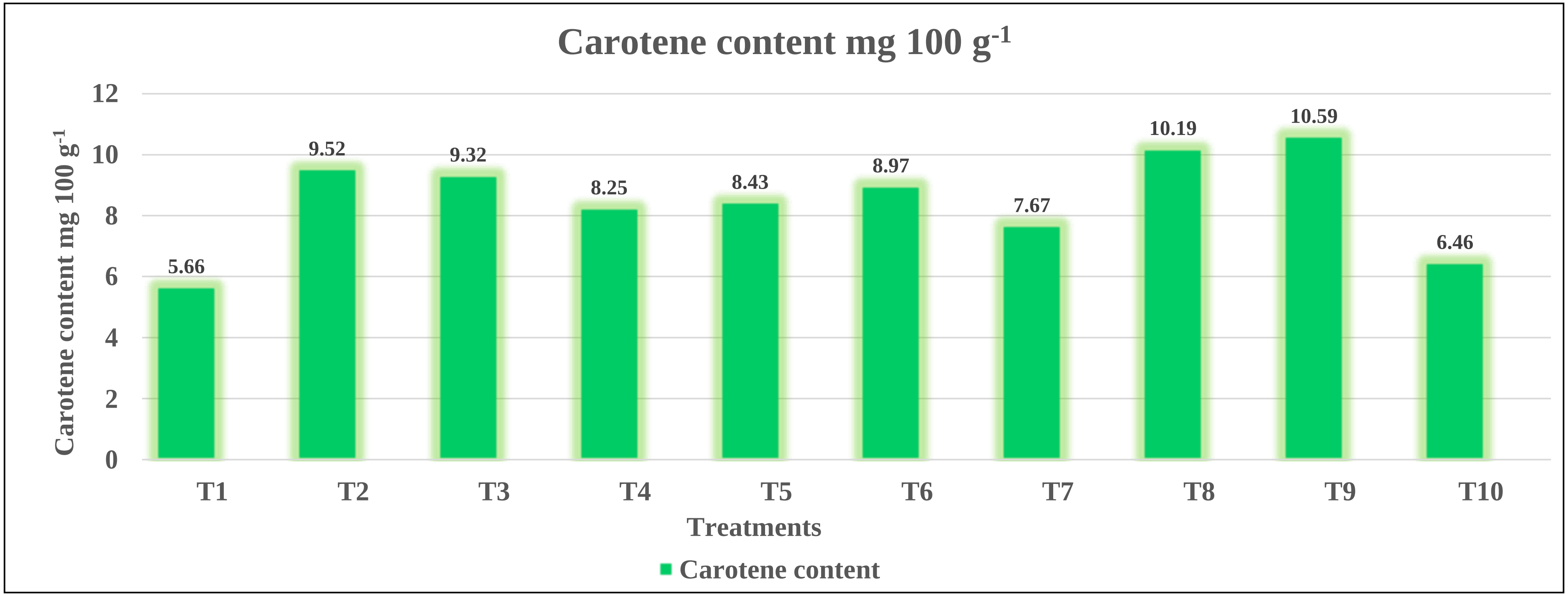

Fig.17 Effect of inorganic nutrients and biofertilizers on Carotene content (mg 100 g^{-1}) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

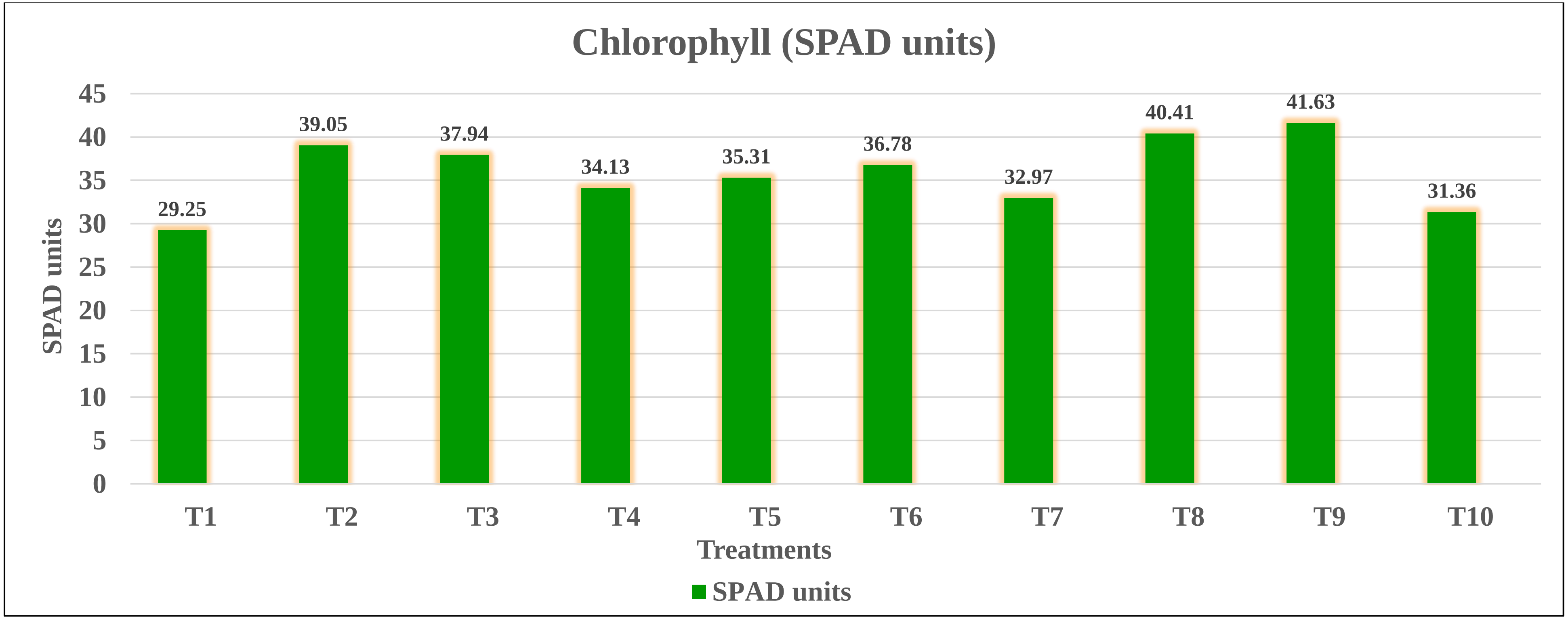

Fig.18 Effect of inorganic nutrients and biofertilizers on Chlorophyll (SPAD units) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (47.24 %) followed by T_8 (T_5 + Arka vegetable special @ 5 g L^{-1}) (47.32 %). The maximum physiological loss in weight (55.31 %) was recorded in treatment T_1 (100 % RDF @ 100:25:50 kg ha^{-1}).

The application of biofertilizers probably reduced the respiration rate, which in turn resulted in higher shelf life and reduction in PLW. The higher moisture content in inorganic spinach leads to more percentage of respiration, rotting and decaying due to microbial activity and ultimately decrease its shelf life. Higher physiological loss in weight (%) recorded in treatment T_1 may be due to loss of water in the fresh produce can cause reduction in turbidity, loss of nutritional quality and undesirable changes in colour. The weight loss is mainly caused by water transpiration and respiration.

5. Soil nutrient analysis

5.1.1 Macronutrients

The available N_2, P_2O_5 and K_2O were significantly influenced by the application of inorganic nutrients and biofertilizers. The results were presented in Table 4.17. and Fig.20

5.1.1 Soil Available nitrogen (kg ha^{-1})

After harvest soil available nitrogen status was significantly influenced by the application of inorganic nutrients and biofertilizers and their combinations to the experiment soils. The highest post harvest soil available nitrogen (202.60 kg ha^{-1}) was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 gm $litre^{-1}$) followed by T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (192.60 kg ha^{-1}) The lowest post harvest soil available nitrogen (85.60 kg ha^{-1}) was recorded T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1}).

5.1.2. Soil Available phosphorous (kg ha^{-1})

Significantly maximum phosphorous (159 kg ha^{-1}) was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 gm $litre^{-1}$) under the study. It was followed by the treatment T_6 (50 % RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (114.6 kg ha^{-1}) while, minimum phosphorous content (62.30 kg ha-1) was recorded in treatment T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1}) (Table 4.17) respectively.

Table 4.16. Effect of inorganic nutrients and biofertilizers on Physiological loss in weight (%) in spinach beet Cv. Pusa Bharati

Treatments	Physiological loss in weight (%)			
	Day - 1	**Day - 2**	**Day - 3**	**Mean**
T_1 – 100% RDF @ 100:25:50 Kg/ha	26.57	66.45	87.65	55.31
T_2 - 75% RDF + Azotobacter + PSB + KSB (Each @1.25 Kg/ha)	19.97	44.46	74.47	48.48
T_3 - 50% RDF + Azotobacter + PSB + KSB (Each @ 2.5 Kg/ha)	20.01	47.35	75.60	49.17
T_4 - 25% RDF + Azotobacter + PSB + KSB (Each @ 3.75Kg/ha)	26.52	63.24	81.52	55.09
T_5 - 75% RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	21.11	51.07	76.52	49.51
T_6 - 50% RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	22.30	53.00	77.29	49.75
T_7 - 25% RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	25.88	56.96	80.13	54.45
T_8 – T_5 + Arka vegetable special @ 5 g/litre	18.06	42.79	73.04	47.32
T_9 – T_6 + Arka vegetable special @ 5 g/litre	17.66	40.19	69.43	47.24
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	24.25	56.20	79.55	50.20
S.E (m) ±	**0.182**	**0.182**	**0.182**	**-**
C.D at 5%	**0.542**	**0.542**	**0.542**	**-**

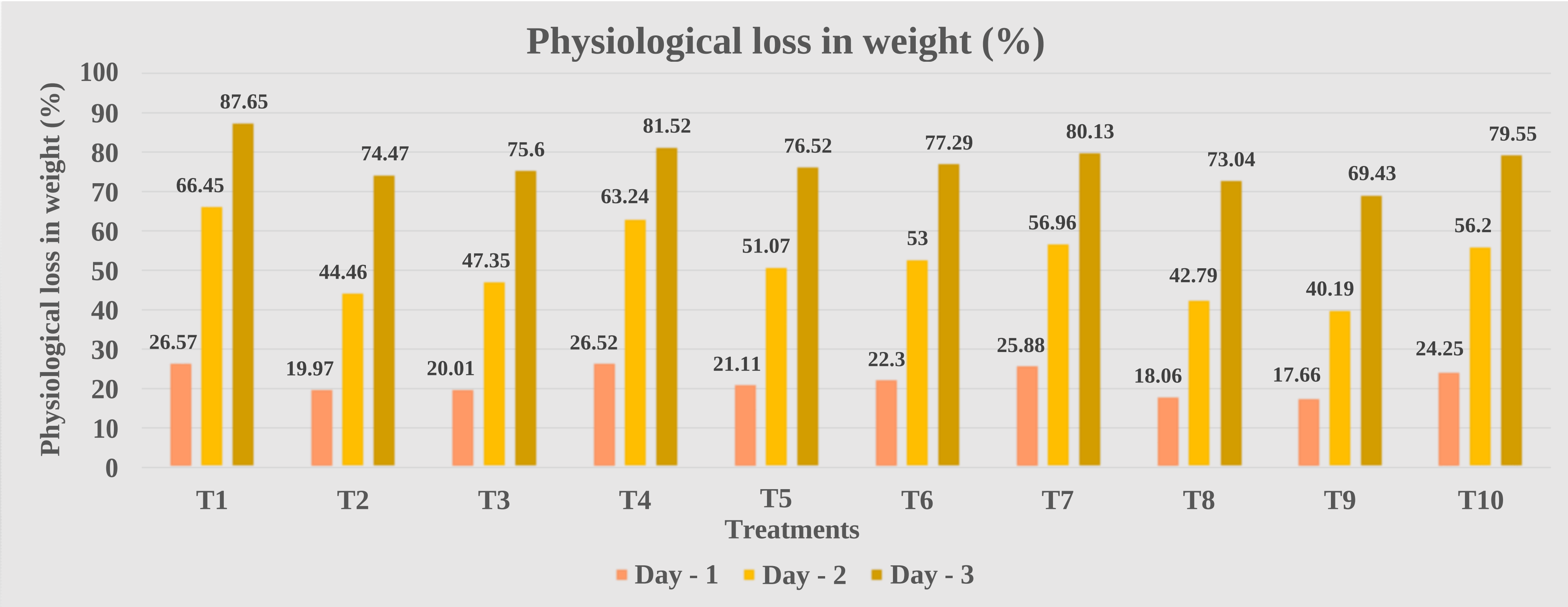

Fig.19 Effect of inorganic nutrients and biofertilizers on Physiological loss in weight (%) in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

5.1.3. Soil Available potassium (kg ha^{-1})

Significantly maximum potassium (316.60 Kg ha^{-1}) was recorded in treatment T_9 (T_6 + Arka Vegetable Special @ 5 gm $litre^{-1}$) followed by T_6 (50% RDF + AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}) (273.60 kg ha^{-1}) and minimum potassium content in (106.00 kg ha^{-1}) was recorded in treatment T_1 (100 % RDF @ 100: 25: 50 kg ha^{-1}) results are presented in Table 4.17.

5.2.1 Micronutrients

The data on micronutrients (Fe, Mn, Zn and Cu) were analyzed in the post-harvest soil samples and is given in Table 4.17 and depicted in Fig.21

Highest concentrations of Fe, Mn, Zn and Cu were obtained under treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) (9.27, 9.59, 3.08 and 3.66 mg kg^{-1}) Lowest concentrations of Fe, Mn, Zn and Cu were obtained under T_1(100% RDF @ 100: 25: 50 kg ha^{-1}) compared to rest of treatments (8.23, 9.11, 2.46 and 2.79 mg kg^{-1})

The data on post-harvest soil analysis revealed meager changes. The post-harvest nutrient levels were more than the intial levels. It appears from the data that application of inorganic, biofertilizers and micronutrients might have been maximized the percentage of these nutrients (Mathavan, 2000).

6. Economics

Higher money value and less cost of cultivation are desirable for getting higher returns the economics of different treatment combinations consisting of land configuration and fertilizer level worked out by considering the prevailing market price of produce and input is furnished. Hence economics of the treatments was worked out and the data pertaining to economics of different treatments are depicted in Table 4.18 and Fig.22

The treatment application of T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded highest benefit cost ratio (6.00) whereas, the minimum benefic cost ratio (3.50) recorded in treatment T_4 (25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg ha^{-1}).

The benefit cost ratio under each treatment was worked out to judge the feasibility of its implementation. The data indicated that maximum profit could be realized under treatment combination with 50 % inorganic nutrients with integration of 50 % biofertilizers which was the highest among all treatments. This might be due to the fact that 50 % inorganic and 50 % organic sources enhances the nutrient availability resulting in vigorous plant growth and dry matter production which in turn resulted in giving higher yields and economics over other treatments. These results are very close to the findings of Chaudhary *et al.* (2011) in fenugreek and reported that maximum net return and B: C ratio with integration of 50% RDF through vermicompost + 50% RDF through inorganic sources and also for realizing good soil health and sustainable production.

Table 4.17. Effect of inorganic nutrients and biofertilizers on soil after harvest of the crop

Treatments	**Macronutrients (kg ha^{-1})**			**Micronutrients (mg kg^{-1})**			
	N	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
T_1 – 100 % RDF @ 100:25:50 kg/ha	95.53	79.30	106.00	8.23	9.11	2.46	2.79
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)	105.81	87.00	254.00	8.63	9.31	2.86	3.11
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)	98.60	82.30	246.00	8.83	9.21	2.77	3.01
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)	85.60	62.30	112.00	8.43	9.15	2.57	2.95
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	154.60	92.00	264.60	8.73	9.18	2.92	3.25
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	192.60	114.60	273.60	8.83	9.22	2.95	3.35
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha	88.56	67.00	150.00	8.87	9.35	2.98	3.38
T_8 – T_5 + Arka vegetable special @ 5 g/litre	190.00	94.00	270.00	9.11	9.56	3.04	3.40
T_9 – T_6 + Arka vegetable special @ 5 g/litre	202.60	159.00	316.60	9.27	9.59	3.08	3.66
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	90.86	77.36	171.00	9.05	9.46	3.01	3.51
S.E (m) ±	**0.73**	**0.97**	**1.33**	**0.09**	**0.03**	**0.03**	**0.03**
CD at 5 %	**2.16**	**2.89**	**3.97**	**0.27**	**0.09**	**0.09**	**0.09**

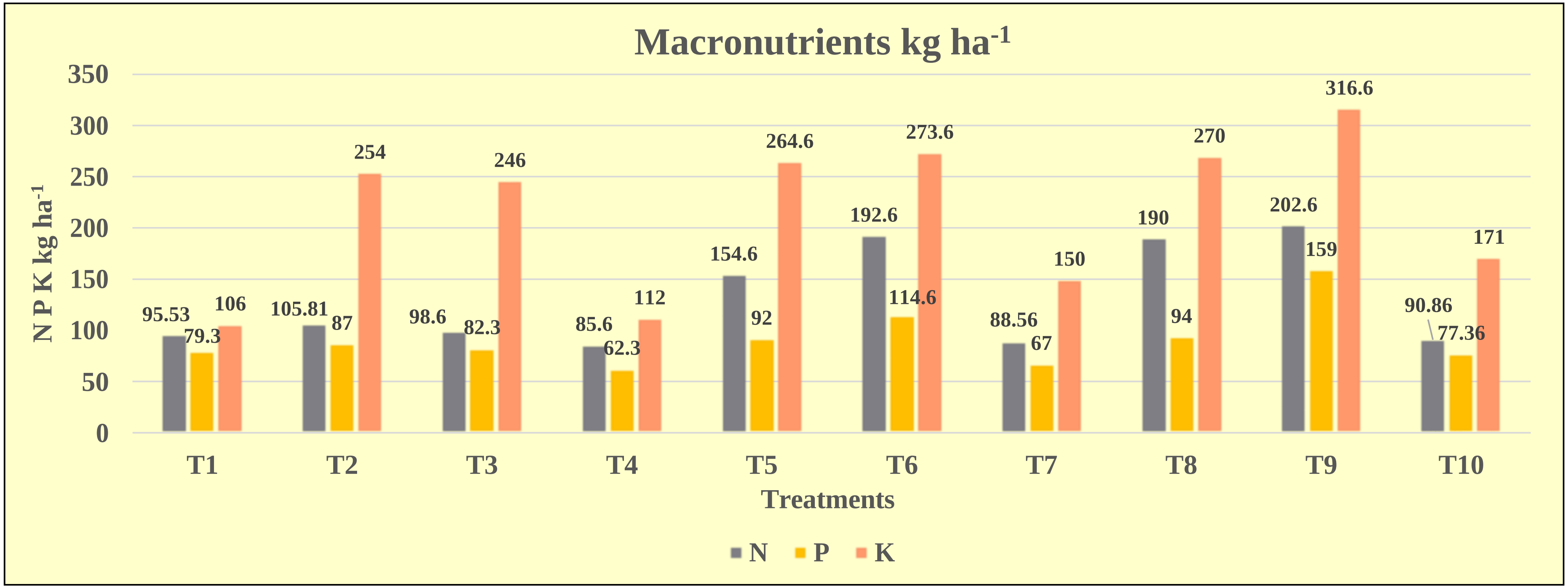

Fig.20 Effect of inorganic nutrients and biofertilizers on macronutrients (kg ha^{-1}) in soil after harvest of the crop.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

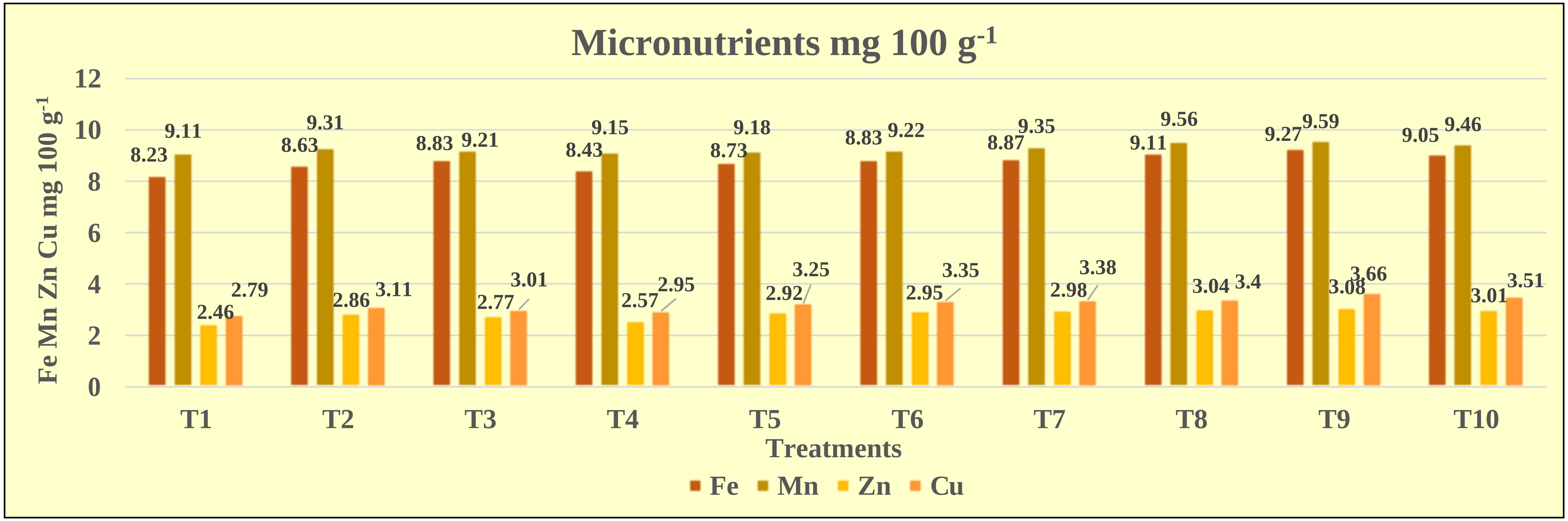

Fig.21 Effect of inorganic nutrients and biofertilizers on micronutrients (mg 100 g^{-1}) in soil after harvest of the crop.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

Table 4.18. Gross returns, net returns ₹ ha $^{-1}$ and benefit cost ratio as influenced by inorganic nutrients and biofertilizers in spinach beet Cv. Pusa Bharati

Treatments	Total yield (q/ha)	Cost of cultivation ₹ ha^{-1}	Gross return ₹ ha^{-1}	Net returns ₹ ha^{-1}	Benefit Cost ratio
T_1 – 100 % RDF @ 100:25:50 kg/ha	296.19	20979	148095	53069	3.52
T_2 – 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)	330.75	18209	165375	64478	4.54
T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5kg/ha)	318.25	17859	159125	61704	4.45
T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75Kg/ha)	235.88	16828	117940	42142	3.50
T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha	347.50	17291	173750	69584	5.02
T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha	388.25	17491	194125	79571	5.54
T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.7 kg/ha	265.57	17129	132785	49264	3.87
T_8 – T_5 + Arka vegetable special @ 5 g/litre	363.25	17759	181625	73054	5.11
T_9 – T_6 + Arka vegetable special @ 5 g/litre	412.75	20611	199375	103214	6.00
T_{10} – T_7 + Arka vegetable special @ 5 g/litre	284.26	20249	142130	65030	4.21

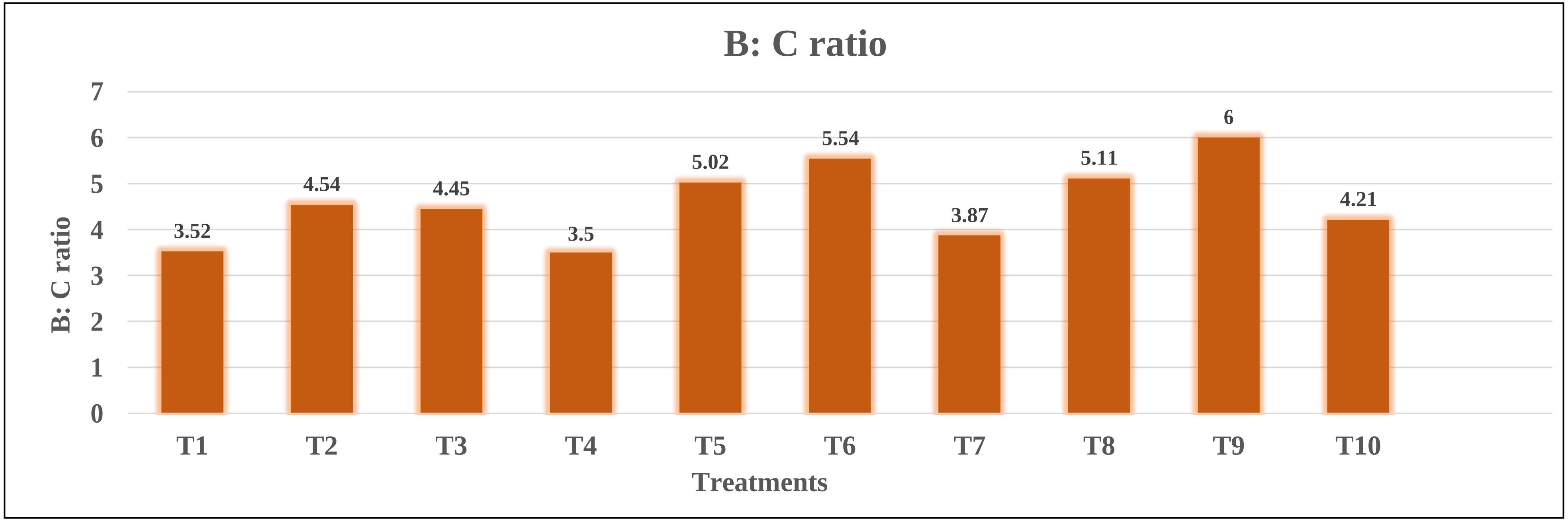

Fig.22 Benefit cost ratio as influenced by inorganic nutrients and biofertilizers in spinach beet Cv. Pusa Bharati.

T_1 – 100 % RDF @ 100:25:50 kg/ha

T_6 – 50 % RDF + AMC @ 5 kg/ha + KSB @ 2.5 kg/ha T_2

– 75 % RDF + Azotobacter + PSB + KSB (Each @ 1.25 kg/ha)

T_7 – 25 % RDF + AMC @ 7.5 kg/ha + KSB @ 3.75 kg/ha

T_3 – 50 % RDF + Azotobacter + PSB + KSB (Each @ 2.5 kg/ha)

T_8 - T_5 + Arka vegetable special @ 5 g/litre

T_4 – 25 % RDF + Azotobacter + PSB + KSB (Each @ 3.75 kg/ha)

T_9 - T_6 + Arka vegetable special @ 5 g/litre

T_5 – 75 % RDF + AMC @ 2.5 kg/ha + KSB @ 1.25 kg/ha

T_{10} - T_7 + Arka vegetable special @ 5 g/litre

Chapter-V

SUMMARY AND CONCLUSIONS

Chapter V

SUMMARY AND CONCLUSIONS

A field experiment entitled **"Effect of inorganic nutrients and biofertilizers on growth, yield and quality of Spinach beet (*Beta vulgaris* var. *bengalensis*) Cv. Pusa Bharati"** was carried out during *Rabi* season in the year 2020-21 at P.G research farm, College of Horticulture, Rajendranagar, Hyderabad.

The treatments consisted of 100% RDF through inorganic (100:25:50 kg of NPK ha^{-1}) (T_1), 75 % RDF through inorganic fertilizers + 25 % Biofertilizers [Azotobacter + PSB +KSB] (Each @ 1.25 kg ha^{-1}) (T_2), 50 % RDF through inorganic fertilizers + 50 % Biofertilizers [Azotobacter + PSB +KSB] (Each @ 2.5 kg ha^{-1}) (T_3), 25 % RDF through inorganic fertilizers + 75 % Biofertilizers [Azotobacter + PSB +KSB] (Each @ 3.75 kg ha^{-1}) (T_4), 75 % RDF through inorganic fertilizers + 25 % Biofertilizers [AMC @ 2.5 kg ha^{-1} + KSB @ 1.25 kg ha^{-1}] (T_5), 50 % RDF through inorganic fertilizers + 50 % Biofertilizers [AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg ha^{-1}] (T_6), 25 % RDF through inorganic fertilizers + 75 % Biofertilizers [AMC @ 7.5 kg ha^{-1} + KSB @ 3.75 kg ha^{-1}] (T_7), T_5 + Arka vegetable special @ 5 g L^{-1} (T_8), T_6 + Arka vegetable special @ 5 g L^{-1} (T_9), T_7 + Arka vegetable special @ 5 g L^{-1} (T_{10}) Randomized block design was adopted with three replications. Foliar application of Arka vegetable special @ 5 g L^{-1} was done at 15, 30 and 45 DAS. The results of the present investigation are summarized here under.

5.1 MORPHOLOGICAL PARAMETERS

- Among the treatment combinations, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded significantly highest plant height (14.94, 26.84 and 35.80 cm), maximum leaf length (10.94, 18.38 ,23.32 cm) and length of leaf petiole (7.79, 10.00 and 14.94 cm) at 15, 30 and 45 DAS.
- Highest leaf width was (4.16, 12.45 and 13.52 cm) recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) at 15, 30 and 45 DAS, whereas at 15 DAS T_6 treatment (50% RDF through inorganic fertilizers +

50% Biofertilizers [AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg $ha^{-1]}$) (3.95 cm) was at par with treatment T_9.

5.2 GROWTH PARAMETERS

- Among the treatment combinations, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded significantly maximum leaf area (120.83, 353.56 and 401.88 cm^2), leaf area index (0.402, 1.178 and 1.339) at 15, 30 and 45 DAS respectively.
- Minimum values (8.91, 12.57 and 6.96 cm^2 g^{-1}) of specific leaf area were recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) at 15, 30 and 45 DAS, whereas maximum values (15.07, 25.57 and 14.64 cm^2 g^{-1}) SLA were recorded in treatment T_4 (25% RDF + Azotobacter+ PSB + KSB) (Each @ 3.75 kg ha^{-1}) Maximum specific leaf weight (0.112, 0.079 and 0.143 g cm^{-2}) was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}) at 15, 30 and 45 DAS respectively.
- Highest leaf area duration between 15 to 30 DAS and 30 to 45 DAS (11.79, 18.75 cm^2 d^{-1}) was recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}).

5.3 YIELD PARAMETERS

- Among the treatment combinations, highest number of leaves (13.16, 16.56 and 19.91), maximum leaf weight (19.38, 38.76, 36.44 g) and leaf yield per plant (41.53, 47.65, 98.11 g) was recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) at 30, 45 and 60 DAS and it was at par with T_6 treatment (50% RDF through inorganic fertilizers + 50% Biofertilizers [AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg $ha^{-1]}$) at 30 DAS (12.58) in number of leaves per plant, leaf weight (18.97 g) and 60 DAS (97.01 g) in leaf yield per plant respectively.
- Highest leaf yield per hectare (412.75 q ha^{-1}) was significantly obtained in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) followed by T_6 treatment (50% RDF through inorganic fertilizers + 50% Biofertilizers [AMC @ 5 kg ha^{-1} + KSB @ 2.5 kg $ha^{-1]}$) (388.25 q ha^{-1}). However lowest

(235.88 q ha^{-1}) leaf yield ha^{-1} was recorded in T_4 (25 % RDF + Azotobacter + PSB + KSB) (Each @ 3.75 kg ha^{-1})

5.4 QUALITY PARAMETERS

- Lowest moisture content (84.46%) with minimum PLW (47.24%) which ultimately increases the shelf life (2.99 days) was obtained in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}).
- Maximum Vitamin-C (65.70 mg 100 g^{-1}), Carotene content (10.59 mg 100g^{-1}) and Chlorophyll (41.63 SPAD units) were recorded in treatment T_9 (T_6 + Arka vegetable special @ 5 g L^{-1}).

5.5 SOIL NUTRIENT ANALYSIS AFTER HARVEST

- Maximum N, P, K (202.60, 159.00, 316.60 kg ha^{-1}) and micronutrients (Fe, Mn, Zn and Cu) (9.27, 9.59, 3.08 and 3.66 mg 100 g $^{-1}$) were recorded in T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}).

5.6 ECONOMICS

- Among the treatment combinations, T_9 treatment (T_6 + Arka vegetable special @ 5 g L^{-1}) recorded higher gross returns (₹ 199375/-), net returns (₹ 103214/-) and benefit cost ratio (6.00). Whereas, lower gross returns (₹ 117940/-), net returns (₹ 42142/-) and benefit cost ratio (3.50)

5.7 Conclusions

- Among all the treatments, T_9 (T_6+ Arka vegetable special @ 5 g L$^{-1)}$ treatment significantly influenced on growth, yield and quality of spinach beet.
- Hence, treatment T_9 (T_6+ Arka vegetable special @ 5 g L$^{-1)}$ was the effective combination of nutrient application on spinach beet with highest benefit cost ratio (6.00)

5.8 Future line of research work

- Standardization of different combinations of biofertilizers and their dosage to enhance the yield and quality of spinach beet.
- Standardization of various storage methods to increase the shelf life of spinach beet.
- Need to study the nutrition content of the crop on usage of the different biostimulants and biofertilizers.

LITERATURE CITED

LITERATURE CITED

Ahmadi, H., Akbar V. P., Dashti, F and Shojaeian, A. 2010. Effect of different levels of nitrogen on yield, nitrate accumulation and several quantitive attributees of five Iranian spinach. *American Eurasian Journal of Agricultural and Environmental Sciences*. 8(4): 468-473.

Aisha, H. A., Magda, M. H., Asmaa, R., Mahmoud and Shafeek, M.R. 2013. Effect of Bio and chemical fertilizers on growth, yield and chemical properties of spinach plant. *Middle East Journal of Agriculture Research*. 2(1): 16-20.

Aishwath, O. P., Lal, G., Kant, K., Sharma, Y. K., Ali, S. F and Naimuddin. 2012. Influence of bio-fertilizers on growth and yield of coriander (*Coriandrum sativum* L.) under Typic Haplustepts. *International J. Seed Spices* 2(2) :9-14.

Anonymous, 2018-19. National Horticulture Board. Ministry of Agriculture and farmer welfare, Government of India.

Babaleshawar, S., Shetty, G. R., Pooja, D. A and Bhat, R. 2020. Performance of Kasuri Methi (*Trigonella corniculate* L) under Hill zone of Karnataka. *Int.J.Curr.Microbiol.App.Sci*. 9(6): 1758-1762.

Balakrishna, R. 1988. Effect of *Azospirillum,* nitrogen and NAA on growth and yield of chilli. *South Indian Horticulture.* 36:218.

Chamangasht, S., Ardakani, M. R., Khavazi, K., Abbaszadeh, B and Mafakheri, S. 2012. Improving Lettuce (*Lactuca sativa* L.) Growth and Yield by the Application of Biofertilizers. *Annals of Biological Research*. 3 (4):1876-1879.

Chaudhary, B. R., Gupta, A. K., Parihar, C. M., Jat, S. L and Singh, D. K. 2011. Effect of integrated nutrient management on fenugreek (*Trigonella-foenum-graceum* L.) *Indian J. Agron.* 51(3):239-241.

Chaudhary, B. M., Varma, L. R., More, S. G., Acharya, M. D and Rabari, S. S. 2018. Effect of Biofertilizers and different sources of organic manures on quality parameters and economics of amaranth (*Amaranthus* spp.) Cv. Arka Suguna. *International Journal of Chemical Studies*. 6(3): 580-585.

Choudhary, M., Jat, R. K., Chand, P and Choudhary, R. 2017. Effect of bio-fertilizers on growth, yield and quality of knol-khol. *Journal of Pharmacognosy and Phytochemistry*. 6(6): 2234-2237.

Chumyani, S. P., Singh, K. V. B and Singh, A. K. 2012. Effect of integrated nutrient management on growth, yield and quality of tomato. *J. Soils and Crop.* 22(1):65-71.

Custic, M., Poliak, M and Cosic, T. 1994. Nitrate content in leaf vegetables as related to nitrogen fertilization in Croalia. *Acta Horiculturae*. 371: 407-412.

Diana, A and Nehru, A. 2014. Impact of micronutrient application in Coriander (*Coriandrum sativum* L.) Cv. CO-4. *Advanced Journal of Seed Science and Technology* 2 (1): 042-046.

Etesami, H., Emami, S and Alikhani, H. A. 2017. Potassium solubilizing bacteria (KSB): Mechanisms, promotion of plant growth, and future prospects - a review. *Journal of Soil Science and Plant Nutrition.* 17 (4):897-911.

Gayathri, V and Malathi, R. 2019. Study on the effect of different bio-fertilizers on the growth of *Amaranthus viridis* L. *International Journal of Current Advanced Research* .8(1):16741-16745.

Godara, A. S., Gupta, U. S., Singh, R and Mehta, R. S. 2012. Effect of different combinations of organic and inorganic nutrient sources on productivity and profitability of fenugreek (*Trigonella-foenium-graecum*). *International J. Seed Spices*. 2(2):34-37.

Hndersah, R., Kalay, M., Kuswaryan., S and Hermawan, W. 2019. Application of biofertilizer to decrease inorganic fertilizer dosage in leafy vegetables production in Ambon, Mollucas. *Environmental Technology & Management Conference*. Bandung, Indonesia. OP/GC/006. pp. 1-6.

Kadlag, A. D., Jadhav, A. B and Bharti, R. 2007. Yield and quality of tomato fruit as influenced by organic manures and biofertilizers. *Asian J. Soil Sci.* 2(2): 95-99.

Kalyani, D. P., Sankar, C. R and Prasad D. M. 1996. Studies on the effect of nitrogen and *Azospirillum* on growth and yield of cauliflower. *South Indian Horticulture* 44: (5-6): 147-149.

Karadkhelkar, M. V. 1985. Effect of different levels of nitrogen and FYM in combination on yield and quality of palak. (*Beta vulgaris* var L) var. All green. Thesis submitted to Marathwada Agricultural University, Parbhani, Maharashtra.

Kanaujia, S. P., Singh, V. B and Singh, A. K. 2010. Integrated nutrient management for quality production of radish (*Raphanus sativus*.L.) in acid alfisol. *Journal of soils and crops.* 20(1): 1-9.

Khadse, V. A., Mohod, A. A., Chirde, P. N and Chauvhan, A. K. 2021. Response of leafy vegetables under organic and integrated nutrient management. *The Pharma Innovation Journal*.10(5): 04-06.

Kisan, B., Shruthi, H., Sharanagouda, H., Revanappa, S. B and Promod, N. K. 2015. Effect of Nano-Zinc Oxide on the leaf physical and nutritional quality of Spinach. *Agrotechnol.* 5:1.

Kumar, S and Sharma, S. K. 2007. Effect of integrated nutrient strategies in tomato production. *Indian J. Hort.* 64(1): 96-97.

Kumar, V., Malik, V. F and Singh, B. 2010. The response of integrated nutrient management (INM) on growth, yield and quality of tomato. *Society for Recent Development in Agriculture.* 10(1): 72-76.

Lindsay, W. L and Norvell, W. A. 1978. Development of DTPA soil testing for Fe, Zn, Cu, Mn. *Soil science American Procedure journal*. 42: 421-428.

Maheswari, U. M and Kalaiyarasi, M. 2015. Comparative study of liquid biofertilizer and carrier based biofertilizer on green leafy vegetables. *International Journal of Pharmaceutical Sciences review and research.* 33(1). Article No. 42. pp. 229-232.

Malav, J. K., Patel, J. K., Pavaya, B. B., Patel and Patel, V. R. 2018. Effect of Different Organic Sources on Fenugreek (*Trigonella foenum-graecum* L.) under Organic Farming Module. *Int.J.Curr.Microbiol.App.Sci* . 7(2): 17-25.

Mathavan, C. M. 2000. Performances of some decontaminants in abetting the toxic metal effects in polluted agricultural soils. Thesis submitted to Acharya N.G Ranga Agricultural University, Hyderabad.

Maurya, K. R and Goswami, R. K. 1985. Effect of N P K fertilizers on growth yield and quality of carrot. *Progressive Horticulture* 17(3): 212-217.

Meena, K., Ram, R. B., Meena, M. L., Meena, J. K and Meena, D. C. 2017. Effect of organic manures and bio-fertililizers on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica* Plenck.) Cv. KTS-1.

Metson, A. J.1956. Methods of chemical analysis for soil survey samples. *N Z Soil Bur Bull n°* .12.

Mohandas, S. 1999. Bio-fertilizer of horticultural crops. *Indian Horticulture*. 43(4):32-37.

Morschmer, H. (1986). *Mineral nutrition of higher plants*. Academic Press. Horcourt Brace Jovanovich Publishers., London, San Diego, Newyork and Tokyo.673.

Mounika, Y, G., Sivaram, G. T., Reddy, S. S. P and Ramaiah, M. 2017. Effect of biofertilizers and micronutrients on growth, leaf yield and quality of coriander (*Coriandrum sativum* L.) Cv. Sadhana. *J. Hortl. Sci.* 12(2): 113-117.

Murphy, J and Riley, J. P.1962. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. *Analytica Chimica Acta.* 27, 31-36.

Nath, P. 1976. Origin and taxonomy. *Vegetable Crops.* 3(3):246.

Nisar, F., Mufti, S., Afroza, B., Mushtaq, F., Bhat, R., Andrabi, N., Majid, I and Din, S. 2020. Effect of integrated nutrient management on quality attributes of black carrot. *International Journal of Chemical Studies.* 8(4): 3991-3994.

Olsen, S. R. I., Cole, C. V., Wantanable, F. S and Dean, L. A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U.S.D.A. Circular.* 10: 939.

Padmanabha, K., Umesh, M. R and Krishnapppa, K. S. 2008. Effect of different organic and inorganic sources of nutrients on nutrient content and nutrient uptake in palak. *Asian Journal of Horticulture*.3:2, 256-258.6.

Paithankar, D. H and Gore, A. M. 2018. Nutrient management in Indian spinach (*Beta vulgaris* var. *bengalensis*). *International Journal of Horticulture and Food Science.* 1(1): 25-27.

Panse, R. P and Sukhatme, P. V. 1967. Statistical methods for agricultural workers. Indian council of agricultural research, New delhi.

Pathak, M., Tripathy, P., Dash, S. K., Sahu, G. S and Pattanayak, S. K. 2018. Effect of source of nutrient on growth, yield and quality of Radish (Raphanus sativus L.) in radish - coriander cropping sequence. *The Pharma Innovation Journal*. 6(12): 496-499.

Patel, B. S., Patel, S. G., Patel, S. P and Amin, A. U. 2010. Integrated nutrient management in fenugreek (*Trigonella foenum-graceum* L.). *Journal of Spices and Aromatic Crops*. 19(1&2): 68-70.

Patil, M. B., Mohammed, R. G and Ghadge, P. M. 2004. Effects of inorganic and organic fertilizers on growth, fruit yield and quality of tomato. *J. Maharashtra agric. Univ.* 29(2):124-127.

Phandis, B. P., Jagtap, K. B and Wattamwar, M. J. 2007. Effect of source of fertilization on leaf yield and quality of spinach Cv. All green. *Journal of Maharashtra Agricultural Universities*.322, 214-216.9.

Power, J. F., Willis, W. C., Grunus, D. L and Reicliman, G. A.1967. Effect of soil temperature, phosphorous, and plant age on growth analysis of barley. *Agron. J*. 59:231-234.

Prasad, J. G., Vadodaria, J. R., Karthick, K and Bhavik, V. A. 2017. Effect of Zinc and iron on quality of Amaranth (*Amaranthus* spp.) Cv. Pusa kiran. *International Journal of Agriculture Sciences*. 9(32):4476-4478.

Radford, D. J. 1967. Growth analysis formulae; their use and abuse. *Crop Sci.* 7:171-175.

Rafi, M., Narwadkar, P. R., Prabu, T and Sajindranath, A. K. 2002. Effect of organic and inorganic fertilizers on growth and yield of tomato. *South Indian Hort.* 50(4/6): 522-526.

Ramachandra, H. A and Thimmaraju, K. R .1983. Effect of different levels of nitrogen and phosphorous on nutrient status of amaranthus (*Amaranthus gangeticus* L.) Cv. A-25. *Mysore J. Agric. Sci*.17(3): 256-259.

Ranganna, S. 1986. Handbook of Analysis of Quality Control for fruit and vegetable products. *Tata Mc. Graw Hill Book Co.,* New Delhi.

Rather, M. A., Bhat, A. T., Hajam, M. A., Parray, E. A., Wani, M. A and Bhat, I. A. 2018. To study role of organic manures and biofertilizers on quality and leaf yield of lettuce. *International Journal of Chemical Studies*.6(3): 512-515.

Raturi, H. C., Uppal, G. S., Singh, S. K and Kachwaya, D. S. 2018. Effect of organic and inorganic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annum* L.) grown under polyhouse condition. *Journal of Pharmacognosy and Phytochemistry*. 8(1): 1788-1792.

Raut, R. L., Rawat, A. K and Baghel, S. S. 2006. Soil microbial population on tomato yield as influenced by plant nutrient sources. *International J. agric. Sci.* 2(1):42-43.

Rodge, B. M and Yadlod, S. S. 2009. Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *Asian J. Hort.* 4(1):221-224.

Russel, E. W. 1973. *Soil Conditions and Plant Growth*.10th ed. London.

Sahu, P. K., Naruka, I. S., Haldar, A., Chundawat, R. S and Kumar, H. 2020. Study the effect of integrated nutrient management on vegetative growth of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Pharmacognosy and Phytochemistry*. 9(3): 1389-1394.

Sarkar, R. K., Jana, J. C and Datta, S. 2017. Effect of boron and zinc application on growth, seed yield and seed quality of water spinach (*Ipomoea reptans* Poir.) under terai region of West Bengal. *Journal of Applied and Natural Science*. 9 (3): 1696 -1702.

Sentiyangla, K. S. P., Singh, V. B and Singh, A. K. 2010. INM for quality production of radish (*Raphanus sativus* L.) in acid Alfisol. *Journals of Soils and Crops.* 20(1):1-9.

Sharma, D and Divakara, V. J. 2019. Dissipation of chlorothalonil in leafy vegetables accelerated by use of biofertilizer. *Pest Management in Horticultural Ecosystems.* 25(1):109-115.

Sharma, N., Gupta, A and Samnotra, R. K. 2010. Effect of integrated nutrient management on growth, yield and quality parameters of tomato. *Asian J.Hort.* 5(2): 314-317.

Shinde, A. A., Kadam, A. S and Syed, S. J. 2018. Effects of biofertilizers on growth and yield of Spinach. *International Journal of Chemical Studies*. 6(2):524-527.

Shukla, Y. R., Thakur, A. K and Joshi, A. 2006. Effect of inorganic and organic fertilizers on yield and horticultural traits in tomato (*Lycopersicon esculentum Mill*). *Annals of Biology.* 22(2): 137-141.

Sidhu, M. K., Raturi, H. C., Kachwaya, D. S and Sharma, A. 2019. Role of micronutrients in vegetable production: A review. *Journal of Pharmacognosy and Phytochemistry*. SP1: 332-34.

Sonali, R. A., Soyam, A. P., Wagh, A. P., Dod, P. K., Nagre and Gade, R. M. 2012. Effect of different biofertilizers on growth, yield and quality of fenugreek. *The Asian journal of horticulture.* 7(1): 28-30.

Stancheva, I and Mithova, I. 2002. Effect of different sources and fertilizer rates on lettuce yield and quality under controlled conditions. *Bulgarian Journal of Agricultural Science.*8(2,3):157-113.

Subbiah, B. V and Asija, G. L. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Curre. Sci*. 25: 259 – 260.

Sunanda, B. B., Shetty, G. R and Venkatesh, J. 2014. Influence of integrated nutrient management on growth, yield and quality of KasuriMethi (*Trigonellacorniculata* L.) under hill zone of Karnataka. *International J Seed Spices*. 4(2):62-67.

Tandon, H. 1995. Methods of analysis of soil, plants, waters and fertilizer. Fertilizers Development and Consultation Organization, New Delhi, India.

Tania, C., Das, R., Basanta, T., Chatterjee, R and Chattopadhyay, P.K. 2018. Assessment for Growth and Yield of Coriander (*Coriandrum sativum* linn.) with Micronutrients. *Int.J.Curr.Microbiol.App.Sci* . 7(12): 336-339.

Thamburaj, S and Singh, N. 2015. *Text book of Vegetables, Tuber Crops and Spices.* ICAR, New Delhi.

Tilak, K. V. B. R and Singh, G. 1994. Biofertilizers research gaps and future needs. *Fertilizer News*. 39:11-17.

Tisdale, S. L., Nelson, W. L and Beaton, J. L.1993. Soil Fertility and Fertilizers. 5th ed. USA: Pearson Education, New Jersey.

Tosic, I., Golic, Z and Radosavac, A. 2016. Effects of the application of biofertilizers on the microflora and yield of lettuce (*Lactuca sativa* L.). *Acta Agriculturae Serbic* 42:91-981.

Watson, D. J.1952.The physiological basis for variation in yield. *Adv.Agron*. 4: 101-145.

Yadav, K. K., Nagaich, K. N and Barholia, A. K. 2019. Effect of integrated nutrient management on growth, leaf yield and economics of spinach (*Beta vulgaris* L.) var. Pusa Jyothi. *International Journal of Agriculture Sciences.* 11(8): 8342-8345.

Yeptho, V., Kanujia, S. P., Singh, V. B and Sharma, A. 2012. Effect of integrated nutrient management on grwth, yield and quality of tomato under polyhouse condition. *J. Soils and Crops* 22(2): 246-252.

APPENDICES

APPENDIX-I

Monthly mean meteorological data recorded at ARI, Rajendranagar during Dec 2020 to March 2021

Month	Temperature (⁰C)		Relative Humidity (%)		Rainfall (mm)	No. of rainy days	Sunshine hours	Wind speed (Km hr^{-1})	Evaporation
	Max.	Min.	I	II					
DEC, 2020	28.5	12.5	94	42	0.0	0	8.6	2.7	2.8
JAN, 2021	29.5	15.3	95	45	4.2	1	7.0	3.0	3.1
FEB, 2021	30.7	13.8	88	41	0.4	0	8.5	3.5	4.3
MAR, 2021	36.3	24.8	89	51	112.6	6	8.3	6.0	6.8

APPENDIX-II

PRICES OF INPUTS AND OUTPUTS

S.No.	Particulars	Prices ha^{-1}
1.	Tractor	2500/-
2.	Bed Preparation	6000/-
3.	Seed material cost	3000/-
4.	Fertilizers	
	Urea	1530/-
	Single super phosphate	938/-
	Murate of Potash	750/-
	Azotobacter	225/-
	Phosphorous solubilizing bacteria	225/-
	Potassium solubilizing bacteria	225/-
	Arka microbial consortium	975/-
	Arka vegetable special	3120/-
5.	Weeding	2000/-
6.	Harvesting	1000/-
7.	Transport	500/-