

Effect of Organic and Inorganic Sources of NPK and Bio-fertilizer on Growth, Yield and Quality of Sweet Potato (*Ipomoea batatas* Lam.)

शकरकन्द (*आइपोमिया बटाटस* लेम.) की वृद्धि, उपज तथा गुणवत्ता पर नाइट्रोजन, फॉस्फोरस एवं पोटेश के विभिन्न कार्बनिक एवं अकार्बनिक स्रोतों और जैव उर्वरक का प्रभाव

Jai Singh

Thesis

**Master of Science in Agriculture
(Horticulture)**



2017

**Department of Horticulture
S.K.N. COLLEGE OF AGRICULTURE, JOBNER
SRI KARAN NARENDRA AGRICULTURE UNIVERSITY
JOBNER– 303329**

**Effect of Organic and Inorganic Sources of NPK and
Bio-fertilizer on Growth, Yield and Quality of Sweet
Potato (*Ipomoea batatas* Lam.)**

शकरकन्द (*आइपोमिया बटाटस* लेम.) की वृद्धि, उपज तथा गुणवत्ता
पर नाइट्रोजन, फॉस्फोरस एवं पोटेश के विभिन्न कार्बनिक एवं
अकार्बनिक स्रोतों और जैव उर्वरक का प्रभाव

Thesis

**Submitted to the
Sri Karan Narendra Agriculture University, Jobner
in partial fulfillment of the requirements for
the degree of**

**Master of Science
in the
Faculty of Agriculture
(Horticulture)**

**By
Jai Singh**

2017

Sri Karan Narendra Agriculture University, Jobner
S.K.N. College of Agriculture, Jobner

CERTIFICATE - I

Dated : __ / __ /2017

This is to certify that **Mr. Jai Singh** has successfully completed the Comprehensive Examination held on 13.04.2017 as required under the regulation for **Master's degree**.

(A. K. SONI)

Professor & Head

Department of Horticulture
S.K.N. College of Agriculture,
Jobner

Sri Karan Narendra Agriculture University, Jobner
S.K.N. College of Agriculture, Jobner

CERTIFICATE - II

Dated : __ / __ / 2017

This is to certify that the thesis entitled “**Effect of Organic and Inorganic Sources of NPK and Bio-fertilizer on Growth, Yield and Quality of Sweet Potato (*Ipomoea batatas* Lam.)** submitted for the degree of **Master of Science** in the subject of **Horticulture** embodies bonafide research work carried out by **Mr. Jai Singh** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by advisory committee on __ / __ / 2017.

(A.K. SONI)

Professor & Head

Department of Horticulture

(M. K. SHARMA)

Major Advisor

(R.C. KUMAWAT)

Dean

S.K.N. College of Agriculture,
Jobner

Sri Karan Narendra Agriculture University, Jobner
S.K.N. College of Agriculture, Jobner

CERTIFICATE - III

Dated : __ / __ / 2017

This is to certify that the thesis entitled “**Effect of Organic and Inorganic Sources of NPK and Bio-fertilizer on Growth, Yield and Quality of Sweet Potato (*Ipomoea batatas* Lam.)**” submitted by **Mr. Jai Singh** to the Sri Karan Narendra Agriculture University, Jobner in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Horticulture**, after recommendation by the external examiner, was defended by the candidate before the following members of the advisory committee. The performance of the candidate in the oral examination on her thesis has been found satisfactory. We therefore, recommend that the thesis be approved.

(M. K. SHARMA)

Major Advisor

(O.P. GARHWAL)

Advisor

(B.L. YADAV)

Advisor

(R. P. GHASOLIA)

Director Education, Nominee

(A.K. SONI)

Professor & Head

Department of Horticulture

(R.C. KUMAWAT)

Dean

S.K.N. College of Agriculture,
Jobner

APPROVED

DIRECTOR EDUCATION

Sri Karan Narendra Agriculture University, Jobner

Sri Karan Narendra Agriculture University, Jobner
S.K.N. College of Agriculture, Jobner

CERTIFICATE - IV

Dated : __/ __ /2017

This is to certify that **Mr. Jai Singh** of the **Department of Horticulture**, S.K.N. College of Agriculture, Jobner has made all corrections /modifications in the thesis entitled “**Effect of Organic and Inorganic Sources of NPK and Bio-fertilizer on Growth, Yield and Quality of Sweet Potato (*Ipomoea batatas* Lam.)**” which were suggested by the external examiner and the advisory committee in the oral examination held on __ /__ /2017. The final copies of the thesis duly bound and corrected were submitted on __ / __ /2017 are forwarded herewith for approval.

(M. K. SHARMA)
Major Advisor

(A.K. SONI)
Professor & Head
Department of Horticulture

(R.C. KUMAWAT)
Dean
S.K.N. College of Agriculture, Jobner

Approved

DIRECTOR EDUCATION

Sri Karan Narendra Agriculture University, Jobner

ACKNOWLEDGEMENTS

It is a great pleasure for me to express sincere and deepest sense of gratitude and indebtedness to my esteem major advisor **Dr. M.K. Sharma** Professor and Project Incharge, All India Coordinated Research Project on Arid Zone Fruits, Department of Horticulture, S.K.N. College of Agriculture, Jobner for his invaluable inspiring guidance and encouragement during the course of present investigation and preparation of the manuscript.

It is my unique privilege and duty to express sincere gratitude and regards to the members of advisory committee namely **Dr. O.P. Garhwal** (Asstt. Professor), Department of Horticulture, **Dr. B.L. Yadav** (Professor), Department of Soil Science and Agriculture Chemistry, **Dr. R.P. Ghasolia**, (Asstt. Professor) Department of Plant Pathology, S.K.N. College of Agriculture, Jobner for providing suggestions and guidance as and when needed.

I wish my sincere thanks to **Dr. A.K. Soni** (Professor and Head), Department of Horticulture for his moral support and providing necessary facilities throughout the course of study.

I extend my deep and heartfelt gratitude to **Dr. M.R. Choudhary** (Professor), Department of Horticulture, **Dr. R.C. Kumawat** (Dean), S.K.N. College of Agriculture, Jobner and **Dr. B.S. Sekhawati** (Director of Education) SKNAU, Jobner for their incessant encouragement and support to academic pursuits.

I feel gratified to record my cordial thanks to **Dr. L.N. Bairwa** (Assoc. Professor), Department of Horticulture and **Dr. S.P. Singh** (Asstt. Professor), Department of Horticulture for their valuable co-operation in completing this investigation smooth and easy.

The help provided by **Dr. B.M. Sharma** (Farm Manager), **Dr. S.L. Sharma** (STA), **Dr. C.S. Pareek** (STA) and other non-teaching staff members of the Department of Horticulture is also unforgettable.

I offer my sincere thanks to my seniors Mr. Arun Mahaver, Mr. Suresh Yadav, Ms. Deepika, Mr. Arjun Ola, Mr. Ganpat Lal Yadav, Ms. Pushapa, Ms. Rajbala, Mr. Prem Raj, Mr. Ramavtar, Mr. Om Prakash, Ms. Leela Bhatt, Ms. Sunita, Ms. Manju colleagues Om Prakash Regar, Pushpendra Singh, Suman Meena, Pratistha Diwakar, Kumari Lata, Raunak Sharma, Komal Badala Atma Ram and dear juniors Shashikant Singh, Bhagchand, Kamal, Kavita Gurjar, Manju Netwal, Rajkumar, Sobha Devi, Suman Choudhary, Suman Yadav, Dinesh Panwar, Arvind Kalera, Vikram Godara, Ravi Kant Kargwal, Sameer Malya, Ashvin Dingra, Kamal Panu, Kulveer, Sorabh, Pukhraj Bishnoi friends Late Raj Kumar Nihalaya, Parmod Godara, Kulwant Meel and Vinod Sanv for their regular support, motivation and inspiration.

My vocabulary falls short to express heartiest regards to **Late Mrs. Sugana Devi - Mr. Jai Lal** (Grand Parents), **Mrs. Parwati Devi - Mr. Mohan Lal** (Parents), **Kamala Devi** (Aunt) **Mr. Girdhari Lal-Saroj Devi** (Bhaiya-Bhabhi), **Saroj (Sitro)-Savitri, Santosh, Kailash, Leela Wati and Manohari** (Sister's), **Kalpna, Ekta, Antem, Priyanka, Narendra, Aanad, Aryan, Sahil, Aashu, Priyanshu and Bhavit** (niece's and nephew's) all family members and relatives without whose blessing, affection and encouragement, I could not have completed this task successfully.

At this movement, I am unable to express my emotional feelings in words for my most respectable **Mr. Dhanpat Ram-Roshani Devi** (Bhaiya-Bhabhi) whose affection and blessings brought this task to complete successfully.

I extent my cordial thanks to my best friend **Rukshana Bano** for her moral support, Motivation, joyful company, inspiration. and sustained encouragement provided during academic pursuits.

I also want to pay my cordial thanks to my dear **Anil Kataria, Manoj Kataria, Jaideep Dudy, Satpal Gunpal, Sunil Kataria, Kamal Solanki** for their valuable co-operation and help in various ways to complete this task.

Last but not the least, a million thanks to almighty **Sant Purkharam Manav Dharam Seva Samiti** which made it possible to complete this task and made every job a success for me.

Place : Jobner

Dated: / /2017

(Jai Singh)

LIST OF CONTENTS

Chapter	Title	Page No.
	CERTIFICATE-I	.....
	CERTIFICATE-II	.....
	CERTIFICATE-III	.....
	CERTIFICATE-IV	.....
	ACKNOWLEDGEMENTS	.....
	LIST OF CONTENTS	.....
	LIST OF TABLES	.....
	LIST OF FIGURES	.....
	LIST OF APPENDICES	.....
Chapters No.		
1.	INTRODUCTION	.....
2.	REVIEW OF LITERATURE	.....
3.	MATERIALS AND METHODS	.....
4.	EXPERIMENTAL RESULTS	.....
5.	DISCUSSION	.....
6.	SUMMARY AND CONCLUSION	.....
	BIBLIOGRAPHY	.....
	ABSTRACT	ENGLISH
		HINDI
	APPENDICES	.....

LIST OF TABLES

Table No.	Particulars	Page No.
3.1	Mean weekly meteorological data for crop season (July to December, 2016)	.....
3.2	Physico-chemical characteristics of the soil of experimental field	.....
3.3	Details of treatments with symbol	.....
3.4	Schedule of cultural operations	.....
4.1	Effect of organic and inorganic sources of NPK and biofertilizer on length of vine and number of branches per vine at 45 DAP of sweet potato	.....
4.2	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on length of vine (cm) at 45 DAP of sweet potato	.....
4.3	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on number of branches per vine of sweet potato	.....
4.4	Effect of organic and inorganic sources of NPK and biofertilizer on leaf area at 45 DAP and leaf area index of sweet potato	.....
4.5	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on leaf area (cm ²) at 50 DAP of sweet potato	.....
4.6	Effect of organic and inorganic sources of NPK and biofertilizer on chlorophyll content at 50 DAP of sweet potato	.....
4.7	Effect of different organic and inorganic sources of NPK and biofertilizer on tuber length, tuber weight and diameter of tuber of sweet potato	.....

Contd.....

Table No.	Particulars	Page No.
4.8	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on length of tuber (cm) of sweet potato	.....
4.9	Interactive effect of organic and inorganic sources of NPK and bio-fertilizers on tuber weight (g) of sweet potato	.....
4.10	Interactive effect of organic and inorganic sources of NPK and bio-fertilizers on diameter of tuber (cm) of sweet potato	.....
4.11	Effect of organic and inorganic sources of NPK and biofertilizer on number of tubers and tuber yield of sweet potato	.....
4.12	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per plot (kg) of sweet potato	.....
4.13	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per hectare (q) of sweet potato	.....
4.14	Effect of organic and inorganic sources of NPK and biofertilizer on TSS, protein and starch content in sweet potato tubers	.....
4.15	Effect of organic and inorganic sources of NPK and biofertilizer on net returns and B:C ratio of sweet potato	.....
4.16	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on net returns(₹) per hectare of sweet potato	.....
4.17	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on B:C ratio of sweet potato	.....

LIST OF FIGURES

Figure No.	Particulars	Page No.
3.1	Mean weekly meteorological data for crop season (July to December, 2016)	.....
3.2	Experimental layout plan	.....
4.1	Effect of organic and inorganic sources of NPK and biofertilizer on length of vine (cm) and number of branches per vine at 45 DAP of sweet potato	.....
4.2	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on length of vine (cm) at 45 DAP of sweet potato	.....
4.3	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on number of branches per vine of sweet potato	.....
4.4	Effect of organic and inorganic sources of NPK and biofertilizer on leaf area (cm ²) at 45 DAP of sweet potato	.....
4.5	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on leaf area (cm ²) at 50 DAP of sweet potato	.....
4.6	Effect of organic and inorganic sources of NPK and biofertilizer on leaf area index of sweet potato	.....
4.7	Effect of organic and inorganic sources of NPK and biofertilizer on chlorophyll content (mg/g) at 50 DAP of sweet potato	.....
4.8	Effect of organic and inorganic sources of NPK and biofertilizer on length of tuber (cm) and diameter of tuber (cm) of sweet potato	.....

Contd.....

Figure No.	Particulars	Page No.
4.9	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on length of tuber (cm) of sweet potato	.....
4.10	Effect of organic and inorganic sources of NPK and biofertilizer on tuber weight (g) of sweet potato	.....
4.11	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber weight (g) of sweet potato	.....
4.12	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on diameter of tuber (cm) of sweet potato	.....
4.13	Effect of organic and inorganic sources of NPK and biofertilizer on number of tubers per plot of sweet potato	.....
4.14	Effect of organic and inorganic sources of NPK and biofertilizer on tuber yield per plot (kg) of sweet potato	.....
4.15	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per plot (kg) of sweet potato	.....
4.16	Effect of organic and inorganic sources of NPK and biofertilizer on tuber yield (q) per hectare of sweet potato	.....
4.17	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per hectare (q) of sweet potato	.....
4.18	Effect of organic and inorganic sources of NPK and biofertilizer on TSS (%), protein (%) and starch (%) content in sweet potato tubers	.....
4.19	Effect of organic and inorganic sources of NPK and biofertilizer on net returns (₹/ha) of sweet potato	.....
4.20	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on net returns (₹) per hectare of sweet potato	.....
4.21	Effect of organic and inorganic sources of NPK and biofertilizer on B:C ratio of sweet potato	.....
4.22	Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on B:C ratio of sweet potato	.....

LIST OF APPENDICES

Appendix No.	Particulars	Page No.
I.	Analysis of variance for vine length and number of branches per vine	.....
II.	Analysis of variance for leaf area and leaf area index	.....
III.	Analysis of variance for chlorophyll content in leaves	.....
IV.	Analysis of variance for tuber length and tuber weight	.....
V.	Analysis of variance for diameter of tubers and number of tuber per plot	.....
VI.	Analysis of variance for tuber yield per plot and tuber yield per hectare	.....
VII.	Analysis of variance for protein, TSS and starch content in tuber	.....
VIII.	Analysis of variance for net returns and B:C ratio	.....
IX.	General cost of cultivation (₹/ha) (Excluding the cost of the treatment inputs)	.....
X.	Comparative economics of various treatment combinations	.....

Abbreviations/Symbols

S.No.	Name	Symbols
1.	At the rate of	@
2.	Benefit : cost ratio	B:C ratio
3.	Centimetre	cm
4.	Coefficient of variation	CV
5.	Critical difference	CD
6.	Cultivar	cv.
7.	Degree Celsius	°C
8.	Degree of freedom	df
9.	Desi siemens per meter	dSm ⁻¹
10.	Days after planting	DAP
11.	Di-amonium phosphate	DAP
12.	Electrical conductivity	EC
13.	Etcetera	<i>etc.</i>
14.	(et alibi) and elsewhere	<i>et al.</i>
15.	Farm yard manure	FYM
16.	Figure	Fig.
17.	Gram	g
18.	Hectare	ha
19.	Hours	hrs
20.	Kilogram	kg
21.	Milligram per cubic meter	mg/m ³
22.	Metre	m
23.	Milligram per gram	mg/g
24.	Muriate of potash	MOP
25.	Non-significant	NS
26.	Number	No.
27.	Parts per million	ppm
28.	Per cent	%
29.	Nitrogen	N
30.	Phosphorus	P
31.	Potassium	K
32.	Quintal	q
33.	Quintal per hectare	q ha ⁻¹
34.	Randomized block design	RBD
35.	Recommended dose of fertilizers	RDF
36.	Replication	R
37.	Rupees	₹
38.	Square metre	m ²
39.	Standard error of mean	SEm _±
40.	Single super phosphate	SSP
41.	Standard meteorological week	SMW
42.	That is	<i>i.e.</i>
43.	Tonnes per hectare	t ha ⁻¹
44.	Total soluble solids	TSS
45.	Which are	<i>viz.</i>
46.	United States Department of Agriculture	USDA
47.	Vermicompost	VC

Chapter-1

INTRODUCTION

Sweet potato (*Ipomoea batatas* Lam.) belongs to the family convolvulaceae and historically played an important role in the quest for food and the struggle for human survival in several countries. It is popularly known as “*Sakar Kand*” in India. It was originated in Central America and spread to other parts of the world. Sweet potato is an important starchy food crop grown throughout the tropical and sub-tropical countries. It is a warm-season crop and grows best in abundant sunshine, temperatures above 24°C, sandy loam soil and a well-distributed rainfall of 850-900 mm per annum. It matures in 3-9 months duration or longer depending on the variety (Anonymous, 2003). In India, sweet potato occupies an area over 111 thousand hectares with production of 1338 thousand tonnes. Sweet potato is cultivated throughout India but the main sweet potato growing states are Bihar, Orissa, Uttar Pradesh, Madhya Pradesh, Maharashtra and Karnataka. In Rajasthan it cultivates over an area of 790 hectares with production of 2240 tonnes and productivity 2835 kg per hectare (Anonymous, 2016).

Sweet potato is a very nutritive vegetable, producing substantially high edible energy per hectare per day as compared to rice, wheat, maize and cassava. It contains starch (12.7 g), sugar (4.2 g), vitamin A (709 µg) and protein (1.6 g) per 100 g of edible part (USDA 2009). It is used as boiled and fried vegetable as well as for canning, dehydration and flour manufacturing.

In spite of its importance as food and vegetable, very little attention has been paid for improvement in quality and yield through cultural practices. Sweet potato is the main source of starch and contains 10 per cent starch and 3-6 percent sugar. Tubers are good source of vitamin A, B, C and minerals like phosphorus, iron and calcium. Yellow and orange flesh varieties of sweet potato have more carotene content (Choudhary, 2014).

It is well documented that growth and yield of plants are greatly influenced by a wide range of nutrients. An approach involving chemical fertilizers, organic manures and biofertilizers is only the solution to bridge gap between nutrient demand and supply for giving a boost to the production of sweet potato. The situation further aggravates for the light soils of Rajasthan where nutrient use remains much lesser than the removal by the crops (Gupta, 2001).

According to Mohamed (1984), most of the farmers usually do not apply any fertilizer or just apply a small amount of urea or organic manures of unspecified quantity in sweet potato crops. This may be one of the reason that is why yields obtained by local farmers are lower than yields obtained elsewhere. Patricia and Bansal (1999) reported that sweet potato crop has strict requirement for a balanced fertilization without which growth and development of the plant as well as crop yield and quality of tubers are poor.

Among macro nutrients required by the crop nitrogen is found to be deficient in most of the Indian soils (Arkeri *et al.*, 1956). Availability of nitrogen is of prime importance for growing plants as nitrogen is one of the major and indispensable constituents of protein, nucleic acid and integral part of chlorophyll molecules which are responsible for photosynthesis. Phosphorus is also indispensable constituent of nucleic acid, phosphorus lipids and several enzymes. Potassium imparts vigour and disease resistance to the plants and also regulates water loss from the plant by maintaining the balance between various physiological activities like metabolism, respiration and transpiration. Likewise, most of the root crops, sweet potato has a high requirement for potassium for better quality and high yield of tuber.

In India, the mixed farming system with livestock raising is an integral part of crop production. The farm yard manure is rich in organic matter content and used to supplement the nutrients for plants. The organic manure (FYM) not only provides nutrients to the plants but also improves the soil texture by binding of soil aggregates. Organic manure increases CEC, water holding capacity and phosphate availability of the soil besides improving the

fertilizer use efficiency and microbial population in the soil as well as also reduces nitrogen loss by slow release of nitrogen in the soil.

In recent years, use of vermicompost has been advocated in vegetable crops. Vermicompost is a mixture of worm casting, organic materials, humus, living earthworms, their cocoons and other organisms. Vermicompost is a slow nutrient releasing organic manure which have most of the macro as well as micro nutrients in chelated form and fulfill the nutrient requirement of plants for longer period. Vermicompost helps in reducing C:N ratio, increased humic acid content, cation exchange capacity and water soluble carbohydrates (Talashilkar *et al.*, 1999). It also contains biologically active substance such as plant growth regulators.

Poultry manure is a valuable manure and can serve as a suitable alternate to chemical fertilizers. Poultry manure application registered over 53 per cent increases of N level in the soil, from 0.09 per cent to 0.14 per cent and exchangeable cations also increased with the application of poultry manure (Boateng *et al.*, 2006). In agriculture, the main reason for applying poultry manure is to add of organic amendment to the soil and to provide nutrients in sufficient quantity to the crops through organic source (Warren *et al.*, 2006).

Bio-fertilizer liberates growth promoting substances and vitamins and helps in maintaining the soil fertility. They acts as antagonists and suppress the incidence of soil borne plant pathogens and thus, helps in the bio-control of diseases. Nitrogen fixing, phosphate mobilizing and cellulolytic microorganisms in bio-fertilizers enhance the availability of plant nutrients in the soil and thus, helps in sustainable agricultural production and farming systems (Siddiqui *et al.*, 2014).

Azotobacters are free-living bacteria that fix atmospheric nitrogen in cereal crops without any symbiosis and they do not need a specific host plant. *Azotobacters* are abundant in well drained, neutral soil. They can fix 15-20 kg/ha N per year. *Azotobacter species* can also produce antifungal compounds to fight against many plant pathogens. They also increases

germination of seeds and vigour in young plants leading to improved crop stands (Siddiqui *et al.*, 2014).

A number of factors are responsible for successful cultivation of sweet potato and one of them is judicious supply of nutrients especially N, P and K through the application of poultry Manure, FYM, vermicompost. The bio-fertilizers are responsible for affecting both qualitative as well as quantitative aspects of sweet potato production.

Keeping these facts in mind, a field experiment entitled “**Effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of Sweet potato (*Ipomoea batatas* Lam.)**” was conducted at Horticulture Farm, S.K.N. College of Agriculture Jobner during *kharif* season 2016 with the following objectives.

- (i) To study the effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of sweet potato.
- (ii) To study the interaction effect, if any.
- (iii) To work out the economic feasibility of the treatments.

Chapter-2

REVIEW OF LITERATURE

A brief review of the literature pertaining to the “Effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of Sweet potato (*Ipomoea batatas* Lam.)” is presented in this chapter. An attempt has been made to cite the available information of research on sweet potato as well as other root, tuber, bulb and vegetable crops related to the present study under the following heads.

2.1 Effect of NPK on growth, yield and quality

Sharif Hossain *et al.*, (2003) reported that integration of organic and inorganic sources of nutrients influenced plant height and number of tubers in potato per plant positively.

Alfred and Hartemink (2003) reported that application of nitrogen through inorganic fertilizers and poultry litter @ 100 kg ha⁻¹ produced maximum yield of tubers in sweet potato.

Sparrow and Chapman (2003) reported that the application of nitrogenous fertilizer increased size of the tubers and ultimately increased the tuber yield in potato.

Osundare (2004) conducted an experiment with inorganic and organic fertilizers alone and in combination on sweet potato and found that the combined application of these manures and fertilizers significantly increased length of root tubers by 15, 25 and 39 percent, respectively.

Shanmugasundaram and Savithri (2004) noticed that application of nitrogen at 120 kg ha⁻¹ with FYM (10 t ha⁻¹) and MgSO₄ (2% as foliar spray) recorded higher amount of nitrogen content and uptake of nitrogen in plant foliage and root of carrot.

Love *et al.*, (2005) demonstrated that application of nitrogen @ 150 kg ha⁻¹ gave significant increase in nitrogen content of potato tubers.

Asghar *et al.*, (2006) stated that statistically significant highest root length was recorded where 100 per cent of recommended nitrogen fertilizer was applied which was compared to control.

Adejobi and Odeniyi (2006) reported that application of NPK fertilizers increased plant growth parameters, tuber yield, P, K and Ca content in leaf and tubers of sweet potato as compared to poultry manure treatments.

Baniuniene and Zekaite (2008) designed an experiment to estimate the effects of organic and mineral fertilizers and their combinations on potato tuber yield and quality. Potatoes were grown without and with farmyard manure (40 t ha⁻¹) combined with various combinations of mineral fertilization (N₀P₀K₀, N₉₀P₉₀, P₉₀K₁₂₀, N₉₀P₉₀K₁₂₀). The highest increase (3.8-6.0 t ha⁻¹) in tuber yield was obtained in fertilizer combination with nitrogen.

Raghav *et al.*, (2008) reported that the growth parameters and yield of potato (*Solanum tuberosum* L.) cv. Kufri Chipsona-2 were significantly influenced by the organic manures and chemical fertilizers. Maximum plant height (68.66 cm), number of haulms per hill (7.55), number of tubers per hill (8.33), were recorded with the application of 100 percent recommended dose of NPK (160: 100: 120 ha⁻¹) + 10 t FYM followed by 100 percent of recommended dose of NPK alone.

Jilani *et al.*, (2010) studied the effect of different levels of nitrogen on growth and yield of radish with five N levels (50, 100, 150, 200 and 250 kg/ha) along with control. The results showed that application of higher N levels gave better results for all parameters studied. Maximum number of leaves (18.70, 18.17 and 18.10), leaf length (33.33, 32.80 and 31.10 cm) and fresh weight of leaves (160.67, 132.83 and 140.82 g) were recorded when N was applied @ 150, 200 and 250 kg per hectare, respectively.

Allolli *et al.*, (2011) found that application of FYM @ 10 t ha⁻¹ + NPK @ 50: 25: 50 kg ha⁻¹ significantly improved tuber yield (33.35 t ha⁻¹) in sweet potato.

Yeng *et al.*, (2012) conducted field experiment on sweet potato cv. "Okumkom" to determine the growth and yield response to chicken manure, inorganic fertilizer (NPK 15-15-15) and their combinations. On an average, all the treatments accumulated higher plant dry matter over the growing period than the unamended or control treatment at both locations. Plant dry matter accumulation produced at Mampong-Ashanti was higher than at Wa. The highest marketable root yields of 21.4 and 23.0 t ha⁻¹ were obtained from combinations of 150 kg NPK ha⁻¹ + 1.5 t CM ha⁻¹ and 100 kg NPK ha⁻¹ + 3.0 t CM ha⁻¹ at Wa and Mampong-Ashanti, respectively. Integrated combinations of 150 kg NPK ha⁻¹ + 1.5 t CM/ha and 100 kg NPK ha⁻¹ + 3.0 t CM/ha are recommended for the Guinea savanna and forest-savanna transition zones, respectively, and similar representative environments to obtained maximum yield and reduce cost on nutrient inputs.

Zewide *et al.*, (2012) conducted an experiment to investigate the effect of nitrogen and phosphorus levels on yield and yield components of potato. Four levels of nitrogen (0, 55, 110, 165 kg ha⁻¹) and four levels of phosphorus (0, 20, 40, 60 kg ha⁻¹) were combined in 4x4 factorial arrangement in randomized complete block design with three replications. From this study, they concluded that the higher levels of nitrogen (165 kg ha⁻¹) and phosphorus (60 kg ha⁻¹) can be used for optimum production of potato variety Jalene.

Mehadi *et al.*, (2012) carried out an experiment to assess the effect of different levels of urea along with three levels of cowdung. The result revealed that the application of 150 kg N ha⁻¹ as urea was found suitable for maximum gross and marketable yield (47.35 t ha⁻¹ and 39.0 t ha⁻¹), while 15 t cowdung ha⁻¹ showed better gross and marketable yield (38.13 t ha⁻¹ and 30.42 t ha⁻¹). The combined application of 150 kg N ha⁻¹ and 15 t cowdung ha⁻¹ resulted in

the better performance in gross and marketable yields (51.22 t ha⁻¹ and 43.41 t ha⁻¹) of carrot.

Shukla *et al.*, (2012) carried on an investigation to assess the effect of integrated nutrient management on seed yield and quality of radish cv. Chinese Pink. The maximum seed yield per plant (34.00 g) and seed yield per plot (544.00 g) obtained in treatment T₂ (*Azospirillum* + recommended dose of NPK) and minimum seed yield (24.33 g/plant and 381.67g/plot) was recorded in control.

Singh and Lal (2012) conducted an experiment to standardize suitable dose of potassium for potato cv. Kufri Pukhraj to obtain optimum yield, quality and nutrient use efficiency under different nitrogen levels. The maximum plant height, number of leaves and chlorophyll content were recorded under the highest dose of nitrogen. The maximum plant height and number of leaves per plant, LAI and SPAD value for chlorophyll content recorded at 150 kg N ha⁻¹ and found at par with 225 kg N ha⁻¹, whereas potassium and N application improved tuber size by increasing the number of large and medium grade tuber yield and decreasing the small and very small sized tubers, Maximum yield of 39.83 t per hectare was obtained when N and K were applied @ 225 kg ha⁻¹ and 150 kg ha⁻¹, respectively against a tuber yield of only 14.36 t ha⁻¹ without N and K application in potato.

Abdissa *et al.*, (2012) conducted a field experiment on sweet potato consisting of five levels of FYM (0, 5, 10, 15, 20 t ha⁻¹) and three levels of P (0, 90, 189 kg P₂O₅ ha⁻¹). The result showed that main effect of FYM significantly affected tuberous root length and shoot fresh weight of shoot. However, the main effects of P had non-significant influence on all other parameters. Moreover, the interaction effect of FYM and P significantly affected tuberous root diameter, vine length and dry weight of shoot.

Agyarko *et al.*, (2014) conducted an experiment to assess the impact of sole poultry manure (6 t ha⁻¹), sole NPK (200 kg ha⁻¹) and their combinations

(3 t PM + 100 kg NPK ha⁻¹ and 1.5 t PM + 150 kg NPK ha⁻¹) on sweet potato yield parameters and content of nutrients in soil. The 3 t PM + 100 kg NPK ha⁻¹ produced significantly ($P=0.05$) the highest tuber yield, tuber length, diameter and also the highest percentage of marketable tubers. The results demonstrated that combined application of PM and NPK increased sweet potato tuber yield and soil nutrient levels in a cost effective manner.

Ahamad *et al.*, (2014) conducted an experiment to evaluate the effect of farm yard manure (FYM) with and without potassium fertilizer on potato (*Solanum tuberosum*) yield. The yield improved with application of K fertilizer along with FYM and it was highest at 100 kg K₂O ha⁻¹ when applied along with 30 t ha⁻¹ of FYM. Application of both FYM and K fertilizer significantly influenced the tuber yield as compared to control.

Baloch *et al.*, (2014) reported that maximum plant height was recorded when nitrogen was applied from 100 kg ha⁻¹ and above levels. On the other hand, even half quantity of nitrogen (50 kg/ha) produced more number of leaves and enhanced the fresh weight of plant as compared to control.

Uzma and Qureshi (2014) assessed the effect of farm yard manure on yield, nutrient content and quality of potato (*Solanum tuberosum* L.) and reported that yield and quality of potato tubers were influenced by the levels of nitrogen and farm yard manure. Application of 180 kg N ha⁻¹ along with 24 t FYM ha⁻¹ gave significantly higher yield.

2.2 Effect of FYM on growth, yield and quality

Susan *et al.*, (2003) reported that balanced application of NPK at 100:50:100 kg ha⁻¹ combined with FYM at 12.5 t ha⁻¹ was found beneficial in maintaining starch content of cassava tubers.

Powon *et al.*, (2006) reported that combined application of 100 kg P and 20 t FYM ha⁻¹ gave the maximum plant height in potato and minimum plant height in control.

Subramani *et al.*, (2011) studied the effect of organic nutrients and bio stimulants on growth parameters in radish cv. Pusa Chetki. The organic manures viz. FYM, vermicompost and consortium of biofertilizers were applied in the soil as basal application. The results of the experiment revealed that the growth parameters viz. shoot length, number of leaves, leaf area and shoot weight were recorded highest by the application of FYM @ 25 t ha⁻¹ + consortium of biofertilizers @ 2 kg ha⁻¹ combined with EM @ 1:1000 dilution ha⁻¹ and MMT @ 3 per cent for both seasons.

Ayub *et al.*, (2011) conducted an experiment to assess the effect of different potash sources and their combinations with FYM on growth and yield of potato. Plant height was found highest by the application of FYM. The yield parameters were found significantly higher by the combination of ¼ dose of MOP and ¾ dose of FYM. In this way it is concluded that potash fertilizers with FYM can be a good combination towards obtaining higher yield of potato.

Balemi (2012) conducted an experiment to study the effect of farm yard manure (cattle manure) and inorganic fertilizers on tuber yield of potato (*Solanum tuberosum* L.). Results demonstrated that the application of 20 or 30 t ha⁻¹ FYM + 66.6% of the recommended inorganic NP fertilizers significantly increased total tuber yield over the application of full dose of inorganic NP fertilizers without FYM in vertisol whereas in nitosol, the highest level of FYM (30 t ha⁻¹) + 66.6% of the recommended inorganic NP fertilizers significantly improved total tuber yield over the application of full dose of inorganic NP fertilizers without FYM. The application of 10 t ha⁻¹ FYM + 66.6% of the recommended inorganic NP fertilizers and 20 or 30 t ha⁻¹ FYM + 33.3% of the recommended inorganic NP fertilizers gave a total tuber yield, which was at par with the tuber yield obtained by the application of full dose of inorganic NP fertilizer alone, in both soils. Thus, the application of 10 t ha⁻¹ and 20 or 30 t ha⁻¹ FYM resulted in a saving of 33.3% and 66.6% of the recommended NP fertilizers, respectively without significantly reducing the total tuber yield.

Ahmed *et al.*, (2014) conducted a field experiment at two locations (Samaru and Kadawa) to determine the effect of nitrogen, phosphorous and farm yard manure on the growth of carrot. They concluded that nitrogen and phosphorous application significantly increased the growth of carrot especially at the later stages, while farm yard manure applied at 20 t ha⁻¹ significantly increased the overall growth of carrot plant throughout the growing season.

Garo *et al.*, (2014) studied the effect of the combined application of inorganic fertilizers and FYM on yield and yield components of sweet potato and reported that the combined application of 46 kg N ha⁻¹ and 5 t ha⁻¹ FYM increased 48.55, 48.16 and 46.42 percent marketable root, fresh top weight and total fresh root yield, respectively over control. The finding of the study clearly reflects that yield and yield components of sweet potato can be enhanced by combined application of FYM and inorganic fertilizers. In this study the highest yield (24.12 t ha⁻¹) was achieved by the application of 46 kg ha⁻¹ N and 5 t ha⁻¹ FYM.

Uzma and Qureshi (2014) conducted an experiment to assess the effect of farm yard manure on yield, nutrient content and quality of potato (*Solanum tuberosum* L). The yield and quality of potato tubers were significantly influenced by the rate of application of nitrogen and farm yard manure. Application of 180 kg N ha⁻¹ along with 24 t FYM ha⁻¹ gave significantly higher yield. The concentration of N, P and K content in tubers increased with increasing levels of N and FYM. Addition of N and FYM significantly enhanced the quality of potato tubers.

Umuhoza *et al.*, (2014) studied the role of farm yard manure on carrot nutritional quality and reported that farm yard manure had a positive effect on β -carotene and vitamin C content in carrot. The highest β -carotene (11188 μ g/100 g) and vitamin C (7.980 g/100 g) was recorded from the 20 t FYM ha⁻¹ treatment while, the lowest content was recorded from the carrot that did not received any dose of farm yard manure. However, FYM did not influenced significantly the total soluble solid content in carrot whereby the highest TSS

(10.267 per cent) was obtained in plots without FYM and the lowest TSS (9.997 per cent) was obtained in carrot harvested from the 20 t FYM ha⁻¹ treatment plots.

Sarma *et al.*, (2015) carried out a field experiment to study the effect of organic manures and biofertilizers on growth, yield and quality of carrot at experimental farm, Department of Horticulture, Assam Agricultural University, Jorhat during 2008-09. The result of the study revealed that the combined application of *Azotobacter*, farm yard manure (FYM), rock phosphate (RP) and phosphate solubilizing bacteria (PSB) improved the root yield and other growth traits *viz.* root girth, number of functional leaves and stalk weight of carrot and the highest root yield (19.60 t ha⁻¹) was obtained under this treatment.

2.3 Effect of vermicompost on growth, yield and quality

Shreeniwas *et al.*, (2000) working with ridge gourd cv. Pusa Nasdar found that increasing levels of vermicompost application increased fruit quality particularly the TSS and highest TSS content was recorded in the vermicompost 10 t ha⁻¹ + 50:25:25 kg NPK ha⁻¹ treatment.

Yadav and Vijayakumari (2003) conducted an experiment to evaluate the effect of vermicompost and inorganic fertilizers on the yield parameters of chilli. They reported that higher number of fruits per plant, fruit weight, fruit length and fruit diameter were obtained by applying vermicompost alone.

Bongkyoon (2004) reported that the effect of vermicompost application was favourable as compared to the effect of application of chemical fertilizers alone for potato crop.

Reddy and Reddy (2005) evaluated the effect of different levels of vermicompost (0, 10, 20 and 30 t/ha) and nitrogen fertilizer (0, 50, 100, 150 and 200 kg/ha) on growth and yield of onion cv. N-53 and their residual effects on succeeding radish crop in an onion-radish cropping system. Among

the various treatment combinations, vermicompost at 30 t ha⁻¹ + 200 kg N ha⁻¹ recorded the highest plant height and number of leaves per plant by the application of vermicompost at 30 t ha⁻¹ + 50 kg N ha⁻¹ treatment combination in terms of bulb length, bulb weight and onion bulbs yield ha⁻¹.

Rajan and Mahalakshmi (2007) reported that the number of leaves produced in radish and cowpea seedling were higher in treatment containing 75 per cent vermicompost. The leaf area, tuber length, and weight of radish were higher in the plot received 100 per cent vermicompost.

Shambhavi and Sharma (2008) reported that maximum protein content (9.23 %) was found in potato tubers by the application of chemical fertilizers (NPK) and vermicompost/FYM in potato.

Vijayakumari *et al.*, (2012) conducted an experiment to analyse the effect of farm yard manure (FYM), phosphobacteria, *Azospirillum*, vermicompost, humic acid and NPK on growth and yield of radish (*Raphanus sativus* L.) cv. Pusa chetki and reported that maximum root weight and root length was found in vermicompost treated plants. From this investigation it is inferred that the potting mixture containing farmyard manure, vermicompost, humic acid and NPK could be ideal and suitable for better quality and higher production of radish.

Bhattacharya *et al.*, (2012) studied the effect of vermicompost in combination with chemical fertilizers on yield of potato (*Solanum tuberosum*) and soil characteristics after the cultivation of potato (*Solanum tuberosum*) in a 2 years field trial. The result reflected that the combination of vermicompost and NPK fertilizers (100 %) produced maximum yield of potato.

Frank (2012) conducted a field experiment to assess the potential of water hyacinth [*Eichhornia crassipes* (Mart) Solms-Laubach] + animal manure (cow dung/poultry manure) compost for improving the productivity of cassava (*Manihot esculenta* Crantz) + groundnut (*Arachis hypogaea* L.) intercropping system. Sole groundnut yield decreased significantly when intercropped with

cassava. However, water hyacinth-based vermicompost increased cassava fresh tuber yield over mineral fertilizers.

Mojtaba *et al.*, (2013) suggested that use of 150 kg N ha⁻¹ and vermicompost @ of 12 t ha⁻¹ gained highest tuber yield and avoidance of environmental pollution in potato crop.

Sharma *et al.*, (2013) concluded that sowing of radish seed cv. "Pusa Chetki" with broadcasting method and fertilized with 50: 50: 50 kg N: P: K + 5.0 t FYM + 1.25 t vermicompost + 0.5 t castor cake ha⁻¹ gave maximum fresh root yield (38.58 t/ha) with net realization (Rs. 1, 63,342/ha) and highest CBR (1: 6.52) when grown on sandy loam soils of middle Gujarat.

Kumar *et al.*, (2014) conducted a field experiment taking 11 treatment combinations of different organic manures to study their effects on plant and root growth parameters. It was seen that the plant height was significantly increased by the application of organic manure and it was maximum under treatment T₉ *i.e.* vermicompost + poultry manure (50 % each). Similarly vermicomposting recorded highest number of leaves, root length, and root diameter in Radish.

Panwar and Wani (2014) conducted an experiment during the *kharif* seasons of 2012-14 at the forest nursery and research center, College of Forestry, Allahabad Agriculture University on growth and productivity of *Ipomoea batatas* cv. Pusa Red under poplar based agroforestry system. The experiment was laid out in shade (under trees) conditions with 7 treatments replicated thrice in Randomized Block Design. Nitrogen, potash and phosphorus were applied through organic sources *viz.* FYM, vermicompost, and neem cake. T₃ (vermicompost) recorded highest survival percent, length of vine, number of branches/vine, fresh and dry weight of shoot, tuber yield/plot, number of tubers per plot under poplar trees based cropping system.

Jadhav *et al.* (2014) laid out a pot culture experiment and reported that the yield obtained with 1.2 kg vermicompost + RDF + FYM treatment was significantly higher than all other treatments with respect to growth and yield *i.e.* root length (23.11 cm), single root weight (89.03 g), yield per pot (17.81 kg), yield per ha (59.35 t/ha) and marketable yield (44.51 t/ha) of radish.

2.4 Effect of Poultry manure on growth, yield and quality

Abusaleha and Shanmugavelu (1988) reported that 20 kg nitrogen as ammonium sulphate + 20 kg nitrogen as poultry manure produced maximum plant height, stem girth, number of nodes plant⁻¹ and number of branches plant⁻¹ in okra plants.

Alphonse and Saad (2000) recorded maximum plant height, leaf and stem fresh weight, dry matter content in green house cucumber by the application of FYM + Poultry manure.

Aliyo (2000) reported that the application of FYM + poultry manure at 5 t ha⁻¹ supplemented with 50 kg N ha⁻¹ resulted in significantly higher fruit yield as compared to other treatments in pepper.

Shelke *et al.*, (2001) reported that replacing of 60 per cent nitrogen as urea by poultry manure obtained significantly maximum yield (581 q ha⁻¹) over control (524 q ha⁻¹) in brinjal cv. Krishna Hybrid.

Yadav *et al.*, (2006) reported that maximum protein content in okra fruit was recorded by the application of N (90 kg ha⁻¹) through FYM, vermicompost, poultry manure and urea over control.

Anjali *et al.*, (2006) reported that among the organic N sources, poultry manure stimulated better growth and yield response in okra as compared to farm yard manure.

Mulani *et al.*, (2007) reported that the application of 25 per cent nitrogen through neem cake and 75 per cent through poultry manure was

found superior in the enhancement of growth, yield and quality parameters of bitter gourd.

Meerabai *et al.*, (2007) studied biofarming in bitter gourd (*Momordica charantia* L.) and reported that among organic nutrient sources, poultry manure was found best in increasing the number of harvests, number of fruits plant⁻¹ and total fruit yield. The fruit yield produced by poultry manure was 46.5 per cent higher as compared to control.

Sanwal *et al.*, (2007) reported that among different organic manure treatments significantly higher rhizome yield was recorded with the application of FYM @ 18 t ha⁻¹ in turmeric which was at par with 10 t ha⁻¹ poultry manure.

Jaipaul *et al.*, (2011) conducted a field study on potato and reported that yield of potato was higher in conjoint use of nutrients than organic fertilizers alone but among the organic fertilizers, chicken manure + biofertilizers resulted in maximum plant height (70.73 cm), highest number of tubers (7.5 /plant), highest yield of large sized tubers (40 %), total yield (18.86 t/ha), highest uptake of nutrients (N:P:K: 82.1:18.0:91.2 kg/ha), maximum dry matter (20.06 %), specific gravity (1.06), protein (8.39 %), starch (10.76 %), ascorbic acid content (21.73 mg/100g) and minimum reducing sugars (0.30 %). The highest B:C ratio (4.86) was also obtained in conjoint use of fertilizers and manures followed by the treatment comprising chicken manure and biofertilizers (2.30).

Antoinette *et al.*, (2013) reported that the combined application of 175 kg NPK + 4 t Poultry Manure ha⁻¹ and 175 kg NPK + 6 t cow dung manure ha⁻¹ produced higher levels of the growth and yield parameters than the rest of the treatments in both seasons.

Onwu *et al.*, (2014) reported that application of poultry manure @ 10 t ha⁻¹ significantly increased growth and yield of okra plants. In addition of it also brought about improvement in soil chemical properties like soil pH, total

N, available P, organic matter, exchangeable cations and cation exchange capacity.

Nweke *et al.*, (2013) reported that the poultry manure recorded the highest value in all the parameters and was significantly ($P=0.05$) different from the other treatments in fruit weight (11.63g), number of fruits/plant (23.5) and number of flowers/plant in okra. Goat manure performed competitively better than the pig manure alone, in all the parameters under study, while the control plots showed least performance in this study with a yield of 4.48 kg plot⁻¹.

Peter *et al.*, (2014) conducted a study to evaluate the effect of broiler litter application at rate of 0, 0.5, 1, 2, and 3 t ha⁻¹ on the nutritional and physical properties of sweet potato. Based on findings of this study, application of 0.5 t ha⁻¹ appeared to be appropriate level of broiler litter, which is consistent with nutritional and physical properties of sweet potato and is also advantageous in terms of low cost of farming practices and reduction of water pollution.

Okoli and Nweke (2015) reported that growth and yield parameters increased with the application of increasing levels of poultry manure. The plants treated with 20 t ha⁻¹ poultry manure recorded the highest value in all the parameters studied. Thus 20 t ha⁻¹ of poultry manure should be applied for maximum increase in production of amaranthus.

Shanika and Premanandarajah (2015) reported that significantly maximum nitrogen uptake was registered in sole poultry manure application, maximum residual soil nitrogen (RSN) was recorded in 100 per cent paddy straw integrated with 100 per cent urea and the maximum available soil nitrogen at the time of planting was in 100 per cent poultry manure integrated with 100 per cent urea. Sole poultry manure can be suggested to the farmers especially for the cultivation of okra on sandy regosol in order to maximize the

nitrogen uptake and indirectly induce the better growth performance and to reduce the use of chemical fertilizers.

Fagwalawa and Yahaya (2016) reported that the fresh fruit weight and number of fruits were significantly increased by 125.66 per cent by the application of poultry manure as compared to control in okra.

2.5 Effect of Azotobacter on growth, yield and Quality

Yassin *et al.*, (1994) conducted a field experiment on sweet potato cv CO-3 and registered higher tuber yield when treated with two third recommended dose of nitrogen 26 kg ha^{-1} + 2 kg of *Azospirillum* ha^{-1} with vine dipping + 10 kg *Azospirillum* ha^{-1} as soil application.

Jayathilake *et al.*, (2002) revealed that plant height, number of leaves plant^{-1} , bulb weight and bulb yield in onion were recorded maximum by the application of biofertilizer (*Azotobacter* or *Azospirillum*) in combination with 50 per cent of recommended N through organic manures (FYM or vermicompost) and rest of the NPK through chemical fertilizers.

Vasanthakumar (2003) reported that *Azotobacter* when applied to nursery, seedlings and field soil observed maximum values for number of fruits plant^{-1} , fruit yield plant^{-1} and ha^{-1} and cost benefit ratio in solanaceous crops.

Aswani *et al.*, (2005) studied the effect of four levels of nitrogen (25, 50, 75, and 100 kg ha^{-1}) and two sources of biofertilizer viz. *Azotobacter* (A_1) and *Azospirillum* (A_2) on yield and quality of onion bulb (*Allium cepa* L.) and observed that combination of N_4A_1 (100 kg N ha^{-1} + *Azotobacter*) gave highest bulb yield and fresh weight of bulb, followed by $N_3 A_1$ (75 kg N ha^{-1} + *Azotobacter*) treatment.

Farzana and Radizah (2005) conducted a pot experiment to determine the influence of on plant growth and nutrient uptake and reported that the

rhizobacterial isolates significantly increased plant growth and N,P, K, Ca and Mg uptake in sweet potato.

Bhadoria *et al.*, (2007) conducted an experiment to assess the interaction effect of nitrogen and *Azotobacter* inoculation on days taken to first flowering and fruit setting in tomato and recorded maximum number of flowers by the application of 75 kg N ha⁻¹ + seedling inoculation with *Azotobacter* culture which was at par with 100 kg N ha⁻¹ along with seedling inoculation with *Azotobacter* culture and 100 kg N ha⁻¹ alone.

Bairwa *et al.*, (2009) reported that maximum number of fruits (18.36), fruit yield (182.50 g plant⁻¹ and 135.18 q ha⁻¹), fruit weight (17.65 g), length of fruits (12.26 cm) and thickness of fruits (1.898 cm) in okra was obtained with the application of neem cake 6 q ha⁻¹ + vermicompost 10 q ha⁻¹ + *Azotobacter* + PSB + 60 (%) recommended dose of NPK through inorganic fertilizers.

Nedunchezhiyan *et al.*, (2010) observed that bio-agents such as *Trichoderma*, *Azospirillum*, *Azotobacter* and phosphorus solubilizing bacteria population build up increased in the soil when applied along with organic manures in sweet potato crop.

Saravaiya *et al.*, (2010) reported maximum corm yield (55.33 t ha⁻¹) in elephant foot yam with the application of 100 per cent RDF + inoculation with bio-fertilizers (*Azotobacter*, *Azospirillum* and PSB).

Verma *et al.* (2011) reported that combination of crop residues + *Azotobacter* + phosphobacteria + biodynamic approach + microbial culture was the best treatment among all the treatments for most of the growth and yield parameters under study and gave highest net returns and B:C ratio. Thus, it can be concluded that the biofertilizers (*Azotobacter*, phosphobacteria, microbial culture and biodynamic approach) are an advantageous source for sustainable organic agriculture.

Eid and El-sayed (2012) studied the effect of using 100 (%) compost (15 t) and 50 (%) compost + nitrogen fixing bacteria (*Azotobacter*, and *Pseudomonas* alone or in combination) on potato growth and yield as compared to the conventional mineral fertilization (120-75-150 kg NPK + 5 t compost). No significant differences in tuber yield per plant and per hectare were detected between mineral fertilization (T₁) and using 100% compost (T₂); however, "T₁" significantly produced higher yield per hectare than 50% compost + biofertilizer treatment.

Sarma *et al.*, (2015) found that the combined application of *Azotobacter*, farm yard manure (FYM), rock phosphate (RP) and phosphate solubilizing bacteria (PSB) improved the root yield and other growth traits *viz.* root girth, number of functional leaves and stalk weight of carrot. The highest root yield (19.60 t ha⁻¹) was obtained under this treatment. However, the application of *azotobacter*, vermicompost and PSB also improved yield of carrot.

Prasad *et al.*, (2016) recorded that number of bacterial species are able to exert a beneficial effect on plant growth. Bio-fertilizers combined with organic manure influences the plant growth by enhancing root biomass, thereby the total root surface facilitates higher absorption of nutrients and increase in yield by reducing consumption of natural sources of energy. The organic fertilizers have proved that their application has potential to increase the biomass and productivity of a wide range of crops.

Chapter-3

MATERIALS AND METHODS

A field experiment entitled “**Effect of organic and inorganic sources of N P K and bio-fertilizer on growth, yield and quality of Sweet potato (*Ipomoea batatas* Lam.)**” was conducted during *kharif* season of 2016 at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Rajasthan). The experimental materials and methodology used for treatment evaluation during the course of investigation are being presented in this chapter.

3.1 Experimental site

The field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture (S.K.N. Agriculture University) Jobner, District Jaipur. Jobner is situated at 26° 05' North latitude and 75° 28' East longitude at an elevation of 427 metres above mean sea level, in Jaipur district of Rajasthan. This region falls under agroclimatic zone III-a (Semi-Arid Eastern Plain Zone) of the state.

3.2 Climate and weather

The climate of this region is typically semi-arid, characterized by extremes of temperature during summer and winter season. During summer, the temperature may go as high as 48°C while in winter, it may fall down as low as -1°C. The average annual rainfall of this tract ranges between 300- 400 mm, most of which is contributed by the South-West monsoon during July to August. A total of 587.2 mm annual rainfall was received during the year 2016. The mean weekly weather parameters for crop season, recorded at college meteorological observatory are presented in Table 3.1 and illustrated in Fig. 3.1.

Table 3.1 Mean weekly meteorological data for crop season (July to December, 2016)

SMW* No.	Period		Temperature (°C)		Mean R.H. (%)	Evaporation (mm/day)	Bright Sunshine (hrs)	Rainfall (mm)
	From	To	Maxi.	Min.				
29	16/07/2016	22/07/2016	32.7	25.9	69.5	04.6	04.4	015.8
30	23/07/2016	29/07/2016	31.4	25.1	72.5	04.5	05.8	036.4
31	30/07/2016	05/08/2016	31.4	24.5	81.5	03.0	02.6	070.0
32	06/08/2016	12/08/2016	31.9	24.9	81.5	02.5	01.2	041.0
33	13/08/2016	19/08/2016	31.9	24.2	76.5	04.0	04.3	003.8
34	20/08/2016	26/08/2016	31.9	24.2	76.5	04.0	04.3	001.0
35	27/08/2016	02/09/2016	30.5	24.5	83.5	02.8	01.9	001.0
36	03/09/2016	09/09/2016	32.3	22.5	65	03.4	07.9	000.0
37	10/09/2016	16/09/2016	34.9	22.4	59	06.0	07.7	000.0
38	17/09/2016	23/09/2016	37.9	23.7	56	06.5	08.6	000.0
39	24/09/2016	30/09/2016	37.1	22.7	59	06.6	07.9	000.0
40	01/10/2016	07/10/2016	34.3	23.6	72	05.3	05.1	002.0
41	08/10/2016	14/10/2016	35.2	20.5	61	06.4	07.2	-
42	15/10/2016	21/10/2016	35.3	15.5	47	06.6	06.1	-
43	22/10/2016	28/10/2016	34.3	14.6	51	06.5	05.9	-
44	29/10/2016	04/11/2016	33.0	11.0	55	04.6	08.7	-
45	05/11/2016	11/11/2016	32.0	08.5	49	05.4	09.2	-
46	12/11/2016	18/11/2016	30.4	08.7	53	05.6	09.1	-
47	19/11/2016	25/11/2016	31.0	06.6	49	05.5	09.0	-
48	26/11/2016	02/12/2016	30.5	08.6	53	04.0	09.0	-

* Standard meteorological week

3.3 Soil characteristics of the experimental field

To ascertain physico-chemical characteristics of the soil during the year of experimentation, soil samples from 0-15 cm depth were collected from different locations of experimental field before application of manures and fertilizers. A representative composite sample was prepared by processing and mixing them together and then analysed for physical and chemical characteristics. The results of analysis presented in Table 3.2 showed that the soil was loamy sand in texture, slightly alkaline in reaction, poor in organic carbon with low available nitrogen, phosphorus and medium in potassium.

Table 3.2 Physico-chemical characteristics of the soil of experimental field

S. No.	Parameters	Values	Reference and method of analysis
A. Mechanical analysis			
1.	Coarse sand (%)	26.4	International pipette method (Piper, 1950)
2.	Fine sand (%)	55.4	-do-
3.	Silt (%)	8.20	-do-
4.	Textural class	Loamy sand	-do-
B. Physical analysis			
1.	Bulk density (Mg m ⁻³)	1.51	Method No. 38, USDA Hand Book No. 60 (Richards, 1954)
2.	Particle density (Mg m ⁻³)	2.56	-do-
3.	Porosity (%)	41.55	-do-
C. Chemical analysis			
1.	Available nitrogen (kg ha ⁻¹)	132.75	Alkaline potassium permanganate method (Subhiah and Asija, 1956)
2.	Available phosphorus (kg ha ⁻¹)	17.84	Olsen's method (Olsen <i>et al.</i> , 1954)
3.	Available potash (kg ha ⁻¹)	161.50	Flame photometer method (Metson, 1956)
4.	Organic carbon (%)	0.13	Walkely and Black's rapid titration method (Piper, 1950)
5.	EC of saturation extract at 25°C (dSm ⁻¹)	0.75	Method No. 4, USDA Hand Book No. 60 (Richards, 1954)
6.	pH (1:2 soil water suspension)	8.1	Method No. 21 (b), USDA Hand Book No. 60 (Richards, 1954)
7.	C:N ratio	12:1	-

3.4 Treatment details

The experiment was comprised of 16 treatment combinations with organic and inorganic sources of NPK and bio-fertilizer. The treatments with their symbols are given in Table 3.3 and 3.4.

3.5 Design and layout of experiment

The experiment was laid out in Randomized Block Design (RBD) with 3 replications. Randomization of the treatments was done with the help of Random Number Table (Fisher and Yates, 1963). The layout of experiment, allocation of treatments and other details of the experiment are shown in Fig. 3.2.

The details of experimental layout plan are as under :

- i. Season and year : *Kharif, 2016*
- ii. Name of crop : Sweet potato
- iii. Name of cultivar : IGSP-14
- iv. Number of treatments : 16
- v. Replications : 3
- vi. Total number of plots : 48
- vii. Spacing : 30 x 45 cm
- viii. Plot size : $2.40 \times 2.25 = 5.4 \text{ m}^2$
- ix. Net transplanted area : 259.2 m^2
- x. Total area under
experiment : 304.2 m^2
- xi. Experimental Design : Randomized Block Design
- xii. Site of experiment : Horticulture farm, S.K.N. College of
Agriculture, Jobner

Table 3.3: Details of treatments with symbol

S. No.	Treatment	Symbol
i.	Control	I ₀
ii.	100 % RDF	I ₁
iii.	100 % FYM	I ₂
iv.	50 % RDF + 50 % FYM	I ₃
v.	100 % Vermicompost	I ₄
vi.	50 % RDF + 50 % Vermicompost	I ₅
Vii	100 % Poultry Manure	I ₆
viii.	50 % RDF + 50 % Poultry Manure	I ₇
Bio-fertilizer		
i.	Control	B ₀
ii.	<i>Azotobacter</i>	B ₁

The doses of organic and inorganic sources of N P K are as follows: FYM @ 20 t/ha, Poultry manure @ 5 t/ha, Vermicompost @ 7 t/ha and recommended dose of N P K is 100, 60 and 120 kg per ha respectively. The dose of *azotobacter* is 400 ppm.

3.4 Schedule of cultural operations carried out in the experimental field during the period of study

The details of cultural operations and harvesting give in Table 3.4 as under.

Table 3.4: Schedule of cultural operations

S. NO.	Particulars	Date of operation	Remarks
1.	Ploughing and planking of field	16-08 2016	Tractor
2.	Preparation of beds	17-08-2016	Manually
3.	Application of Manures and fertilizers	18-08-2016	Manually
4.	Planting of vine cuttings	19-08-2016	Manually
5.	Irrigation to establish vine cuttings of sweet potato	20-08-2016	Manually
6.	Irrigation	24-08-2016 to 15-12-2016	Manually
7.	Gap filling	23-08-2016	Manually
8.	hoeing and weeding	11-09-2016	Manually
9.	Top dressing	15-09-2016	Manually
10.	Spray of insecticides	03-10-2016	Manually
11.	Harvesting of tubers	18-11-2016 to 20-12-2016	Manually

3.5 Raising of the experimental crop

The schedule of different pre and post sowing operations carried on during the crop season and details of crop raising are described as under:

3.5.1 Field preparation

The experimental field was thoroughly and cross-ploughed with the help of mould board plough and cross-harrowing was done with tractor. Planking and leveling were followed after this and soil was brought to a fine tilth. Beds (plots) of 2.40 m × 2.25 m size were prepared. Paths and channels were also prepared according to the layout plan of the experiment.

3.5.2 Application of treatments

3.5.2.1 Application of inorganic fertilizers and organic manures

(i) NPK application: As per the treatments nitrogen, phosphorus and potassium were applied through urea, single super phosphate and murate of potash, respectively in the experiment. The recommended dose of NPK was 100 : 60 : 120 kg ha⁻¹.

Nitrogen: The urea was applied in two split doses, first half dose was applied at the time of planting of vines, while remaining half dose was applied 30 days after planting.

Phosphorus: Phosphorus was through Diammonium phosphate (DAP) as basal dose, as per the treatment at the time of planting.

Potassium: Potassium was applied through murate of potash as basal dose, as per the treatment at the time of planting.

(ii) FYM: As per the treatment well rotten FYM was applied @ 20 t ha⁻¹ and 10 t ha⁻¹ and spreaded and incorporate uniformly in the beds. For the bed size of 2.40 m × 2.25 m, its quantity was calculated and applied after laying out the field before planting of vines.

(iii) Poultry Manure : As per the treatment poultry manure was applied @ 6.6 t ha⁻¹ and 3.3 t ha⁻¹ and spreaded uniformly and incorporated in the beds. For the bed size of 2.40 m × 2.25 m, its quantity was calculated and applied after laying out the field before planting of vines.

(iv) Vermicompost: The vermicompost was applied @ 5 t ha⁻¹ and 2.5 t ha⁻¹ as per the treatments and spreaded uniformly and incorporated in the beds. For the bed size of 2.40 m × 2.25 m, its quantity was calculated and applied after laying out the field before planting of vines.

3.5.3.2 Planting

The vine cuttings were cut for transplanting to the nursery beds when they have six to eight well developed leaves and a good root system. The vines were planted on 20th August, 2016.

3.5.2.3 Irrigation

The crop was irrigated immediately after planting for establishment of planted vines and thereafter subsequent irrigations were given at an interval of 10-15 days or as when required depending upon the soil and weather conditions.

3.5.2.4 Gap filling

To replace the unsuccessful or dead vines, gap filling was done in early period, to maintain the uniform plant population.

3.5.2.5 Intercultural operations

In order to provide favorable conditions for vine growth time to time intercultural operations were carried out. In this context, weeding and hoeing was done 30 days after planting. However, second weeding was done 55 days after planting only in channels and outer borders. For better tuber yield and quality earthing up was also performed after each hoeing and weeding operation.

3.5.2.6 Plant protection measures

To protect the plant from termites, chloropyriphos 20 EC @ 0.75 kg ha⁻¹ was applied in entire field immediately after planting with irrigation water. To check the attack of sweet potato weevil, leaf folder, sphingid caterpillar, Bihar hairy caterpillar and brown hairy caterpillar malathion 50 EC (0.05%) was spread after 45 days of planting of the vines. To reduce the attack of rodents, zinc phosphide tablets were kept inside the soil holes in the experimental plots and the holes were blocked with soil after putting the tablets.

3.5.4 Harvesting of tubers

The harvesting of tubers was started from 18th November, 2016 and last till 20th December, 2016. Harvesting was done with the help of sharp khurphi and observation on different tuber parameters of tagged vines were recorded.

3.6 Treatment evaluation and observations recorded

Five plants/vines were randomly selected from each plot and tagged and the following observations were recorded from these plants/vines.

3.6.1 Growth attributes

3.6.1.1 Vine length (cm)

Vine length of sweet potato was recorded at 45 days after planting of vines. Length of five tagged vines was recorded from base level to the apex of the longest leaf with the help of meter scale and average length was calculated.

3.6.1.2 Chlorophyll content in leaves (mg/g)

The chlorophyll content of sweet potato leaves at 50 days after planting was estimated through the method advocated by Arnon (1949). The leaf sample of 100 mg was grinded in 10 ml of 80 percent acetone, centrifuged for 10 minutes at 2000 rpm and prepared final volume to 10 ml. The resultant absorbance of clear supernatant was measured by spectronic 20 at 652 nm and presented in terms of mg/g fresh weight of leaves.

$$\text{Total chlorophyll (mg/g)} = \frac{A_{(652)} \times 29 \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{Weight of sample (g)}}$$

Where,

A = Absorbance specific wave lengths

α is the path length = 1 cm

3.6.1.2 Leaf area (cm²)

The leaf area of first five leaves from base of main vine of five tagged plants of each plot were obtained at 45 days after planting by leaf area meter (LIGR-3100, Lincoln, USA) and the average leaf area (cm²) plant⁻¹ was calculated by number of leaves per plant.

3.6.1.3 Leaf area index

Leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area ($LAI = \text{Leaf area} / \text{Ground area}, m^2 / m^2$) in broadleaf canopies.

3.6.1.4 Number of branches per vine

Number of branches of sweet potato was recorded at 45 days after planting. Number of branches of five tagged plants was recorded from base level to the apex of the longest leaf and average number of branches was calculated.

3.6.2 Yield and yield attributes

3.6.2.1 Tuber length (cm): The length of tubers was measured by scale and average was calculated.

3.6.2.2 Tuber weight (g): Weight of tubers was taken from the tagged plants after removing of soil from the tubers and average weight of tuber vine⁻¹ was calculated.

3.6.2.3 Diameter of tuber (cm): The diameter of tubers from the basal portion of the tuber was measured with the help of vernier calipers.

3.6.2.4 Number of tubers per plot: The total number of tubers per plot was counted and recorded.

3.6.2.5 Tuber yield (kg/plot): The tuber yield per plot (kg) was calculated by weighing in single pan balance.

3.6.2.6 Tuber yield (q/ha): The tuber yield ha⁻¹ in quintals was calculated on the basis of the total tuber yield per plot.

3.6.3 Quality parameters

3.6.3.1 Protein content in tuber

The tuber samples were analyzed separately for nitrogen content (%) by colorimetric method (Snell and Snell, 1949). Nitrogen content (%) multiplied with 6.25 factor to calculate protein content (A.O.A.C. 1980).

Nitrogen was estimated by digesting tuber samples with sulphuric acid using hydrogen peroxide for removing black colour. Estimation of nitrogen was done by colorimetric method using spectronic-20 after development of colour with Nessler's reagent (Snell and Snell, 1949). Nitrogen was calculated and expressed in percentage.

3.6.3.2 TSS (%) content of tuber: Total soluble solids (TSS) content in per cent was determined with the help of hand refractometer at the time of harvesting of tubers.

3.6.3.3 Starch content in tuber (% dry weight)

Starch content of sweet potato tubers was determined by gelatinization. The known volume of dried powdered tuber extraction with 60% perchloric acid, formation of a starch iodine complex, acid hydrolysis, with 0.7 N HCl, neutralization with sodium hydroxide, boiling of an aliquot in a phosphate sugar reagent, formation of Cu_2O precipitate, dissolutions of the precipitate with KI and 2N H_2SO_4 , addition of starch indicator and determination of free glucose by titration with 0.005 N $\text{Na}_2\text{S}_2\text{O}_3$ (A.O.A.C. 1960, analytic method).

3.7 Economic feasibility of the treatments

The economics of the treatments is the most important consideration for making any recommendation to the farmers for adoption of any recommendation. For calculating economics, the average yield of different treatments along with prevailing market rates of the produce and cost of inputs were used and B:C ratio was computed by dividing gross returns with cost of cultivation for each treatment. The details of economics for each treatment are given in appendices at the end.

3.8 Statistical analysis

To test the significance of variance in the data obtained from the various growth, yield and quality characters the technique of analysis of variance was adopted as suggested by Fisher (1950) for randomized block design. Significance of difference in the treatment effect was tested through 'F' test at 5 percent level of significance and CD (critical difference) was calculated, wherever the results found significant. The analysis of variance for all the data discussed is given in the appendices at the end. Results are summarized in tables and depicted with graphical representations at appropriate places.

Chapter-4

EXPERIMENTAL RESULTS

The results of the field experiment entitled “**Effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of sweet potato (*Ipomoea batatas* Lam.)**” conducted during *kharif* season, 2016-17 at Horticulture farm, S.K.N. College of Agriculture, Jobner (Jaipur) are presented and described in this chapter. The data pertaining to growth, yield and quality of sweet potato recorded during the course of investigation have been statistically analysed. The analysis of variance for the data have been presented in the appendices (I to X) at the end. The results of all the main effects and only significant interactions have been presented in succeeding paragraphs. Some of the characters have also been depicted graphically, wherever necessary to provide better understanding of important trends.

4.1 Growth attributes

4.1.1 Length of vine (cm)

The data (Table 4.1 and Fig 4.1) regarding the Length of vine (cm) at 45 DAP revealed significant effect of organic and inorganic sources of NPK and bio-fertilizer.

The maximum vine length (80.65 cm) recorded with 50% RDF + 50% vermicompost (I_5), while minimum vine length (51.24 cm) in control. However, treatment I_5 was statistically at par with 50% RDF + 50% poultry manure (I_5). The increase in vine length under 50% RDF + 50% vermicompost was registered 57.40, 13.26, 28.96, 8.14, 18.10 and 23.87 per cent more over I_0 , I_1 , I_2 , I_3 , I_4 and I_6 , respectively.

Table : 4.1 Effect of organic and inorganic sources of NPK and biofertilizer on length of vine and number of branches per vine at 45 DAP of sweet potato

Treatment	Vine length (cm)	Number of branches per vine
Organic and inorganic sources of		
NPK		
I ₀ - Control	51.24	3.60
I ₁ - 100% RDF	71.21	4.70
I ₂ - 100% FYM	62.54	4.05
I ₃ - 50 % RDF + 50 % FYM	74.58	4.90
I ₄ - 100 % Vermicompost	68.29	4.30
I ₅ - 50 % RDF + 50 % VC	80.65	5.99
I ₆ - 100 % Poultry Manure	65.11	4.15
I ₇ - 50 % RDF + 50 % PM	77.25	5.90
S.Em.±	1.24	0.03
CD (P=0.05)	3.58	0.10
Biofertilizer		
B ₀ - Control	54.84	4.39
B ₁ – <i>Azotobacter</i>	82.87	5.01
S.Em.±	0.76	0.02
CD (P=0.05)	2.19	0.06

Similarly the application of bio-fertilizer significantly influenced the vine length of sweet potato at 45 DAP. The maximum vine length (82.87 cm) recorded in treatment B₁ (*Azotobacter*), which was found significantly superior over control. The increase in vine length under the treatment B₁ was found to be 51.11 per cent more as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on vine length

The data presented in Table 4.2 and depicted in Fig. 4.2 clearly indicated significance of the combined effect of organic and inorganic sources of NPK and bio-fertilizer on vine length. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum (97.06 cm) vine length, while the minimum vine length (40.81 cm) was recorded under treatment combination I₀B₀. However, I₅B₁ treatment combination was statistically at par to I₇B₁ treatment combination, which was 92.97 cm.

4.1.2 Number of branches per vine at 45 DAP

A critical review of data presented in Table 4.1 and depicted in Fig 4.1 revealed that organic and inorganic sources of NPK and bio-fertilizer significantly influenced the number of branches per vine at 45 DAP.

The maximum number of branches per vine (5.99) recorded in 50% RDF + 50% vermicompost treatment, while minimum number of branches per vine (3.60) in control. However, the treatment I₅ was statistically at par with 50% RDF + 50% poultry manure, The increase in number of branches per vine under the influence of 50% RDF + 50% vermicompost treatment was registered 66.39, 27.45, 47.90, 22.24, 39.30 and 1.53 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Table : 4.2 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on length of vine (cm) at 45 DAP of sweet potato

Treatment	I₀	I₁	I₂	I₃	I₄	I₅	I₆	I₇	Mean
B ₀	40.81	56.72	49.81	59.40	54.39	64.24	51.86	61.53	54.84
B ₁	61.67	85.70	75.27	89.76	82.19	97.06	78.36	92.97	82.87
Mean	51.24	71.21	62.54	74.58	68.29	80.65	65.11	77.25	
SEm±			1.75						
CD (p=0.05)			5.07						

Data further indicated that application of bio-fertilizer also significantly influenced the number of branches per vine. The maximum number of branches per vine (5.01) recorded in treatment B₁ (*Azotobacter*), which was found significantly superior over control (4.39). The increase in number of branches per vine under the treatment B₁ was found to be 14.13 per cent higher as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on number of branches per vine

The data presented in Table 4.3 and depicted in Fig 4.3 clearly indicates the significant effect of combined application of organic and inorganic sources of NPK and bio-fertilizer on number of branches per vine. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum (6.39) number

of branches per vine, while the minimum number of branches per vine (3.36) recorded under treatment combination I_0B_0 . However, I_5B_1 treatment combination was statistically at par to I_7B_1 treatment, which was 6.29.

Table : 4.3 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on number of branches per vine of sweet potato

Treatment	I_0	I_1	I_2	I_3	I_4	I_5	I_6	I_7	Mean
B_0	3.36	4.39	3.78	4.58	4.02	5.59	3.88	5.51	4.39
B_1	3.84	5.01	4.32	5.22	4.58	6.39	4.42	6.29	5.01
Mean	3.60	4.70	4.05	4.90	4.30	5.99	4.15	5.90	
SEm \pm			0.048						
CD									
(p=0.05)			0.139						

4.1.3 Leaf area (cm²)

It is amply clear from data presented in Table 4.4 and depicted in Fig 4.4 that organic and inorganic sources of NPK and bio-fertilizer significantly influenced the leaf area (cm²) at 45 days after planting of sweet potato.

The maximum leaf area (14850.20 cm²) was recorded with 50% RDF + 50% vermicompost, while (7025.45 cm²) minimum leaf area recorded under control. Treatment I_5 found statistically at par with 50% RDF + 50% poultry manure. The increase in leaf area under 50% RDF + 50% vermicompost was registered

111.38, 48.35, 62.38, 31.53, 51.08, 55.89 and 7.73 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Table : 4.4 Effect of organic and inorganic sources of NPK and biofertilizer on leaf area at 45 DAP and leaf area index of sweet potato

Treatment	Leaf area (cm ²)	Leaf area index
Organic and inorganic sources of NPK		
I ₀ - Control	7025.45	5.20
I ₁ - 100% RDF	10010.25	7.42
I ₂ - 100% FYM	9145.25	6.77
I ₃ - 50 % RDF + 50 % FYM	11290.51	8.36
I ₄ - 100 % Vermicompost	9829.52	7.28
I ₅ - 50 % RDF + 50 % VC	14850.20	11.00
I ₆ - 100 % Poultry Manure	9525.92	7.06
I ₇ - 50 % RDF + 50 % PM	13785.28	9.47
S.Em.±	405.73	0.54
CD (P=0.05)	1171.84	1.57
Biofertilizer		
B ₀ - Control	9307.23	6.89
B ₁ – <i>Azotobacter</i>	11808.52	8.75
S.Em.±	248.46	0.33
CD (P=0.05)	717.60	0.96

A critical review of data revealed that application of bio-fertilizer significantly influenced the leaf area of sweet potato at 45 DAP. The maximum leaf area (11808.52 cm²) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (9307.23). The increase in leaf area under the treatment B₁ was found to be 26.87 per cent higher as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on leaf area

The data given in Table 4.5 and depicted in Fig 4.5 clearly indicates the significant influence of the combined effect of organic and inorganic sources of NPK and bio-fertilizer on leaf area. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum leaf area (16609.30 cm²). While the minimum leaf area (6193.24 cm²) was recorded under treatment combination I₀B₀.

Table : 4.5 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on leaf area at 50 DAP of sweet potato

Treatment	I ₀	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	Mean
B ₀	6193.24	8824.47	8061.94	9953.08	8665.15	13091.10	8397.51	11271.34	9307.23
B ₁	7857.66	11196.03	10228.56	12627.94	10993.89	16609.30	10654.33	14300.48	11808.52
Mean	7025.45	10010.25	9145.25	11290.51	9829.52	14850.20	9525.92	12785.91	
SEm±			261.49						
CD (p=0.05)			755.24						

4.1.4 Leaf area index

Data presented in Table 4.4 and depicted in Fig 4.6 indicates the significant influence of organic and inorganic sources of NPK and bio-fertilizer in leaf area index.

The maximum leaf area index (11.00) was recorded with 50% RDF + 50% vermicompost, while minimum leaf area index (5.20) in control. However, treatment I₅ found statistically at par with 50% RDF + 50% poultry manure. The increase in leaf area index under 50% RDF + 50% vermicompost registered 111.38, 48.35, 62.38, 31.53, 51.08, 55.89 and 7.73 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

A critical review of data revealed that application of bio-fertilizer significantly influenced the leaf area index. The maximum leaf area index (8.75) recorded in treatment B₁ (*Azotobacter*), which was found significantly superior over control (6.89). The increase in leaf area index under the influence of treatment B₁ found 26.87 per cent higher as compared to control.

The interaction effect of organic and inorganic sources of NPK and bio-fertilizer pertaining to leaf area index found to be non-significant.

4.1.5 Total Chlorophyll content in leaves (mg/g)

It is explicit from the data (Table 4.6 and Fig 4.7) that the chlorophyll content in leaves at 50 DAP was significantly affected by organic and inorganic sources of NPK and bio-fertilizer.

The maximum chlorophyll content (1.23 mg/g) recorded with 50% RDF + 50% vermicompost (I₅), while minimum Chlorophyll (0.88 mg/g) content in leaves recorded under control. Treatment (I₅) was found statistically at par with 50% RDF + 50% poultry manure. The increase in chlorophyll content under

50% RDF + 50% vermicompost was registered 39.77, 7.89, 10.81, 6.96, 8.85 and 9.82 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Table : 4.6 Effect of organic and inorganic sources of NPK and biofertilizer on chlorophyll content in leaves at 50 DAP of sweet potato

Treatment	Chlorophyll (mg/g)
Organic and inorganic sources of NPK	
I ₀ - Control	0.88
I ₁ - 100% RDF	1.14
I ₂ - 100% FYM	1.11
I ₃ - 50 % RDF + 50 % FYM	1.15
I ₄ - 100 % Vermicompost	1.13
I ₅ - 50 % RDF + 50 % VC	1.23
I ₆ - 100 % Poultry Manure	1.12
I ₇ - 50 % RDF + 50 % PM	1.18
S.Em.±	0.03
CD (P=0.05)	0.07
Biofertilizer	
B ₀ - Control	0.99
B ₁ – <i>Azotobacter</i>	1.25
S.Em.±	0.02
CD (P=0.05)	0.05

A critical analysis of data revealed that application of bio-fertilizer significantly influenced the chlorophyll content of leaves of sweet potato at 50 DAP. The maximum chlorophyll content (1.25 mg/g) recorded in treatment B₁ (*Azotobacter*), which was found significantly superior over control (0.99). The increase in chlorophyll content under the treatment B₁ was found to be 26.44 per cent higher as compared to control.

The interaction effect of different organic and inorganic sources of NPK and bio-fertilizers found to be non-significant pertaining to chlorophyll content in leaves.

4.2 Yield and yield attributes

4.2.1 Tuber length (cm)

Data presented in Table 4.7 and depicted in Fig 4.8 indicated that the length of tuber was significantly affected by organic and inorganic sources of NPK and bio-fertilizer.

The maximum length of tuber (16.62 cm) was recorded with 50% RDF + 50% vermicompost treatment, while minimum length (10.16 cm) under control. However, treatment I₅ was found statistically at par with treatment 50% RDF + 50% poultry manure. The increase in length of tuber under 50% RDF + 50% vermicompost was registered 63.58, 8.98, 17.71, 6.54, 10.43 and 11.17 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Application of bio-fertilizer significantly influenced the length of tuber of sweet potato. The maximum tuber length (17.05 cm) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control

(12.43 cm). The increase in length of tuber under the influence of treatment B₁ was found to be 37.21 per cent higher over control.

Table : 4.7 Effect of organic and inorganic source of NPK and biofertilizer on length of tuber, weight of tuber and diameter of tuber of sweet potato

Treatment	Length of tuber (cm)	Weight of tuber (g)	Diameter of tuber (cm)
Organic and inorganic sources of NPK			
I ₀ - Control	10.16	202.22	5.12
I ₁ - 100% RDF	15.25	258.45	9.12
I ₂ - 100% FYM	14.12	240.25	8.50
I ₃ - 50 % RDF + 50 % FYM	15.60	262.58	9.60
I ₄ - 100 % Vermicompost	15.05	251.15	8.85
I ₅ - 50 % RDF + 50 % VC	16.62	277.21	10.18
I ₆ - 100 % Poultry Manure	14.95	245.94	8.68
I ₇ - 50 % RDF + 50 % PM	16.18	269.65	9.85
S.Em.±	0.18	3.36	0.22
CD (P=0.05)	0.52	9.72	0.65
Biofertilizer			
B ₀ - Control	12.43	188.37	6.63
B ₁ – <i>Azotobacter</i>	17.05	313.49	10.84
S.Em.±	0.11	2.06	0.14
CD (P=0.05)	0.32	5.95	0.40

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on length of tuber

The data given in Table 4.8 and depicted in Fig 4.9 clearly indicates the influence of the combined effect of organic and inorganic sources of NPK and bio-fertilizer on length of tuber. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum length of tuber (19.23 cm), while the minimum tuber length (8.57 cm) was recorded under treatment combination I₀B₀. However, I₅B₁ treatment combination was statistically at par to I₇B₁ treatment combination, which was 18.72 cm.

Table : 4.8 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber length (cm) of sweet potato

Treatment	I₀	I₁	I₂	I₃	I₄	I₅	I₆	I₇	Mean
B ₀	8.57	12.86	11.91	13.15	12.69	14.01	12.61	13.64	12.43
B ₁	11.75	17.64	16.33	18.05	17.41	19.23	17.29	18.72	17.05
Mean	10.16	15.25	14.12	15.60	15.05	16.62	14.95	16.18	
SEm±			0.257						
CD (p=0.05)			0.742						

4.2.2 Tuber weight (g)

It is evident from the data presented in Table 4.7 and depicted in Fig 4.10 that the tuber weight was significantly affected by the application of organic and inorganic sources of NPK and bio-fertilizer in sweet potato.

The maximum weight of tuber (277.21 g) was recorded with 50% RDF + 50% vermicompost, while minimum tuber weight (202.22 g) control. However, treatment I₅ found statistically at par with 50% RDF + 50% poultry manure. The increase in tuber weight under 50% RDF + 50% vermicompost was registered 37.08, 7.26, 15.38, 5.57, 10.38 and 12.71 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Application of bio-fertilizer significantly influenced the tuber weight of sweet potato. The maximum tuber weight (313.49 g) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (188.37 g). The increase in tuber weight under the influence of treatment B₁ was found to be 66.42 per cent higher as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber weight

The data presented in Table 4.9 and depicted in Fig 4.11 clearly indicates significant effect of combined application of organic and inorganic sources of NPK and bio-fertilizer on tuber weight. Data indicated that the treatment combination I₅B₁ resulted in significantly higher tuber weight (346.32 g), while the minimum tuber weight (151.81 g) was recorded under treatment combination I₀B₀. However, I₅B₁ treatment combination was statistically at par to I₇B₁ treatment combination, which was 336.88 g.

4.2.3 Diameter of tuber (cm)

The data present in Table 4.7 and depicted in Fig 4.8 reflects significantly influence of organic and inorganic sources of NPK and bio-fertilizer on diameter of tuber.

Table : 4.9 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber weight (g) of sweet potato

Treatments	I ₀	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	Mean
B ₀	151.81	194.02	180.35	197.12	188.54	208.10	184.63	202.42	188.37
B ₁	252.63	322.88	300.15	328.04	313.76	346.32	307.25	336.88	313.49
Mean	202.22	258.45	240.25	262.58	251.15	277.21	245.94	269.65	
SEm±			4.76						
CD (p=0.05)			13.74						

The maximum diameter of tuber (10.18 cm) was recorded with 50% RDF + 50% vermicompost (I₅), while minimum diameter of tuber (5.12 cm) in control. However, the treatment I₅ found statistically at par with 50% RDF + 50% poultry manure and 50% RDF + 50% FYM. The increase in diameter of tuber under 50% RDF + 50% vermicompost was registered 98.83, 11.62, 19.76, 15.03 and 17.28 per cent more over I₀, I₁, I₂, I₄ and I₆, respectively.

Data indicated that application of bio-fertilizer significantly influenced the diameter of tuber. The maximum diameter of tuber (10.84 cm) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (6.63 cm). The increase in diameter of tuber under the treatment B₁ was found to be 63.57 per cent higher over control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on diameter of tuber

The data given in Table 4.10 and depicted in Fig 4.12 clearly indicates the significant trend of combined effect of organic and inorganic sources of NPK and bio-fertilizer on diameter of tuber. Data indicated that the treatment combination I₅B₁ resulted in significantly more diameter of tuber (12.64 cm), while the minimum diameter of tuber (3.89 cm) was recorded under treatment combination I₀B₀. However, I₅B₁ treatment combination found statistically at par to I₇B₁ treatment combination, which was 12.23.

Table : 4.10 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on diameter of tuber (cm) of sweet potato

Treatment	I ₀	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	Mean
B ₀	3.89	6.92	6.45	7.28	6.72	7.72	6.59	7.47	6.63
B ₁	6.35	11.32	10.55	11.92	10.98	12.64	10.77	12.23	10.84
Mean	5.12	9.12	8.50	9.60	8.85	10.18	8.68	9.85	
SEm±			0.32						
CD (p=0.05)			0.91						

4.2.4 Number of tubers per plot

A closer view of data presented in Table 4.11 and depicted in Fig 4.13 revealed that organic and inorganic sources of NPK and bio-fertilizers significantly influenced the number of tubers per plot.

The maximum number of tubers per plot (49.05) was recorded with 50% RDF + 50% vermicompost, while minimum number of tubers per plot (34.45) in control. The increase in number of tubers per plot under 50% RDF + 50% vermicompost was registered 42.38, 21.05, 34.68, 9.12, 20.72, 27.44 and 5.14 per cent higher over I₀, I₁, I₂, I₃, I₄, I₆ and I₇ respectively.

Application of bio-fertilizer significantly influenced the number of tubers per plot. The maximum number of tubers per plot (43.08) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (38.00). The increase in number of tubers under the influence of treatment B₁ was found to be 8.47 per cent higher as compared to control.

The interaction effect of organic and inorganic sources of NPK and bio-fertilizer was found to be non-significant pertaining to number of tubers per plot.

4.2.5 Tuber yield (kg/plot)

The data presented in Table 4.11 and depicted in 4.14 revealed that application of organic and inorganic sources of NPK and bio-fertilizer significantly influenced the tuber yield of sweet potato.

The maximum tuber yield (13.73 kg) recorded with 50% RDF + 50% vermicompost, while minimum tuber yield (7.04 kg) in control. The increase in tuber yield under 50% RDF + 50% vermicompost was registered 95.18, 29.84, 55.40, 15.20 33.25, 43.64 and 8.09 per cent more over I₀, I₁, I₂, I₃, I₄, I₆ and I₇ respectively.

Application of bio-fertilizer significantly influenced the tuber yield. The maximum tuber yield (13.62 kg) was recorded with treatment B₁ (*Azotobacter*),

which was found significantly superior over control (7.55 kg). The increase in tuber yield under the influence of treatment B₁ was found to be 80.51 per cent higher as compared to control.

Table : 4.11 Effect of organic and inorganic sources of NPK and biofertilizer on number of tubers and tuber yield of sweet potato

Treatment	Number of tubers	Tuber yield (kg/plot)	Tuber yield (q/ha)
Organic and inorganic sources of NPK			
I ₀ - Control	34.45	7.04	130.32
I ₁ - 100% RDF	40.52	10.58	195.90
I ₂ - 100% FYM	36.42	8.84	163.68
I ₃ - 50 % RDF + 50 % FYM	44.95	11.92	220.79
I ₄ - 100 % Vermicompost	40.63	10.31	190.88
I ₅ - 50 % RDF + 50 % VC	49.05	13.73	254.35
I ₆ - 100 % Poultry Manure	38.49	9.56	177.08
I ₇ - 50 % RDF + 50 % PM	46.65	12.71	235.31
S.Em.±	0.37	0.31	5.66
CD (P=0.05)	1.07	0.88	16.34
Biofertilizer			
B ₀ - Control	39.71	7.55	139.77
B ₁ – <i>Azotobacter</i>	43.08	13.62	252.30
S.Em.±	0.23	0.19	3.46
CD (P=0.05)	0.66	0.54	10.00

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per plot

The data presented in Table 4.12 and depicted in Fig 4.15 clearly indicated significant effect of combined application of organic and inorganic sources of NPK and bio-fertilizer on tuber yield. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum tuber yield (17.68 kg), while the minimum tuber yield (5.02 kg) was recorded under treatment combination I₀B₀.

Table : 4.12 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield (kg) per plot of sweet potato

Treatment	I₀	I₁	I₂	I₃	I₄	I₅	I₆	I₇	Mean
B ₀	5.02	7.54	6.30	8.50	7.35	9.79	6.82	9.06	7.55
B ₁	9.06	13.61	11.38	15.34	13.27	17.68	12.31	16.35	13.62
Mean	7.04	10.58	8.84	11.92	10.31	13.73	9.56	12.71	
SEm±			0.43						
CD (p=0.05)			1.25						

4.2.6 Tuber yield (q/ha)

A critical review of data presented in Table 4.11 and depicted in Fig 4.16 revealed that application of organic and inorganic sources of NPK and bio-fertilizer significantly influenced tuber yield of sweet potato.

The maximum tuber yield (254.35 q) recorded with 50% RDF + 50% vermicompost, while minimum tuber yield (130.32 q) in control. The increase in tuber yield under treatment 50% RDF + 50% vermicompost was registered 95.18, 29.84, 55.40, 15.20 33.25, 43.64 and 8.09 per cent more over I₀, I₁, I₂, I₃, I₄, I₆ and I₇ respectively.

Application of bio-fertilizer significantly influenced the tuber yield. The maximum tuber yield (252.30 q) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (139.77 q). The increase in tuber yield under the treatment B₁ was found to be 80.51 per cent higher as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per hectare

The data presented in Table 4.13 and depicted in Fig 4.16 clearly indicates the significant effect of combined application of organic and inorganic sources of NPK and bio-fertilizer on tuber yield. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum tuber yield (327.35 q), while the minimum tuber yield (92.91q) was recorded under treatment combination I₀B₀.

Table : 4.13 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on tuber yield per hectare of sweet potato

Treatment	I ₀	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	Mean
B ₀	92.91	139.67	116.70	157.42	136.09	181.35	126.25	167.77	139.77
B ₁	167.72	252.12	210.65	284.16	245.67	327.35	227.90	302.84	252.30
Mean	130.32	195.90	163.68	220.79	190.88	254.35	177.08	235.31	
SEm±			8.00						
CD (p=0.05)			23.10						

4.3 Quality attributes

4.3.1 TSS (%)

It is clear from the data mentioned in Table 4.14 and depicted in Fig 4.18 that the organic and inorganic sources of NPK and bio-fertilizer significantly influenced the TSS content (%) of tubers of sweet potato.

The maximum TSS content (4.62%) was recorded with 50% RDF + 50% vermicompost, while minimum TSS content (3.75%) in control. However, treatment I₅ was statistically at par with 50% RDF + 50% poultry manure. The increase in TSS content under 50% RDF + 50% vermicompost was registered 23.20, 11.33, 16.08, 7.44, 11.86 and 14.36 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Table : 4.14 Effect of organic and inorganic sources of NPK and biofertilizer on TSS, protein and starch content in sweet potato tubers

Treatment	TSS (%)	Protein (%)	Starch (%)
Organic and inorganic sources of NPK			
I ₀ - Control	3.75	1.35	10.25
I ₁ - 100% RDF	4.15	1.98	12.65
I ₂ - 100% FYM	3.98	1.62	12.26
I ₃ - 50 % RDF + 50 % FYM	4.30	2.02	12.85
I ₄ - 100 % Vermicompost	4.13	1.88	12.58
I ₅ - 50 % RDF + 50 % VC	4.62	2.23	13.75
I ₆ - 100 % Poultry Manure	4.04	1.78	12.49
I ₇ - 50 % RDF + 50 % PM	4.55	2.10	13.28
S.Em.±	0.09	0.07	0.30
CD (P=0.05)	0.27	0.19	0.87
Biofertilizer			
B ₀ - Control	3.67	1.72	11.42
B ₁ – <i>Azotobacter</i>	4.71	2.02	13.60
S.Em.±	0.06	0.04	0.18
CD (P=0.05)	0.17	0.12	0.53

Application of bio-fertilizer significantly influenced the TSS content. The maximum TSS content (4.71%) recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (3.67%). The increase in

TSS content under the treatment B₁ was found to be 28.57 per cent higher as compared to control.

The interaction effect of combined application of organic and inorganic sources of NPK and bio-fertilizer found to be non-significant pertaining to TSS content.

4.3.2 Starch (%)

An examination of data given in Table 4.14 and depicted in Fig 4.18 indicated that starch content in tuber significantly increased under the influence of organic and inorganic sources of NPK and bio-fertilizer.

The maximum starch content (13.75%) recorded with 50% RDF + 50% vermicompost, while minimum starch content (10.25%) in control. However, treatment I₅ was statistically at par with 50% RDF + 50% poultry manure. The increase in starch content under 50% RDF + 50% vermicompost was registered 34.15, 8.70, 12.15, 7.00, 9.30 and 10.09 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Application of bio-fertilizer significantly influenced the starch content of sweet potato tubers. The maximum starch content (13.60%) recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (11.42%). The increase in starch content under the influence of treatment B₁ was found to be 19.10 per cent higher as compared to control.

The interaction effect of combined application of organic and inorganic sources of NPK and bio-fertilizers found to be non-significant.

Table : 4.15 Effect of organic and inorganic sources of NPK and biofertilizer on net returns and B:C ratio of sweet potato

Treatment	Net returns (₹/ha)	B:C ratio
Organic and inorganic sources of NPK		
I ₀ - Control	81043	1.07
I ₁ - 100% RDF	154022	1.90
I ₂ - 100% FYM	111076	1.30
I ₃ - 50 % RDF + 50 % FYM	181749	2.18
I ₄ - 100 % Vermicompost	140522	1.59
I ₅ - 50 % RDF + 50 % VC	220424	2.60
I ₆ - 100 % Poultry Manure	127156	1.49
I ₇ - 50 % RDF + 50 % PM	199173	2.39
S.Em.±	5829	0.07
CD (P=0.05)	16835	0.20
Biofertilizer		
B ₀ - Control	84476	1.01
B ₁ – <i>Azotobacter</i>	219315	2.62
S.Em.±	3569	0.04
CD (P=0.05)	10309	0.12

4.3.3 Protein content (%)

The analysis of data present in Table 4.14 and depicted in Fig 4.18 indicated that protein content in sweet potato tubers increased significantly with the application of organic and inorganic sources of NPK and bio-fertilizer.

The maximum protein (2.23%) content was recorded with 50% RDF + 50% vermicompost, while minimum protein (1.35%) content in control. However, treatment I₅ was statistically at par with 50% RDF + 50% poultry manure. The increase in protein content under 50% RDF + 50% vermicompost was registered 65.19, 12.63, 37.65, 10.40, 18.62 and 25.28 per cent more over I₀, I₁, I₂, I₃, I₄ and I₆, respectively.

Table : 4.16 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on net returns (Rs./ha) of sweet potato

Treatment	I ₀	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	Mean
B ₀	36260	86650	54803	105805	74878	132920	66267	118228	84476
B ₁	125827	221393	167350	257693	206166	307927	188045	280118	219315
Mean	81043	154022	111076	181749	140522	220424	127156	199173	
SEm±			8243						
CD (p=0.05)			23808						

Application of bio-fertilizer significantly influenced the protein content of sweet potato tubers. The maximum protein (2.02%) content was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (1.72%). The increase in protein content under the influence of treatment B₁ was found to be 17.65 per cent higher as compared to control.

The interaction effect of combined application of organic and inorganic sources of NPK and bio-fertilizer found to be non-significant as far as protein content is concerned in sweet potato tubers.

4.4 Economics

4.4.1 Net returns

The analysis of the data presented in Table 4.15 and depicted in Fig 4.19 indicated that net returns per hectare of sweet potato increased significantly with the application of organic and inorganic sources of NPK and bio-fertilizer.

The maximum net returns of ₹ 220424 was recorded with 50% RDF + 50% vermicompost, while minimum net returns of ₹81043 was recorded under control. The increase in net returns under 50% RDF + 50% vermicompost was registered 171.98, 43.11, 98.44, 21.28, 56.86, 73.35 and 10.67 per cent more over I₀, I₁, I₂, I₃, I₄, I₆ and I₇, respectively.

Table : 4.17 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on B:C ratio of sweet potato

Treatment	I ₀	I ₁	I ₂	I ₃	I ₄	I ₅	I ₆	I ₇	Mean
B ₀	0.48	1.07	0.64	1.27	0.85	1.57	0.78	1.42	1.01
B ₁	1.67	2.73	1.96	3.09	2.33	3.63	2.20	3.36	2.62
Mean	1.07	1.90	1.30	2.18	1.59	2.60	1.49	2.39	
SEm±			0.10						
CD (p=0.05)			0.28						

Application of bio-fertilizer significantly influenced the net returns. The maximum net returns of ₹ 219315 were recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over control (₹ 84476). The increase in net returns under the influence of treatment B₁ was found to be 159.62 per cent higher as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on net returns

The data given in Table 4.16 and depicted in Fig 4.20 clearly reflects significant effect of combined use of organic and inorganic sources of NPK and bio-fertilizer on net returns. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum net returns of ₹ 307927, while the minimum net returns of ₹ 36260 was recorded under treatment combination I₀B₀.

4.4.2 B:C Ratio

The perusal of data (Table 4.15 and Fig 4.21) showed that application of organic and inorganic sources of NPK and bio-fertilizer significantly influenced the B:C ratio.

The maximum B:C ratio (2.60) was recorded with 50% RDF + 50% vermicompost, while minimum B:C ratio (1.07) recorded under control. The increase in B:C ratio in 50% RDF + 50% vermicompost treatment combination was registered 141.70, 36.81, 99.73, 18.99, 63.79, 74.47 and 8.58 per cent more over I₀, I₁, I₂, I₃, I₄, I₆ and I₇, respectively.

Application of bio-fertilizer significantly influenced the benefit cost ratio of sweet potato crop. The maximum B:C ratio (2.62) was recorded with treatment B₁ (*Azotobacter*), which was found significantly superior over

control(1.01). The increase in B:C ratio under the influence of treatment B₁ was found to be 159.32 per cent higher as compared to control.

Interactive effect of organic and inorganic sources of NPK and bio-fertilizer on B:C ratio

The perusal of data (Table 4.17 and Fig 4.22) clearly indicates significant effect of combined application of organic and inorganic sources of NPK and bio-fertilizer on B:C ratio. Data indicated that the treatment combination I₅B₁ resulted in significantly maximum B:C ratio (3.63), while the minimum B:C ratio (0.48) was recorded under treatment combination I₀B₀. However, I₅B₁ treatment combination was statistically at par to I₇B₁, which was 3.36.

Chapter-5

Discussion

The results of field experiment entitled “**Effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of sweet potato (*Ipomoea batatas* Lam.)**” have been presented in this chapter. It is endeavored to discuss the significant findings or those assuming a definite pattern in respect of various parameters studied so as to establish cause and effect relationship in light of existing evidences and available references.

5.1 Effect of organic and inorganic sources of NPK on Growth, Yield and Quality

The results of present investigation revealed that organic and inorganic sources of NPK resulted in significant increase and the maximum vine length, number of branches per vine, leaf area at 45 DAP and leaf area index and chlorophyll content at 50 DAP were observed with 50 % RDF + 50 % vermicompost, which was significantly higher over control, 100 % RDF, 100 % FYM, 50 % RDF + 50 % FYM, 100 % vermicompost and 100 % poultry manure, but statistically at par with 50 % RDF + 50 % poultry manure (Table 4.1, 4.4 and 4.6).

In the present investigation, significant increase was observed in vine length, number of branches and number of leaves per plant with different sources of organic and chemical fertilizers. Similarly, findings are also reported by Cortez jaun *et al.*, (2010) and Maurya and Muthoo (1986). They explained that organic manures not only slowly releases the nutrients from itself but also prevents losses of chemical fertilizers through denitrification, volatilization and leaching by binding the nutrients and releasing for crop use with the passage of time. The findings of the present study clearly indicated that vermicompost played a significant role in enhancing the growth of sweet potato. The beneficial

effect of vermicompost on plant growth might be attributed to the fact that the earthworms mineralized the macro and micronutrients during vermicomposting and made available to crop plants for longer period. In addition, also improved soil structure, aeration and water holding capacity of the soil. These results are in close conformity with the findings of Vanmathi and Selvakumari (2012) and Yadav and Vijayakumari (2003).

The application of poultry manure also enhanced the vegetative growth of sweet potato, which might be due to higher nutrient content, rapid mineralization, optimum C/N ratio and more availability of nitrogen, leading to better growth and yield. Addition of poultry manure also helps in reduction in soil pH due to liberation of CO₂ and organic acids during decomposition and the decomposition product may give rise to naturally complexing agents and also increases soil biomass which solublizes the native soil nutrients in available form for the plants. These results are in agreement with findings of Anjali *et al.*, (2006) and Makinde and Ayoola (2012).

Poultry manure might have provided nutrients to the the plant in readily available form for easy absorption by the plant roots, hence there was a boost in the morphological growth of the plant (Onwu *et al.* 2014).

The increase in plant growth attributes with the application of poultry manure and vermicompost might be due to the fact that organic manures not only provided nutrients to the plant but also improved the physical condition of soil in respect of granulation, friability, porosity and developed a balanced nutritional environmental in both soil *rhizosphere* and plant system. The increase in plant growth characters with the application of vermicompost, poultry manure *and azotobacter* in combination with 50% or 100% RDF might be due to better availability of plant nutrients and maintenance of balanced C:N ratio throughout the growing period of the crop (Marimuthu *et al.*, 2002 and Surrender Rao and Sitaramaya, 2000).

The integration of organic manures in combination with inorganic fertilizers was found significant in improving the overall plant growth, yield and soil macro nutrient status than the sole application of either of these nutrients. The combined use of organic and inorganic nutrients might improved in solubilization of plant nutrients that lead to increased uptake of NPK. Combined application of organic and inorganic sources of NPK reduces the nutrient losses, improve fertilizer use efficiency and thereby increased soil nutrient availability for the plants (Prativa and Bhattarai, 2011).

The better efficiency of organic and inorganic sources of NPK might be due to the fact that the organic manures would have provided the micronutrients in an optimum range to the plant. Application of organic manures would have helped in enhancing the metabolic activities in the plant system through the supply of such important micronutrients in the early growth phase which in turn must have encouraged the overall growth of the vines per plant. This is in close conformity with the findings of Alam (2006) and Azad (2000), who have also reported highest plant growth due to the combined application of organic manures and chemical fertilizers in tomato.

Application of 50 % RDF + 50% vermicompost significantly increased yield attributes viz. tuber length and tuber weight over control, 100 % RDF, 100 % FYM, 50 % RDF + 50 % FYM, 100 % vermicompost and 100 % poultry manure but statistically at par with 50 % RDF + 50 % poultry manure (Table 4.7).

Significant increases in number of tubers per plot, tuber yield per plot and tuber yield per hectare was observed due to application of 50 % RDF + 50 % vermicompost over the rest of treatments but in case of tuber diameter 50 % RDF + 50 % vermicompost was statistically at par with 50 % RDF + 50% poultry manure and 50 % RDF + 50 % FYM (Table 4.7 and 4.11).

Such increase in yield and yield attributes with the application of vermicompost and poultry manure with integration of 50% and 100% RDF

might be due to better utilization of nutrients like nitrogen for reproductive growth rather than for vegetative growth (Gowda *et al.*, 1979). The increases in yield and yield attributes might be due to various plant metabolic processes that resulted in more production of carbohydrates due to higher uptake of nitrogen and ultimately helped in increasing yield and quality of sweet potato tubers.

The beneficial effect of vermicompost on yield and yield attributes might be attributed to its ability to provide nutrients throughout the growing season. The availabilities of balanced C:N ratio might have increased the synthesis of carbohydrates with ultimate improvement in yield and yield attributes. These findings are in conformity with the finding of Sharma *et al.*, (2009), Sharma *et al.*, (2010) and Yadav and Yadav (2010).

The increase in yield and yield attributes with poultry manure might be because of rapid availability and utilization of nitrogen for various internal plant processes for production of carbohydrates. Later on these carbohydrates undergo hydrolysis and get converted into sugars which ultimately helped in increasing yield with better quality. These results are in accordance with the findings of Meerabai *et al.*, (2007).

The supply of NPK and other nutrients through the organic and inorganic sources, increases the proportion of carbohydrate used in vegetative part of plant while proportion of translocation to the root decreases. On the other hand, the increase in leaf: root ratio could be due to the auxin effect. The concentration of auxin released by organic fertilizers might have influence on plants. The concentration of auxin is much lower for roots than for tops, so that between these two critical values an increasing concentration of auxin tends to inhibit root growth and promotes top/vegetative growth. These findings are in accordance with the results obtained by Joshi and Patil (1992) and Asghar *et al.*, (2006).

The increase in yield might be due to sustained availability of nutrients throughout the growing phase and also due to enhanced carbohydrate

synthesis and effective translocation of photosynthates to sink *i.e.* tuber. The proportion and activity of beneficial microbes would have been at the higher rate during fermentation and thus helped in synthesis of growth substances, which might have resulted in better yield. These findings are in conformity with the results obtained by Velmurugan *et al.*, (2005).

Application of 50 % RDF and 50 % vermicompost significantly enhanced the TSS, starch and protein content in sweet potato tubers over control, 100 % RDF, 100 % FYM, 50 % RDF + 50 % FYM, 100 % vermicompost and 100 % poultry manure, but statistically at par with 50 % RDF + 50 % poultry manure (Table 4.14). This increase in above parameters in sweet potato tubers may be due to creation of better nutritional environment in the root zone of the crop as a result of solubilization of organic matter and chelation of available nutrients, for growth and development of the vines. It may also be due to the increased activity of nitrate reductase enzyme and enhanced synthesis of certain amino acids and protein as reported by Ramesh *et al.*, (2006). The increase in protein, starch, TSS, nitrogen, phosphorus and potassium content in tubers of sweet potato by application of multi nutrient combination might be due to the improved translocation of nitrogenous compounds and nutrients from various plant parts to tubers and synthesis of common precursor of chlorophyll and ammonia assimilating enzymes.

Desuki *et al.*, (2005) also reported that improvement in fresh and dry weight of root could be due to the fact that the organic fertilizers carry almost all micro and macronutrients required for plant growth.

It is an established fact that organic manures not only improve chemical, physical and biological properties of soil but also play a vital role in increasing soil water holding capacity. The balanced nutritional environment of the soil with sufficient soil moisture content might have helped in better uptake of nutrients and ultimately into higher protein content in the tubers. Furthermore, the application of organic manures coupled with 50 % RDF might have maintained optimum level of nutrients and better soil environment due to which

inherent nutrients supplying capacity of soil get improved and also complexing of nutrient and flux of availability of nutrients on autolysis of microbial cells (Shuman and Hargrover, 1985).

Total soluble solids and crude protein content in potato tuber is a function of the amount of pectin, which is related to the ability to take up nutrients and convert sucrose to carbohydrate in the tuber (Kandil *et al.*, 2011). The increase in TSS content of sweet potato tubers by the addition of manures might be due to better availability of nutrients in addition to nitrogen and phosphorus fertilizers which in turn improved the fresh bio mass production of tubers through increased nutrients uptake by the plant. Similar results with respect to the increase in TSS content of tubers at the time of harvest due to combined application of inorganic fertilizer and organic manure was also reported by Kandil *et al.*, (2011), Islam *et al.*, (2013), Chatterjee *et al.*, (2008), Fatideh and Asil (2012), Hailu *et al.*, (2008). The high crude protein content might be due to higher nitrogen content in tubers in these treatments as cattle manure supplements additional nitrogen to the soil and ultimately the uptake of nitrogen by the plant get improved. These results in accordance with findings of Raupp, (1996), Honeycutt (1998). Bartova *et al.*, (2008) and Ozturk *et al.*, (2010).

In addition to this, it could be due to better availability of required nutrients in the crop root zone resulting from its solubilization by the organic acids produced from the decomposed cattle manure and also the increased uptake by sweet potato roots due to their association with mycorrhizal filaments. Moreover, application of manures to the soil may provide K which may be attributed to the vital role in physiological processes inside the plant, enzymatic activities, water absorption and transpiration that reflected on N-accumulation. These results are in accordance with those reported by El-Sirafy *et al.*, (2008), Ghosh *et al.*, (2000), White *et al.*, (2009). Taheri *et al.*, (2011). These scientists also reported that fertilizers and manure in the soil increases phosphorus uptake by plants and hence, phosphorus play significant role in physiological and biochemical reactions such as photosynthesis, translocation and conversion sugars into starch in the plants.

5.2 Effect of Bio-fertilizers on Growth, Yield and Quality

The results of present investigation showed that the vegetative growth characters such as vine length, number of branches per vine at 45 DAP, leaf area at 45 DAP, leaf area index, chlorophyll content at 50 DAP as well as yield and quality attributes tuber length, tuber weight, diameter of tuber, number of tubers per plot, yield per plot and per hectare, TSS, starch and protein content in sweet potato tubers significantly increased by the application *Azotobacter* over the control.

These findings clearly indicate that *Azotobacter* played a significant role in enhancing the growth attributes of sweet potato vines. *Azotobacter* liberate growth promoting substances and vitamins and helps to maintain soil fertility. *Azotobacters* are free-living bacteria that fix atmospheric nitrogen in vegetable crops without any symbiosis and they do not need a specific host plant. (Jnawali *et al.*, 2015).

Azotobacter has beneficial effect on crop growth and yield through, biosynthesis of biologically active substances, stimulation of rhizospheric microbes and producing phytopathogenic inhibitors, modification of nutrient uptake and ultimately boosting biological nitrogen fixation in the plants. The presence of *Azotobacter sp.* in soils has beneficial effects on plants, but the abundance of these bacteria is related to many factors such as soil physico-chemical (e.g. organic matter, pH, temperature, soil moisture) and microbiological properties. Its abundance varies with the depth of the soil profile. *Azotobacter* is much more abundant in the rhizosphere of plants that is surrounding the soil around the plant roots and this abundance also depends on the crop species. (Jnawali *et al.*, 2015).

The increase in TSS, protein and starch content in sweet potato tubers due to *Azotobacter* application over control seems to be due to its ability to increase the availability of nutrients, which in turn increased the TSS, starch and protein content in sweet potato tubers.

These beneficial effects of *Azotobacter* on plants attributed to an improvement in root development, an increase in the rate of water and mineral uptake by roots, displacement of fungi and plant pathogenic bacteria and, to a lesser extent, biological nitrogen fixation. Besides N₂ fixation, *Azotobacter* synthesizes and secretes considerable amounts of biologically active substances like vitamins B, nicotinic acid, pantothenic acid, biotin, heteroxins, gibberelins *etc.* which enhances root growth of the plants. Another important characteristic of *Azotobacter* association with crop improvement is secretion of ammonia in the rhizosphere in presence of root exudates, which helps in modification of nutrient uptake by the plants. The ability of *Azotobacter* to produce plant growth regulatory substances along with N₂ fixation stimulate plant growth, productivity and quality. The changes that occur in the plant roots help in better transport of minerals and water in the plant system. All these factors produce positive effects on crop yield especially for vegetables and cereals (Ramakrishnan and Selvakumar, 2012).

Interactive effect of different organic and inorganic sources of NPK and bio-fertilizer

Combined application of organic and inorganic sources of NPK and bio-fertilizer significantly enhanced the plant growth, yield and quality attributes *viz.*, vine length, leaf area, number of branches per vine, tuber length, tuber weight, diameter of tuber, tuber yield per plot, tuber yield per hectare, net returns and B:C ratio.

The significant increase in these attributes under the influence of application of organic and inorganic sources of NPK along with inoculation with bio-fertilizer (*Azotobacter*) was largely a function of improved growth and subsequent increase in yield and other yield attributes as described above. The interactive advantage of combined application of organic and inorganic sources of NPK and bio-fertilizer generally proved superior over the use of each component alone. These results of the present study clearly indicated that 50 % RDF + 50 % vermicompost applied with *Azotobacter* played a significant role

in enhancing the growth of sweet potato.

The use of biofertilizer in integration with organic and inorganic sources of NPK helps in safeguarding the soil health and also improves the quality of crop products. They activate soil biologically and restore natural soil fertility and also provide protection against some soil born diseases, with replacing of chemical nitrogen and phosphorus by 25 per cent. A synergistic interaction between organic manures and biofertilizers has resulted in enhanced production of growth promoting substances like gibberellic acid, indole acetic acid and dihydrozeatin which have positive influence on the physiological processes in plant system (Prasad *et al.*, 2016 and Eid and El-sayed 2012), resulting in enhanced vine length, leaf area, number of branches per vine, tuber length, tuber weight, diameter of tuber, and ultimately increased tuber yield (Farzana and Radizah 2005 and Yassin *et al.*, 1994).

5.3 Economics feasibility of the treatments

Among different organic and inorganic sources of NPK and bio-fertilizer alone and in combination, significantly maximum net returns of Rs. 220424 ha⁻¹ and B:C ratio 2.60:1 was obtained by application of 50 % RDF + 50 % vermicompost. Similarly, application of *Azotobacter* as vine inoculation also fetched significantly maximum net returns of Rs. 219315 ha⁻¹ and B:C ratio 2.62:1 (Table 4.15).

Interactive effect of 50 % RDF + 50 % vermicompost along with *Azotobacter* (I₅B₁) obtained maximum net return of Rs. 307927 ha⁻¹ and B:C ratio 3.63.

Chapter-6

SUMMARY AND CONCLUSION

Results of the field experiment entitled “**Effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of Sweet potato (*Ipomoea batatas* Lam.)**” presented and discussed in the preceding chapter are summarized as under.

6.1 Effect of organic and inorganic sources of NPK

6.1.1 Application of 50 % RDF + 50 % vermicompost recorded maximum vine length at 45 DAP (80.65 cm), which was statistically at par to 50 % RDF + 50 % poultry manure, while this parameter was recorded minimum (51.24 cm) under control.

6.1.2 The maximum number of branches per vine at 45 DAS (5.99) was recorded with 50 % RDF + 50 % vermicompost, which was statistically at par to 50 % RDF + 50 % poultry manure, while this parameter was recorded minimum (3.60) under control.

6.1.3 Application of 50 % RDF + 50 % vermicompost recorded significantly maximum values for leaf area at 45 DAP (14850.20 cm²) and leaf area index (11.00), which were statistically at par to 50 % RDF + 50 % poultry manure, while these parameters were recorded minimum (7025.45 cm² and 5.20) value under control.

6.1.4 Application of 50 % RDF + 50 % vermicompost resulted significantly maximum chlorophyll content in leaves at 50 DAP (1.23 mg/g), which was statistically at par to 50 % RDF + 50 % poultry manure, while this parameter was recorded minimum (0.88 mg/g) value under control.

- 6.1.5 Application of 50 % RDF + 50 % vermicompost recorded significantly maximum values for tuber length (16.62 cm) and tuber weight (277.21 g), which were statistically at par to 50 % RDF + 50 % poultry manure, while minimum value for these parameters recorded under control.
- 6.1.6 The significant maximum diameter of tuber (10.18 cm) was obtained in 50 % RDF + 50 % vermicompost treatment, which was statistically at par to 50 % RDF + 50 % poultry manure and 50 % RDF + 50 % FYM, while minimum value recorded under control.
- 6.1.7 The significant maximum number of tubers (49.05), tuber yield per plot (13.73 kg) and tuber yield per hectare (254.35 q) were recorded under 50 % RDF + 50 % vermicompost treatment and minimum in control.
- 6.1.8 Application of 50 % RDF + 50 % vermicompost recorded significant maximum protein (2.23 %), TSS (4.62 %) and starch (13.75 %) content in sweet potato tubers, which was statistically at par to 50 % RDF + 50 % poultry manure and 50 % RDF + 50 % FYM and minimum in control.
- 6.1.9 Significantly higher net returns of ₹ 220424 ha⁻¹ and B:C ratio 2.60:1 were recorded with the application of 50 % RDF + 50 % vermicompost and minimum in control.

6.2 Effect of Bio-fertilizer

- 6.2.1 Application of *Azotobacter* recorded maximum vine length at 45 DAP (82.87 cm) and minimum in control.

- 6.2.2 The maximum number of branches per vine at 45 DAP (5.01) was recorded with *Azotobacter*, while this parameter was recorded minimum under control.
- 6.2.3 Application of *Azotobacter* resulted significantly maximum chlorophyll content in leaves (1.25 mg/g) and minimum in control.
- 6.2.4 Application of *Azotobacter* resulted significantly maximum leaf area (11808.52 cm²) and leaf area index (8.75), while minimum value for these parameter were recorded under control.
- 6.2.5 Application of *Azotobacter* recorded significantly maximum values for tuber length (17.05 cm), tubers weight (313.49 g), diameter of tuber (10.84 cm) and number of tubers per plot (43.08), while all these characters recorded minimum value under control.
- 6.2.6 The significant maximum tuber yield per plot (13.62 kg) and tuber yield per hectare (252.30 q) with *Azotobacter*, while minimum of these characters recorded under control.
- 6.2.7 Application of *Azotobacter* recorded significantly maximum protein (2.02 %), TSS (4.71 %) and starch (13.60 %) content in sweet potato tubers, while minimum of these characters recorded under control.
- 6.2.8 Significantly higher net returns of ₹ 219315 ha⁻¹ and B:C ratio 2.62:1 recorded with the application of *Azotobacter*, whereas minimum were recorded under control.

6.3 Interactive effect of organic and inorganic sources of NPK and bio-fertilizer

Combined application of 50 % RDF + 50 % vermicompost with *Azotobacter* (I_5B_1) recorded significantly maximum vine length (97.06 cm), number of branches per vine (6.39), leaf area (16609.30 cm²), tuber length (19.23 cm), tuber weight (346.32 g), diameter of tuber (12.64 cm), tuber yield per plot (17.68 kg), tuber yield per hectare (327.35 q), net returns (₹ 307927/ha) and B:C ratio (3.63:1). However, it was at par with I_7B_1 , combination in case of vine length, number of branches per vine, tuber length, tuber weight, diameter of tuber and B:C ratio. Whereas as minimum growth, yield and quality attributes were recorded in control (I_0B_0).

CONCLUSION

On the basis of results obtained in present investigation, the application of 50 % RDF + 50 % vermicompost along with *Azotobacter* (I_5B_1) proved to be the most superior treatment in terms of the highest tuber yield (327.35 q ha⁻¹), net return (Rs. 307927 ha⁻¹) and B:C ratio (3.63) of sweet potato. Therefore, the sweet potato growers are advised to apply 50 % RDF + 50 % vermicompost along with *Azotobacter* to get higher yield of better quality and fetch better returns per unit area. However, the results are indicative and requires further experimentation to arrive at more consistent results.

BIBLIOGRAPHY

- A.O.A.C. 1980. Official method of analysis 13th Edn. Association of Official Agricultural Chemists, Washington.
- A.O.A.C.1960. Official Method of Analysis, 18 Edn. Association of Official Agricultural Chemists, 1608. Broadnon Drive, Champaign, Illinois, USA.
- Abusaleha and Shanmugavelu, K.G. 1988. Studies on the effect of organic v/s inorganic source of nitrogen on growth yield and quality of okra (*Abelmoschus esculentus* (L.) Monech). *Indian Journal of Horticulture*, 45(3-5) : 312-318.
- Adejobi, S.K. and Odeniyi, S.O. 2006. Comparative effect of poultry manure and NPK fertilizer on growth, yield and nutrient content of sweet potato (*Ipomoea batatas* L.). <http://hdl.handle.net/123456789/1329>.
- Agyarko, K., Dapaah, H.K., Buah, S. and Frimpong, K.A. 2014. Sweet potato (*Ipomoea batatas*) yield parameters, soil chemical properties and cost benefit ratios following incorporation of poultry manure and inorganic NPK fertilizers in low nutrient Ghanaian soils. *International Journal of Plant and Soil Science*, 3 (2) : 129-138.
- Ahamad, S., Dagar, J.C. and Mani, D. 2014. Impact of FYM and potassium interactions on potato yield multivated on moderate saline soils. *Journal of Soil Salinity and Water Quality*, 6 (1) : 59-63.
- Ahmed, A., Sambo, B.E., Arunah, U.L and Odion, E.C. 2014. Response of farm yard manure and inorganic fertilizers for sustainable growth of carrot (*Daucus carota* L.) in Northern Nigeria. *Journal of Agriculture and Veterinary Science*, 7 (2): 18-25.
- Alfred, E. and Hartemink 2003. Integrated nutrient management research with sweet potato in Papua New Guinea. *Outlook on Agriculture*, 32 (3) : 173 – 183.

- Ali, M.B., Lakun, H. I., Sani, S. M. and Adamu,H.M. 2014. Effect of organic manure and sowing date on the growth and yield of okra (*Abelmoschus esculentus*) in Samaru, Nigeria. *International Journal of Agronomy and Agricultural Research*, 5(5): 111-117.
- Aliyo, L. 2000. Effect of organic and mineral fertilizers on growth, yield and composition of pepper (*Capsicum annum*). *Biological Agriculture and Horticulture*, 18(1): 29-36.
- Allolli, T.B., Athani, S.L and Imamasahed, S.J. 2011. Effect of integrated nutrient management on yield and economics of sweet potato. *Asian Journal of Horticulture*, 6: 218 – 220.
- Alphonse, M. and Shaad, E.M. 2000. Growing green house cucumber in FYM and chicken manure media in combination with foliar application of zinc, boron and mangnease. *Egyptian Journal of Horticulture*, 27(3): 315-356.
- Anjali, D., Warade, S.D., Anarse, S.A., Rashmi Bhoge and Amolic, V. L. 2006. Effect of organic manures on growth, yield and keeping quality of okra (*Abelmoschus esculentus* L.) cv. Phule Kirti. *Annual Review of Plant Physiology*, 20(1) : 65-68
- Anonymous, 2003. Sweet potato treasure for the poor in Lima, Peru. International Potato Center : 25.
- Anonymous, 2016. Indian Horticulture Database-2016. National Horticultural Board, Gurgaon.
- Antoinette, S A., Emmanuel, K. A., Kofi, A. and Harrison, K.D. 2013. Growth and yield of okra (*Abelmoschus esculentus*) as affected by organic and inorganic fertilizers. *ARPJN Journal of Agricultural and Biological Science*, 8(12): ISSN 1990-6145.
- Arkeri, H.R., Chalan, G.V., Satyanarayan, P. and Dona-hue, R.L. 1956. Soil management in India. *Asian Publishing house*, Bombay.

- Arnon, D.I. 1949. Copper enzymes in isolated chloroplast polyphenol oxidase in *Beta vulgaris*. *Physiology*, 24 : 1-5.
- Asghar, H.N., Ishaq, Z.A., Zahir, Z.A., Khalid, M. and Arshad, M. 2006. Response of radish to integrated use of nitrogen fertilizer and recycled organic waste. *Pakistan Journal of Botany*, 38 (3) : 691-700.
- Aswani, G., Paliwal, R. and Sarolia, D.K. 2005. Effect of nitrogen and bio-fertilizer on yield and quality of rabi onion (*Allium Cepa* L) Cv. Puna Red. *Agricultural Sciences Digest*, 25(2): 124 - 126.
- Ayub, C.M., Manan, A., Pervez, M.A., Shahid, M.A., Ashraf, M.I. and Akhtar, N. 2011. Growth and yield response of potato crop to different sources of potash. *International Journal for Agro Veterinary and Medical Sciences*, 5 (3) : 316-321.
- Azad, A.K. 2000. Effects of plant spacing, source of nutrients and mulching on growth and yield of cabbage. M.Sc. Thesis. Department of Horticulture, Bangladesh Agriculture University, Mymensingh, 15-40.
- Balemi, T. 2012. Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato in Ethiopia. *Journal of Soil Science and Plant Nutrition*, 12 (2), 257-265.
- Baloch, P.A., Riaz Uddin, Nizamani, F.K., Solangi, A.H. and Siddiqui, A.A. 2014. Effect of nitrogen, phosphorus and potassium fertilizers on growth and yield characteristics of radish (*Raphanus sativus* L.). *American-Eurasian Journal of Agriculture and Environment Science*, 14 (6) : 565-569.
- Baniuniene, A. and Zekaite, V. 2008. The effect of mineral and organic fertilizers on potato tuber yield and quality. *AGRONOMIJAS VESTIS (Latvian Journal of Agronomy)*, 11 : 202-205

- Bartova, V., Barta, J., Divis, J., Svajner, J. and Peterka, J. 2008. Crude protein content in tubers of starch processing potato cultivars in dependence on different agro-ecological conditions. *Journal of Central European Agriculture*, 10 (1) : 57-66.
- Bhadoria, S.K.S., Dwivedi, Y.C. and Kushwah, S.S. 2007. Flowering and fruiting behavior is affected by *Azotobactor* and nitrogen in tomato. *Indian Journal of Horticulture*, 64(3): 366- 368.
- Bhattacharya, S.S., Iftikar, W., Sahariah, B. and Chattopadhyay, G.N. 2012. Vermicomposting converts fly ash to enrich soil fertility and sustain crop growth in red and lateritic soils. *Resour Conserv Recycl*, 65 : 100-106.
- Boateng, S., Zickermann, A.J. and Kornaharens, M. 2006. Effect of poultry manure on growth and yield of maize. *West Africa Journal of Applied Ecology*, 9:1-11.
- Bongkyoon, K. 2004. Effect of vermicompost on growth of fall cropping potato in volcanic ash soil. *Korean Journal of Crop Sciences*, 49 : 305-308.
- Chatterjee, R., Jana, J.C. and Paul, P.K. 2008. Vermicompost substitution influences shelf life and fruit quality of tomato (*Lycopersicon esculentum* Mill.). National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Sonapat, Haryana, India.
- Choudhary, B.R. 2014. Vegetables. Kalyani publishers, 264 – 269.
- Cortez jaun, W., Filho Arthur, B. and Countinho edson, L. 2010. Cattle manure and N-urea in radish crop (*Raphanus sativus*). *Ciencia e Investigacion Agraria*, 37 (1) : 45-53.
- Desuki, El-M., Salman, S.R., El-Nemr, M.A. and Abdel Mawgoud, M.R. (2005). Effect of plant density and nitrogen application on the growth, yield and

quality of radish (*Raphanus sativus* L.).. *Journal of Agronomy*, 4 : 225-229.

Eid R., Rasha and El-Sayed, S.F. 2012. Effect of organic and bio-fertilization, on potato productivity. *Special Issue New Medit N. 4/2012*.

El-Sirafy, Z.M., Abbady, K.A., El-Ghamry, A.M. and El-Dissoky, R.A. 2008. Agro-economic evaluation of conventional and controlled release potassium fertilizers for potato crop. *Australian Journal of Basic and Applied Sciences*, 2 (4) : 1092-1103.

Fagwalawa, L. D. and Yahaya, S. M. 2016. Effect organic manure on the growth and yield of okra. *Imperial Journal of Inter disciplinary Research*, 2(3) ISSN: 2454-1362.

Farzana, Y. and Radizah, O. 2005. Influence of *rhizobacterial* inoculation on growth of sweet potato cultivar. *Journal of Biological Science*,1(3) : 176-179.

Fatideh, M.M. and Asil, M.H. 2012. Onion yield, quality and storability as affected with different soil moisture and nitrogen regimes. *South Western Journal of Horticulture, Biology and Environment*, 3 (2) : 145-165.

Fisher, R.A. 1950. *Statistical Methods for Research Workers*. Oliver and Boyd Edinburgh, London.

Fisher, R.A. and Yates, F. 1963. *Statistical Tables* - Oliver and Boyd, Edinburgh, London.

Frank, O.O. 2012. Water hyacinth based vermicompost on yield, yield components and yield advantage of cassava + groundnut. Intercropping system. *Journal of Tropical Agriculture*, 50 (1-2) : 49-52.

- Garo, G., Gedebo, A. and Kena, K. 2014. Combined effects of inorganic fertilizers and farm yard manure on root yield and above ground biomass of sweet potato (*Ipomoea batatas* Lam.). *Journal of Scientific Research and Reviews*, 3 (2): 028-033.
- Ghanti , S. And Sharangi, A.B. 2009. Effect of bio-fertilizers on growth, yield and quality of onion cv. Sukhsagar. *Journal of Crop and Weed*, 5(1):120-123.
- Ghosh, S.C., Asanuma, K., Kusutani, A. and Toyota, M. 2000. Nitrogen distribution and uptake efficiency traits of potato under different nitrogen regimes. *Pakistan Journal of Biological Science*, 3 (6) : 943-948.
- Gowda, K.T.K., Seetaram, A. and Venkataraman, M.N. 1979. Response of sunflower hybrid to spacing and fertilizer levels. *Current Research*, 8 : 43-45.
- Gupta, A.K. 2001. Nutrient mixing in agro-climatic zones of Rajasthan. *Fertilizer News* 46 (9): 39-46.
- Hailu, S., Seyoum, T. and Dechassa, N. 2008. Effect of combined application of organic P and inorganic N fertilizers on post harvest quality of carrot. *African Journal of Biotechnology*, 7 (13) : 2187-2196.
- Honeycutt, C.W. 1998. Crop rotation impact on potato proteins. *Plant Foods Human Nutrition*, 52 : 279-291.
- Islam, Md.M., Akhter, S., Majid, N.M., Ferdous, J. and Alma, M.S. 2013. Integrated nutrient management for potato (*Solanum tuberosum* L.) in grey terrace soil (Aric Albaquipt). *Australian Journal of Crop Science*, 7 (9) : 1235-1241.
- Jadhav, P.B., Patel, D.J., Kireeti, A., Patil, N.B., Dekhane, S.S., Harad, N.B. and Jadhav, K.P. 2014. Effect of different levels of vermicompost on

- growth and yield of radish cv. Local Variety. *International Journal of Information Research and Review*, 1 (2): 029-031.
- Jaipaul, Sharma, S. and Sharma, A.K. 2011. Effect of organic fertilizers on growth, yield and quality of potato under rainfed conditions of central Himalayan region of Uttarakhand, *Potato Journal*, 38(2): 176-181.
- Jayathilake, P.K.S., Reddy, I.P., Shrihari, D., Neeraja, G. and Reddy, R. 2002. Effect of nutrient management on growth yield and yield attributes of rabi onion (*Allium cepa*). *Vegetable Science*, 29(2): 184-185.
- Jilani, M.S., Burki, T. and Waseem, K. 2010. Effect of nitrogen on growth and yield of radish. *Journal of Agriculture Research*, 48 (2): 219-225.
- Jnawali, A. D., Ojha, R. B. and Marahatta, S. 2015. Role of *Azotobacter* in Soil Fertility and Sustainability. *Advances in Plants & Agriculture Research*, 2(6) : 69.
- Joshi, P.C. and Patil, N.S. 1992. Note on effect of plant density, nitrogen and phosphorous on yield of radish. *Indian Journal of Horticulture*, 49 (3): 265-266.
- Kadlag, R.R., Kapadiya, P.K., Bhor, P.R., Chandore, H.D. and Joshi, M.D. 2010. Effect of organic, inorganic fertilizer and biofertilizers on growth of okra (*Abelmoschus esculentus* L. (Moench) cv. Gujarat Okra-2. *Haryana Journal of Horticultural Sciences*, 39 (3&4) : 316-317.
- Kandil, A.A., Attia, A.N., Badawi, M.A., Sharief, A.E. and Abido, W.A.E. 2011. Influence of water stress and organic and inorganic fertilization on quality, storability and chemical analysis of potato (*Solanum tuberosum* L.). *Journal of Applied Sciences Research*, 7 (3) : 187-199.

- Kareem, I. 2013. Fertilizers treatment effects on yield and quality parameters of sweet potato (*Ipomoea batatas*). *Research Journal of Chemical and Environmental Sciences*, 1: 40-49.
- Kumar, S., Sutanu, M., Kumar, S. and Singh, H.D. 2014. Efficacy of organic manures on growth and yield of radish (*Raphanus sativus* L.) cv. Japanese White. *International Journal of Plant Science*, 9 (1) : 57-60.
- Love, S.L., Stark, J.C. and Salaiz, T. 2005. Response of four potato cultivars to rate and timing of nitrogen fertilizer. *American Journal of Potato Research*, 82 : 21-31.
- Marimuthu, R., Babu, S., and Vairavan 2002. Utility of different sources of vermicompost and in nutrient status on the growth and yield of nutrient of groundnut cv. VRI 2. *Legume Research*, 25 : 266-269.
- Maurya, A.N. and Muthoo, A.K. 1986. A note on the effects of foliar spray of urea on the growth characters and yield cv. Pusa Rashmi. *Haryana Journal of Horticultural Sciences*, 15 (1/2) : 149-150.
- Meerabai, M., Jayachandran, B. K. and Asha, K.R. 2007. Biofarming in bitter gourd (*Momordica charantia* L.). *Acta Horticulturae*, 752:349-352.
- Mehadi, T.A., Siddique, M.A. and Shahid, S.B. 2012. Effects of urea and cowdung on growth and yield of carrot. *Journal of Bangladesh Agricultural University*, 10 (1): 9–13.
- Metson, A.J. 1956. Methods of chemical analysis for soil survey samples. Bull no. 2, Deptt. Science Md. Research Soil Bureau 12.
- Mohamed, M. 1984. Effects of bed preparation and nitrogen fertilization on growth yield and quality of sweet potato (*Ipomoea batatas*). *Acta Horticulture*, 143: 311-318.

- Mojtaba, S.Y., Mohammadreza, H., Seyyed, H., Mohammad, T., and Darzi 2013. Effect of nitrogen fertilizer and vermicompost on vegetative growth, yield and NPK uptake by tuber of potato. *International Journal of Agriculture and Crop Sciences*, 5 (18) : 2033-2040.
- Mulani, T.G., Musmade, A.M., Kadu, P.P. and Mangave, K.K. 2007. Effect of organic manures and biofertilizers on growth, yield and quality of bitter gourd (*Momordica charantia* L.) cv. Phule Green Gold. *Journal of Soils and Crops*, 17(2) : 258-261
- Nedunchezhiyan M. Byju G. and Dash S.N. Effects of organic production of orange fleshed sweet potato (*Ipomoea batatas* L.) on root yield, quality and soil biological health, *International Research Journal of Plant Science*, 1(6): 136-143.
- Nedunchezhiyan, M., Srinivasulu, R.D. and Haribabu, K. 2003. Nitrogen management practices on quality characters of sweet potato (*Ipomoea batatas* Lam.). *Journal of Root Crops*, 29 (2) : 69-72.
- Nweke, I. A., Ijearu, S. I. and Igili, D. N. 2013. Effect of different sources of animal manure on the growth and yield of okra [*Abelmoschus esculentus* (L.) Moench] in Ustoxic Dystropept at Enugu South Eastern, Nigeria. *International Journal of Scientific & Technology Research*, 2(3): ISSN 2277-8616.
- Okoli, P.S.O., and Nweke I. A. 2015 Effect of Different Rates of Poultry Manure On Growth and Yield of Amaranthus (*Amaranthus Cruentus*). *Journal of Agriculture and Veterinary Science*, (8): pp. 73-76.
- Olsen, S.R., Cal, C.W., Wantple and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with NaHCO₃, USDA Circular, 1969 : 931.

- Onwu, A. C., Abubakar, J. R. and Unah, P. O. 2014. Effect of poultry manure on growth, yield of okra and soil properties in Makurdi, North Central Nigeria. *International Journal of Agricultural and Food Science*, ISSN 2249-8516.
- Osundare, B. 2004. Effect of fertilizer types and different companion crops on the performance of sweet potato. *Moor Journal of Agriculture Research*, 5 (2) : 88-94.
- Ozturk, E., Kavurmac, Z., Kara, K. and Polat, T. 2010. The effects of different nitrogen and phosphorus rates on some quality traits of potato. *Potato Research*, 53 : 309-312.
- Panwar, S. and Wani, A.M. 2014. Effect of organic production on growth and productivity of sweet potato (*Ipomoea batatas* L.) under poplar based agro forestry system. *International Journal of Advanced Research*, 2 (12) : 229-232.
- Patricia, I. and Bansal, S.K. 1999. Potassium and integrated nutrient management in potato. *Proceedings of the Global Conference on Potato*, December 6-11-1999, New Delhi, India: 1-3.
- Peter N. Gichuhi, Kokoasse Kpombrekou-A & Adelia C. Bovell-Benjamin 2014. Nutritional and physical properties of organic Beaugard sweet potato [*Ipomoea batatas* (L.)] as influenced by broiler litter application rate. *Food Science & Nutrition* 2014; 2(4): 332– 340.
- Piper, C.S. 1950. Soil and plant analysis. Inter Service Inc., New York.
- Powon, M.P., Aguyoh, J.N. and Mwaj, A.V. 2006. Growth and tuber yield of potato (*Solanum tuberosum* L.) under different levels of phosphorus and farm yard manure. *Agricultra Tropica Et Subtropica*, 39 (3).

- Prasad, H., Sajwan, P., Kumari M. and Solanki, S. 2016. Effect of Organic Manures and Biofertilizer on Plant Growth, Yield and Quality of Horticultural Crop. *International Journal of Chemical Studies*, 5(1): 217-221.
- Raghav M., Kumar, T. and Kamal, S. 2008. Effect of organic sources on growth, yield and quality of potato. *Annals of Horticulture*, 1 : 67-70.
- Rajan, M.R. and Mahalakshmi, R. 2007. Effect of vermicompost prepared from hotel wastes on growth and production of radish and cowpea. *Environment and Ecology*, 25 S (Special 4) : 1194-1197.
- Ramakrishnan, K. and Selvakumar, G. 2012. Effect of biofertilizers on enhancement of growth and yield on Tomato [*Lycopersicum esculentum* (Mill.)]. *International Journal of Research in Botany*, 2(4): 20-23.
- Ramesh, P., Singh, M., Panwar, N.R., Singh, A.B. and Ramana, S. 2006. Response of pigeon pea (*Cajanus cajan*) varieties to organic manures and their influence on fertility and enzyme activity of soil. *Indian Journal of Agriculture Science*, 76 (4) : 252-254.
- Raupp, J. 1996. Quality investigations with products of the long term fertilization trial in Darmstadt. In : Raupp, J. Quality of Plant Products Grown with Manure Fertilization. Proceedings of the fourth meeting fertilization system in organic farming, *Publications institute for Biodynamic Research*, 9 ; 13-33.
- Reddy, K.C. and Reddy, K.M. 2005. Differential levels of vermicompost and nitrogen on growth and yield in onion (*Allium cepa* L.) – radish (*Raphanus sativus* L.) cropping system. *Journal of Research*, ANGRAU, 33 (1) : 11-17.

- Richards, L.A. 1954. Diagnosis and improvement of saline and alkaline soils. Hand Book No.60 USDA.
- Sanwal, S.K., Laxminarayana, K., Yadav, R.K., Rai, N., Yadav, D.S. and Mousumi Bhuyan 2007. Effect of organic manures on soil fertility, and growth, physiology, yield and quality of turmeric. *Indian Journal of Horticulture*, 64(4) : 444-449.
- Saravaiya, S.N., Choudhary, P.P., Patel, D.A., Patel, N.B., Ahir, M.P. and Patel, V.I. 2010. Influence of integrated nutrient management on growth and yield parameters of elephant foot yam under south Gujrat condition. *The Assam Journal of Horticulture*, 5 (1): 58-60.
- Sarma, I., Phookan, D.B. and Boruah, S. 2015. Influence of manures and biofertilizers on carrot (*Daucus carota* L.) cv. early Nantes growth, yield and quality. *Journal of Eco - friendly Agriculture*, 10(1): 25-27.
- Shambhavi, S. and Sharma, R.P. 2008. Influence of vermicompost on quality of potato (*Solanum tuberosum*) in wet temperate zone of Himachal Pradesh. *Indian Journal of Plant Physiology*, 13 : 185-190.
- Shanika, W. and Premanandarajah, P. 2015. Direct and residual effect of organic manures, urea integration on okra grown in sandy regosol. *International Journal of Environmental Sciences*, 5(5): ISSN 0976 – 4402.
- Shanmugasundaram, R. and Savithri, P. 2004. Effect of nitrogen levels organic and amendments on nitrogen nutrition of carrot. *Agriculture Science Digest*, 24 : 5-8.
- Sharif Hossain A.B.M., Hakim, M.A. and Onguso, M. 2003. Effect of manures and fertilizers on the growth and yield of potato. *Pakistan Journal of Biological Sciences*, 6 : 1243-1246.

- Sharma, R.P., Datt, N. and Chander, G. 2009. Effect of vermicompost, FYM and chemical fertilizers on yield, nutrient uptake and soil fertility in okra [*Abelmoschus esculentus* (L.) Moench] - onion (*Allium cepa*) sequence in wet temperate zone of Himachal Pradesh. *Journal of Indian Society of Soil Science*, 57(3): 357-361.
- Sharma, T.R., Pandey, A.K., Updhyaya, S.D. and Agrawal, S.B. 2010. Effect of vermicompost on yield and quality of *kharif* season okra [*Abelmoschus esculentus* (L.) Moench]. *Vegetable Science*, 37(1-2): 181-183.
- Sharma, U.G., Vihol, N.J. and Chavda, J.C. 2013. Influence of plant density and nutrient management on growth, yield and quality of radish (*Raphanus sativus* L.) cv. 'Pusa Chetki'. *Asian Journal of Horticulture*, 8 (2): 671-676.
- Shelke, S.R., Adsule, R.N. and Amrutsagar, V.M. 2001. Effect of conjunctive use of organic sources with urea fertilizer on soil chemical properties, yield and quality of brinjal. *Journal of the Indian Society of Soil Science*, 49(3) : 506-508.
- Shreeniwas, C.H., Murlidhar, S. and Rao, M.S. 2000. Yield and quality of ridge gourd fruits as influenced by different levels of inorganic fertilizers and vermin-compost. *Annals of Agricultural Research*, 21 : 262-266.
- Shukla, Y.R., Mehta, S. and Sharma, R. 2012. Effect of integrated nutrient management on seed yield and quality of radish (*Raphanus sativus* L.) cv. Chinese Pink. *International Journal of Farm Sciences*, 2 (1): 47-53.
- Shuman, L.M. and Hargrover, W.L. 1985. Effect of tillage on the distribution of manures, copper, iron and zinc in soil fractions. *Soil Science Society of American Journal*, 49 : 1117-1121.

- Siddiqui, A.K., Shivle, R. and Mangodia, N. 2014. Possible role of Biofertilizer in organic agriculture. *International Journal of Innovative Research and Studies*, 3(9): 2319-9725.
- Singh, S.K. and Lal, S.S. 2012. Effect of potassium nutrition in potato yield, quality and nutrient use efficiency under varied levels of nitrogen application. *Potato Journal*, 39 (2): 155-165.
- Snell, P.D. and Snell, G.T. 1949. Colorimetric methods of analysis, 3rd Edn. II D Van Nostrand Co. Inc. New York.
- Sparrow, L.A. and Chapman, S.R. 2003. Effects of nitrogen fertilizer on potato (*Solanum tuberosum* L. cv. Russet Burbank) in Tasmania yield and quality. *Australian Journal of Experimental Agriculture*, 43 : 631-641.
- Subramani, A., Anburani, A. and Gayathiri, M. 2011. Response of growth parameters of radish (*Raphanus sativus* L.) to various organic nutrients and bio stimulants. *Asian Journal of Horticulture*, 6 (1): 32-34.
- Surrender Rao, S. and Sitaramaya, M. 2000. Performance of alternate organic nitrogen sources in an inceptisol under rice. In proceedings of International Conference Managing atural Resources for sustainable Agricultural Production in the 21st Century, New Delhi, 3, 1464-1465.
- Prativa, K.C. and Bhattarai, B.P. 2011. Effect of Integrated nutrient management on the growth, yield and soil nutrient status in tomato. *Nepal Journal of Science and Technology*, 12 : 23 – 28.
- Susan, J.K., Ravindran, C.S. and Mohankumar, C.R. 2003. Cassava starch content as modified by continuous application of manures and fertilizers. *Journal of Root Crops*, 29 (2) : 64-68.

- Taheri, N., Sharif-Abad, H.H., Yousefi, K. and Mousavi, S.R. 2011. Effect of organic manure with phosphorus and zinc on yield of seed potato. *Australian Journal of Basic and Applied Sciences*, 5 (8) : 775-780.
- Talashilkar, S.C., Bhangarath, P.P. and Mehta 1999. Changes in chemical properties during composting of organic residues as influenced by earthworm activity. *Journal of the Indian Society Soil Science*, 47 (1): 50-53.
- Teshome – Abdissa, M. and Nigussie – Dechassa, R. 2012. Yield and yield component of sweet potato as affected by farm yard manure and Phosphorus application. *Basic Research Journal of Agricultural Science and Review*, 1 (2): 31-42.
- Umuhoza, J.N.K., Sylvestre, H. and Philippe, S. 2014. Nutritional quality of carrot (*Daucus carota* L.) as influenced by farm yard manure. *World Journal of Agricultural Sciences*, 2 (5): 102-107.
- USDA, (U.S. Department of Agriculture), Agricultural Research Service 2009, USDA Nutrient Data Laboratory Home Page, <http://www.ars.usda.gov/ba/blmrr/ndl>, accessed 14 September 2012.
- Uzma, B. and Qureshi, F. 2014. Effect of nitrogen and farm yard manure on growth, nutrient content and quality of potato (*Solanum tuberosum* L.). *An International Quarterly Journal of Biology and Life Sciences*, 2 (3): 786-791.
- Vanmathi, J.S. and Selvakumari, M.N. 2012. The influence of vermicompost on the growth and yield of *Hibiscus esculentus*. *Elixir Applied Botany*, 44: 7416-7419.

- Vasanthakumar, S. K. 2003. Studies on beneficial endorhizosphere bacteria in solanaceous crop plants. *M. Sc. (Ag.) Thesis* submitted to *University of Agricultural Sciences, Dharwad, Karnataka*.
- Velmurugan, M., Balakrishnamoorthy, G. and Ananthan. M. 2005. Studies on organic farming practices on growth, yield and quality of radish (*Raphanus sativus* L.) cv. Pusa Chetki. *South Indian Horticulture*, 53 (1-6) : 337-339.
- Verma, Satish K., Asati , B.S., Tamrakar, S.K., Nanda H.C. and Gupta, C.R. 2011. Effect of organic components on growth, yield and economic returns in potato. *Potato J.* 38 (1): 51-55.
- Vijayakumari, B., Sasikala, V. and Poornima, C.P. 2012. Effect of organic and inorganic manures on biometric and yield parameters of radish (*Raphanus savitus* L.) cv. Pusaphepki. *International Journal Plant Sciences*, 7 (1): 130-134.
- Warren, J.G., Phillips, S.B., Mullins, G.L., Keahey, D. and Penn C.J. 2006. Environmental and production consequences of using alumamended poultry litter as a nutrient source for corn. *Journal of Environmental Quality*, 35: 172-182.
- White, P.J., Bradshaw, J.E., Dale, M.F.B. and Ramsay, G. 2009. Relationships between yield and mineral concentrations in potato tubers. *Horticultural Science Journal*, 44 (1) : 1-6.
- Yadav, H. and Vijayakumari, B. 2003. Influence of vermicompost with organic and inorganic manures on biometric and yield parameters of chilli (*Capsicum annuum* L.). *Crop Research*, Hissar, 25 (2) : 236-243.

- Yadav, P., Singh, P. and Yadav, R.L. 2006. Effect of organic manures and nitrogen levels on growth, yield and quality of okra. *Indian Journal of Horticulture*, 63(2) : 215-217.
- Yadav, S.S. and Yadav, N. 2010. Effect of integrated nutrient management on yield of okra in zaid crop. *Bhartiya Krishi Anusandhan Patrika*, 25 : 2-4.
- Yassin, M., Thamburaj, S., Iruloppan, I., Balashanmugam, P.V. and Lakshmanan, V. 1994. Response of sweet potato (*Ipomea batatas*) to application of *Azosprillum*. *South Indian Horticulture Journal.*, 42(6) : 358-360.
- Yeng, S.B., Agyarko, K., Dapaah, H.K., Adomako, W.J. and Asare, E. 2012. Growth and yield of sweet potato (*Ipomoea batatas* L.) as influenced by integrated application of chicken manure and inorganic fertilizer. *African Journal of Agricultural Research*, 7 (39) : 5387-5395.
- Zewide, I., Mohammed, A. and Tulu, S. 2012. Effect of different rates of nitrogen and phosphorus on yield and yield components of potato (*Solanum tuberosum* L.) at Masha District, Southwestern Ethiopia. *International Journal of Soil Science*, 7: 146-156.

Effect of Organic and Inorganic Sources of NPK and Bio-fertilizer on Growth, Yield and Quality of Sweet Potato (*Ipomoea batatas* Lam.)

Jai Singh*
(Research Scholar)

Dr. M. K. Sharma **
(Major Advisor)

ABSTRACT

A field experiment was conducted to study "Effect of organic and inorganic sources of NPK and bio-fertilizer on growth, yield and quality of Sweet potato (*Ipomoea batatas* Lam.)" during Kharif season 2016 at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur). The experiment consists of 16 treatment combinations viz., organic and inorganic sources of NPK (Control, 100 % RDF, 100 % FYM, 50% RDF + 50 % FYM, 100 % vermicompost, 50 % RDF + 50 % vermicompost, 100 % poultry manure and 50 % RDF + 50 % poultry manure) and bio-fertilizer (Control and *Azotobacter*). The total 16 treatment combinations were tested in randomized block design with three replications.

The application of 50 % RDF + 50 % vermicompost to the sweet potato crop significantly increased the vine length at 45 DAP (cm), number of branches per vine at 45 DAP, chlorophyll content in leaves (mg/g) at 50 DAP, leaf area (cm²) at 45 DAP, leaf area index, tuber length (cm), tuber weight (g), TSS (%), starch (%) and protein (%) content in tuber as compared to Control, 100 % RDF, 100 % FYM, 50% RDF + 50 % FYM, 100 % vermicompost and 100 % poultry manure, which was statistically at par with 50 % RDF + 50 % poultry manure, but in case of diameter of tuber (cm) the treatment 50 % RDF + 50 % vermicompost was statistically at par with 50 % RDF + 50 % poultry manure and 50 % RDF + 50 % FYM. Whereas the application of 50 % RDF + 50 % vermicompost also significantly increased the number of tubers per plot, tuber yield per plot (kg) and tuber yield per hectare (q) as compared to Control, 100 % RDF, 100 % FYM, 50% RDF + 50 % FYM, 100 % vermicompost, 100 % poultry manure and 50 % RDF + 50 % poultry manure.

The application of *Azotobacter* significantly increased all the growth, yield and quality parameters of sweet potato crop as compared to control.

The combined application of 50 % RDF and 50 % vermicompost + inoculation with *Azotobacter* and 50 % RDF and 50 % poultry manure + inoculation with *Azotobacter* both proved to be most superior treatment combinations in terms of vine length (cm), number of branches per vine, tuber length (cm), tuber weight (g), diameter of tuber (cm) and B:C ratio, whereas the combined application of 50 % RDF and 50 % vermicompost + inoculation with *Azotobacter* proved to be most superior treatment combination in terms of leaf area (cm²), tuber yield per plot, tuber yield per hectare and net returns per hectare.

The combined application of 50 % RDF and 50 % vermicompost + inoculation with *Azotobacter* combination gave maximum net return of ₹ 307927 ha⁻¹ and B:C ratio 3.63:1.

* Post graduate student, Department of Horticulture, S.K.N. College of Agriculture (Sri Karan Narendra Agricultural University, Jobner).

** M.Sc. (Ag.) thesis submitted to Sri Karan Narendra Agricultural University, Jobner for partial fulfillment of requirement for degree under the supervision of **Dr. M. K. Sharma**, Professor, Department of Horticulture, S.K.N. College of Agriculture, Jobner.

शकरकन्द (आइपोमिया बटाटस लेम.) की वृद्धि, उपज तथा गुणवत्ता पर नाइट्रोजन, फॉस्फोरस एवं पोटैश के विभिन्न अकार्बनिक एवं कार्बनिक स्रोतों और जैव उर्वरक का प्रभाव

जय सिंह*
(शोधार्थी)

डॉ. एम.के. शर्मा**
(मुख्य सलाहकार)

अनुक्षेपण

श्री कर्ण नरेन्द्र कृषि महाविद्यालय, जोबनेर के उद्यान प्रक्षेत्र पर खरीफ ऋतु 2016 के दौरान “शकरकन्द (आइपोमिया बटाटस लेम.) की वृद्धि, उपज तथा गुणवत्ता पर नाइट्रोजन, फॉस्फोरस एवं पोटैश के विभिन्न अकार्बनिक एवं कार्बनिक स्रोतों और जैव उर्वरक का प्रभाव” विषयक एक प्रयोग सम्पन्न किया गया। इस प्रयोग में 16 संयोजनो जैसे नाइट्रोजन, फॉस्फोरस एवं पोटैश के विभिन्न अकार्बनिक एवं कार्बनिक स्रोतों (नियंत्रण, 100 प्रतिशत उर्वरक की अनुमोदित मात्रा, 100 प्रतिशत गोबर की खाद, 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत गोबर की खाद, 100 प्रतिशत केचुए की खाद, 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद, 100 प्रतिशत मुर्गियों की खाद, 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत मुर्गियों की खाद) एवं एवं जैव उर्वरक (नियंत्रण एवं ऐजेटोबेक्टर) के उपचारों के समूहों को यादृच्छिक भूखण्ड अभिकल्पना में तीन पुनरावृत्तियों के साथ प्रयोग किया गया।

शकरकंद की फसल में 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद ने बेल की लम्बाई (सेमी) रोपण के 45 दिन बाद, शाखाओं की संख्या रोपण के 45 दिन बाद, पत्तियों में पर्ण हरित की मात्रा (मिलिग्राम/ग्राम) रोपण के 50 दिन बाद, पत्ति का प्रक्षेत्र (सेमी²) रोपण के 45 दिन बाद, पत्ति प्रक्षेत्र गुणांक, कन्द की लम्बाई (सेमी), कन्द का भार (ग्राम), कन्द में कुल घुलनशील शर्करा (प्रतिशत), स्टार्च (प्रतिशत), प्रोटीन की मात्रा (प्रतिशत) को नियंत्रण, 100 प्रतिशत उर्वरक की अनुमोदित मात्रा, 100 प्रतिशत गोबर की खाद, 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत गोबर की खाद, 100 प्रतिशत केचुए की खाद, 100 प्रतिशत मुर्गियों की खाद के अपेक्षाकृत सार्थक रूप से बढ़ाया परन्तु इन सभी वृद्धि, उपज एवं गुणवत्ता के मापदण्डों में 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत मुर्गियों की खाद को सर्वश्रेष्ठ उपचार के समकक्ष पाया गया। जबकि कन्द के परिमाण (सेमी) में 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद उपचार को 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत मुर्गियों की खाद एवं 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत गोबर की खाद को सर्वश्रेष्ठ उपचार के समकक्ष पाया गया। लेकिन, कन्द की संख्या, कन्द की उपज (किग्रा/क्यारी), कन्द उपज (क्वि./है.) में 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद को नियंत्रण, 100 प्रतिशत उर्वरक की अनुमोदित मात्रा, 100 प्रतिशत गोबर की खाद, 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत गोबर की खाद, 100 प्रतिशत केचुए की खाद, 100 प्रतिशत मुर्गियों की खाद एवं 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत मुर्गियों की खाद उपचारों की तुलना में सार्थक रूप से सर्वश्रेष्ठ पाया गया।

जैव उर्वरक ऐजेटोबेक्टर का निवेशित करने पर शकरकन्द फसल में वृद्धि, उपज व गुणवत्ता के सभी मापदण्डों में नियंत्रण की अपेक्षाकृत सार्थक रूप से सर्वश्रेष्ठ पाया गया।

समन्वित रूप से 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद तथा ऐजेटोबेक्टर एवं 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत मुर्गियों की खाद तथा ऐजेटोबेक्टर के साथ निवेशित करने पर बेल की लम्बाई (सेमी), शाखाओं की संख्या, कन्द की लम्बाई (सेमी), कन्द का भार (ग्राम), कन्द का परिमाण एवं लाभ : लागत अनुपात मापदण्डों में सर्वश्रेष्ठ पाया गया जबकि 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद को ऐजेटोबेक्टर से निवेशित करने पर पर्ण प्रक्षेत्र (सेमी), कन्द की उपज प्रति क्यारी (किग्रा), कन्द की उपज प्रति है. (क्वि.) एवं शुद्ध आय में श्रेष्ठतम पाया गया।

समन्वित रूप से 50 प्रतिशत उर्वरक की अनुमोदित मात्रा + 50 प्रतिशत केचुए की खाद को ऐजेटोबेक्टर के साथ निवेशित करने पर शुद्ध लाभ रु 307927/है. तथा लाभ : लागत अनुपात 3.63:1 सर्वाधिक पाया गया।

* स्नातकोत्तर छात्र, उद्यान विज्ञान विभाग, श्री कर्ण नरेन्द्र कृषि महाविद्यालय, (एस.के.एन. कृषि विश्वविद्यालय, जोबनेर), जोबनेर।

** स्नातकोत्तर (कृषि) के उद्यान विज्ञान विषय में उपाधि प्राप्ति की आंशिक पूर्ति हेतु वर्तमान शोध कार्य डॉ. एम.के. शर्मा, आचार्य, उद्यान विज्ञान विभाग, श्री कर्ण नरेन्द्र कृषि महाविद्यालय, (एस.के.एन. कृषि विश्वविद्यालय, जोबनेर) के निर्देशन में पूर्ण किया गया।

Appendix-I

Analysis of variance for vine length and number of branches per vine

Sources of variance	d.f.	Mean sum of squares	
		Vine length (cm)	Number of branches per vine
Replication	2	2.723	0.011
I	7	524.941**	4.491**
B	1	9428.117**	4.613**
IxB	7	21.746*	0.020*
Error	30	9.227	0.007

** Significant at 0.05% level of significance

Appendix-II

Analysis of variance for leaf area and leaf area index

Sources of variance	d.f.	Mean sum of squares	
		Leaf area (cm ²)	Leaf area index
Replication	2	167371.792	0.577
I	7	34537550.529**	18.951**
B	1	75077643.225**	41.195**
IxB	7	484627.208*	0.266
Error	30	205133.706	1.776

** Significant at 0.05% level of significance

Appendix-III

Analysis of variance for chlorophyll content in leaves

Sources of variance	d.f.	Mean sum of squares
		chlorophyll content (mg/g)
Replication	2	0.003
I	7	0.064**
B	1	0.817**
IxB	7	0.001
Error	30	0.004

** Significant at 0.05% level of significance

Appendix-IV

Analysis of variance for tuber length and tuber weight

Sources of variance	d.f.	Mean sum of squares	
		Tuber length (cm)	Tuber weight (g)
Replication	2	0.638	30.939
I	7	24.093**	3210.021**
B	1	256.628**	187851.047**
IxB	7	0.593*	199.513*
Error	30	0.198	67.899

** Significant at 0.05% level of significance

Appendix-V
Analysis of variance for diameter of tubers and number of tuber per plot

Sources of variance	d.f.	Mean sum of squares	
		Diameter of tubers (cm)	Number of tubers per plot
Replication	2	0.047	0.819
I	7	14.886**	155.679**
B	1	213.150**	135.712**
IxB	7	0.866*	0.257
Error	30	0.301	0.824

** Significant at 0.05% level of significance

Appendix-VI
Analysis of variance for tuber yield per plot and tuber yield per hectare

Sources of variance	d.f.	Mean sum of squares	
		Tuber yield per plot (kg)	Tuber yield per hectare (q)
Replication	2	1.242	368.498
I	7	28.263**	9692.274**
B	1	443.119**	151961.416**
IxB	7	2.328**	798.447**
Error	30	0.561	191.928

** Significant at 0.05% level of significance

Appendix-vii

Analysis of variance for protein, TSS and starch content in tubers

Sources of variance	d.f.	Mean sum of squares		
		Protein (%)	TSS (%)	Starch (%)
Replication	2	0.014	0.049	1.003
I	7	0.478**	0.507**	6.378**
B	1	1.103**	13.167**	57.115**
IxB	7	0.003	0.008	0.048
Error	30	0.026	0.053	0.540

** Significant at 0.05% level of significance

Appendix-VIII

Analysis of variance for net returns and B:C ratio

Sources of variance	d.f.	Mean sum of squares	
		Net returns (Rs.)	B:C ratio
Replication	2	178076114.364	0.051
I	7	13075446438.131**	1.766**
B	1	218176734171.493**	31.109**
IxB	7	1149763982.316**	0.144**
Error	30	203850989.169	0.029

** Significant at 0.05% level of significance

Appendix-IX
General cost of cultivation (Rs/ha) (Excluding the cost of the treatment inputs)

S. No.	Particulars	Unit	Rate per unit (₹)	Cost/ha (₹)
I. Variables				
A. Labour charges				
1.	Sowing of root cuttings and cutting treatments	15 man days	200	3000
2.	Weeding and care of nursery beds	14 man days	200	2800
3.	Layout of experiment	15 man days	200	3000
4.	Application of manure and fertilizers	20 man days	200	4000
5.	Transplanting of vines	20 man days	200	4000
6.	Gap filling	6 man days	200	1200
7.	Irrigation labour	20 man days	200	4000
8.	Weeding and hoeing	30 man days	200	6000
9.	Spraying of insecticides	11 man days	200	2200
10.	Harvesting and selling of tubers	60 man days	200	12000
11.	Miscellaneous			1000
	Subtotal			43200
	B. Services charges of land preparation	By tractor for 12.0 Hrs	300/hr	3600
C. Cost of material inputs				
	Cuttings of root	1085 kg/ha	10	10850
1.	Fungicides for cutting treatments	4 lit	296.75	1187
2.	Irrigation cost (9 irrigation in terms of electricity charges)	9	800/irrigation	7200
3.	Chloropyriphos	3 lit	350	1050
4.	Malathion	2 lit	274	548
	Sub total			20835
II. Fixed costs				
1.	Rental value of land	-	-	5500
2.	Interest on working	-	-	1500
3.	Depreciation cost	-	-	600
	Sub total			7600
	Total cost of cultivation			75235

General cost of cultivation = I A + I B + I C + II (43200 + 3600 + 20835 + 7600)

General cost of cultivation = 75235

Appendix-X

Comparative economics of various treatment combinations

S. NO.	Treatment	Treatment cost (₹/ha)	Common cost of cultivation (₹/ha)	Total cost (₹/ha)	Fruit yield (q/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Additional returns (₹/ha)	B:C ratio
1.	I ₀ B ₀	0	75235	75235	92.91	111495	36260	0	0.48
2.	I ₀ B ₁	200	75235	75435	167.72	201262	125827	89567	1.67
3.	I ₁ B ₀	5720	75235	80955	139.67	167605	86650	50390	1.07
4.	I ₁ B ₁	5920	75235	81155	252.12	302548	221393	185133	2.73
5.	I ₂ B ₀	10000	75235	85235	116.70	140038	54803	18543	0.64
6.	I ₂ B ₁	10200	75235	85435	210.65	252785	167350	131090	1.96
7.	I ₃ B ₀	7860	75235	83095	157.42	188900	105805	69545	1.27
8.	I ₃ B ₁	8060	75235	83295	284.16	340988	257693	221433	3.09
9.	I ₄ B ₀	13200	75235	88435	136.09	163313	74878	38618	0.85
10.	I ₄ B ₁	13400	75235	88635	245.67	294801	206166	169906	2.33
11.	I ₅ B ₀	9460	75235	84695	181.35	217615	132920	96660	1.57
12.	I ₅ B ₁	9660	75235	84895	327.35	392822	307927	271667	3.63
13.	I ₆ B ₀	10000	75235	85235	126.25	151502	66267	30007	0.78
14.	I ₆ B ₁	10200	75235	85435	227.90	273480	188045	151785	2.20
15.	I ₇ B ₀	7860	75235	83095	167.77	201323	118228	81968	1.42
16.	I ₇ B ₁	8060	75235	83295	302.84	363413	280118	243858	3.36