PRODUCTIVITY OF SPINACH BEET AS INFLUENCED BY VARIETIES AND NUTRIENT DOSES

by

VINOD ALUR

(2014-11-218)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695522

KERALA, INDIA

2017

DECLARATION

I, hereby declare that this thesis entitled **"PRODUCTIVITY OF SPINACH BEET AS INFLUENCED BY VARIETIES AND NUTRIENT DOSES"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani
Date:07-10-2017

Vinod Alur
(2014-11-218)

CERTIFICATE

Certified that this thesis entitled **"PRODUCTIVITY OF SPINACH BEET AS INFLUENCED BY VARIETIES AND NUTRIENT DOSES"** is a record of bonafide research work done independently by Mr. Vinod.Alur (2014-11-218) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellayani
Date:07-10-2017

Dr. Sheeba Rebecca Isaac
(Major Advisor, Advisory Committee)
Professor
Department of Agronomy
College of Agriculture, Vellayani,
Thiruvananthapuram

CERTIFICATE

We, the undersigned members of the advisory committee of Mr. Vinod Alur (2014-11-218) a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that this thesis entitled **"PRODUCTIVITY OF SPINACH BEET AS INFLUENCED BY VARIETIES AND NUTRIENT DOSES"** may be submitted by Mr. Vinod.Alur (2014-11-218), in partial fulfilment of the requirement for the degree.

(Chairman, Advisory Committee)
Dr. Sheeba Rebecca Isaac
Professor
Department of Agronomy
College of Agriculture, Vellayani,
Thiruvananthapuram

7.10.17

Dr. Sheela, K. R.
(Member, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture, Vellayani,
Thiruvananthapuram

7/10/17

Dr. . L. Girija devi.
(Member, Advisory Committee)
Professor
Department of Agronomy
College of Agriculture, Vellayani,
Thiruvananthapuram

Dr. Susha. S. Thara.
(Member, Advisory Committee)
Assistant Professor
Department of Plant Pathology,
College of Agriculture, Vellayani,
Thiruvananthapuram

EXTERNAL EXAMINER
7/10/17

Dr.P.V. Rao
Senior Scientist (Agronomy),
Regional Agricultural Research Station
Lam, Guntur
Andhra Pradesh

ACKNOWLEDGEMENT

First and foremost, praises and thanks to the Almighty, for giving me the courage, confidence to complete my research work successfully.

I am pleased to place my profound etiquette to ***Dr. Sheeba Rebecca Isaac****, Professor, Department of Agronomy, College of agriculture vellayani and the Chairman of my Advisory Committee. I am extremely grateful for her valuable guidance, suggestions, constructive criticism, support and dedication amidst his busy schedule without which this piece of work was never been possible. I feel immense pleasure in expressing my thankfulness for her help and unfailing patience throughout my research work and preparation of the thesis.*

I wish to express my heartfelt gratitude to ***Dr. Sheela, K. R.,*** *Professor and Head, Department of Agronomy and Member of my Advisory Committee for her critical suggestions and timely advice throughout the course programme.*

I am extremely grateful to ***Dr. L.Girija devi****, Professor, Department of Agronomy and Member, Advisory Committee for her authentic advice, inspiring guidance, periodic suggestions and critical evaluation during the course of this work. I also convey my heartfelt thanks for her friendly approach, compassionate heart and timely help throughtout the post graduate programme.*

I greately acknowledge with sincere gratitude to ***Dr. Susha S. Thara,*** *Assistant Professor, Department of Plant Pathology and Member of my Advisory Committee for her transcendent suggestions and valuable guidance throughout the course of investigation.*

I express my sincere thanks to my teachers ***Dr. M. Meerabai and Dr. V. L. Geethakumari*** *for their mental support and motherly affection throughout the post graduate programme.*

I am thankful to ***Dr. Vijyaraghavakumar*** *(Dept. of Agricultural Statistics)* ***Dr. Babu Mathew*** *(Professor and Head, Instructional farm), for their valuable suggestions and timely help rended throughout my period of work.*

I am greatful to ***Kerala Agricultural University*** *for getting me the junior research fellowship during the tenure of the M. Sc. (Ag.) programme.*

My heartfelt thanks to ***Gayathri chechi, Pintu chechi, Atul chetan, and Devi mam*** *who have helped me at various stages of my work.*

I express my love and affection to my beloved classmates ***Dona, Ishrath, Anjali K., Amala, Anjali Hari, Elsa, Sheeba, Eldhose and Vinod Mavarkar, my dear juniors Harishma,S.J., Reshma, M.R., Akhila,C.Thampi., Sethulakshmi.V.S., Limisha,N.P., Bhashma, E.K.,***

Anjana,S.,Madankumar,M.,*and* ***Niranjan*** *for their help, companionship and generous assistance throughout my M. Sc. tenure.*

I convey my heartiest gratitude to my dear brothers ***shridhar, vijay,*** *for their care and unfalling moral support during the hardtimes and assistance throughout the period of work.*

No words are enough to express my feelings and affection towards my ***Mother, Father, Sister and mava*** *for their love, constant encouragement and moral support which enabled me to pursue this endeavour successfully.*

Vinod Alur

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	-	per cent
@	-	at the rate of
°C	-	Degree Celsius
&	-	and
ADI	-	Acceptable Daily Intake
CD	-	Critical Difference
cm	-	centimetre
cm^2	-	centi metre square
DAT	-	Days After Transplanting
DMP	-	Dry Matter Production
eg.	-	example
et al.	-	co-workers/ co- authors
Fig.	-	Figure
g $plant^{-1}$	-	gram per plant
g	-	gram
h	-	hour
ha^{-1}	-	per hectare
i.e.	-	that is
IST-	-	Indian standards time
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	kilogram
kg ha^{-1}	-	kilogram per hectare

klux	-	kilo lux
mg	-	milligram
mg 100 g^{-1}	-	milligram per 100 gram
mm	-	millimetre
LAD	-	Leaf Area Duration
m^{-2}	-	per metre square
mg kg^{-1}	-	milligram per kg
mha	-	million hectare
MOP	-	Muriate of Potash
mt	-	million tonnes
N	-	Nitrogen
P	-	Phosphorus
pH	-	Negative logarithm of hydrogen ion concentration
ppm	-	parts per million
q ha^{-1}	-	quintals per hectare
SE m	-	Standard Error of mean
t	-	tonnes
t ha^{-1}	-	tonnes per hectare
UV	-	Ultra Violet
var.	-	variety
viz.	-	namely

Dedicated to

My

Parents

Introduction

1. INTRODUCTION

Vegetables form an integral component in human diet. Food grains ensure food security, however, the nutritional security is guaranteed mostly with the inclusion of fruits and vegetables in the diet. They are considered as the cheapest and most readily available sources of important proteins, vitamins, minerals and essential amino acids. India is the second largest producer of vegetable crops with a production of 168.3 mt from an area of 9.54 mha (GOI, 2016) while in Kerala, vegetables are grown in an area of 90553 ha with a production of 1.53 mt (GOK, 2016) .

Amongst all the vegetables, leafy vegetables have high protective food value. Being rich in minerals,this group of vegetablesare also referred to as "mines of minerals".As per Indian Council of Medical Research (ICMR, 2011), the recommended dietary allowance of leafy vegetables for an adult person is 100 g day^{-1}. Leafy vegetables are important, not only in meeting the essential dietary requirements, but, also in countering the micronutrient deficiencies that are increasing at an alarming rate, especially in developing countries.

Commercial cultivation of vegetables is done both as pure crops and as inter crops under open conditions. Nevertheless, the unpredictable weather and heavy incidence of pests limit the cultivation of vegetables in the open conditions. Leafy vegetables are more vulnerable to abiotic and biotic stresses on account of their vegetative growth characters and succulent nature. Year round cultivation of the crops is hence greatly influenced by the season and weather conditions.

Protected cultivation is considered as an alternative strategy for improved productivity and year round cultivation. Substantial improvements in yield and quality have been reported in vegetables when grown in protected structures under controlled environment. The green house technology is considered suitable for leafy vegetables as the protected environment helps to reduce the biotic and abiotic stresses and offset the vagaries of weather to which leafy crops are highly susceptible.

Spinach beet or palak(*Beta vulgaris* L. var. *bengalensis*) belonging to the family Chenopodiaceae, is one of the most popular leafy vegetables grown in India especially in West Bengal, Maharashtra, Rajasthan, Uttar Pradesh, Punjab, Haryana and Gujarat. It is valued for its tender, soft and succulent leaves that are used as vegetable. Also called beet leaf, spinach beet is regarded as the cheapest source of calcium, iron and phosphorus. The crop is also rich in proteins, fat and contains higher fibrous matter which provides necessary roughage in the diet. Spinach beet is the only cultivar of *Beta vulgaris*, which is annual in duration and does not produce swollen roots. The short duration, high nutritive value and relative ease in cultivation at a comparatively low cost upholds its importance among leafy greens.

Although popular in the northern states of the country, spinach beet is a recent introduction in Kerala. Cultivation of the crop is confined to homesteads, even though, the crop has immense potential for commercial cultivation and is of high nutritional value.

Popularizing a new crop for commercial cultivation necessitates the recommendation of varieties suitable to the new environment. Although many high yielding varieties in spinach beet have been evolved and are in cultivation country wide, varieties suited to the environmental conditions of the state are yet to be recommended. Varietal suitability studies have been limited toobservation trials (KVK, 2014). It also calls for a suitable package of practices recommendation for successful cultivation, especially plant nutrition, which is most important.

Balanced nutrition is crucial for optimal plant growth and high quality produce. Leafy vegetables, on account of its high biomass production and short span, require precise and timely application of the essential nutrients through suitable sources. Nitrogen, phosphorus and potassium are the key elements governing the plant growth, leaf production and quality of the greens. Evolving an agronomic package would essentially require standardizing the nutrient dose for the crop.

As spinach beet is a new introduction in the state, scientific studies on the varietal evaluation and nutrient management of the crop have not been attempted until date. Being a short duration crop itis suitable for cultivation in the open and under protected conditions. Keeping in view the above facts, the project was proposed with the following objectives

- to assess the suitability of five spinach beet varieties under open and protected conditions
- to standardize the nutrient dose for spinach beet and
- to work out the economics.

Review of Literature

2. REVIEW OF LITERATURE

Leafy vegetables are the least expensive sources of a number of protective nutrients and are regarded as indispensable components in the human diet. Spinach beet (*Beta vulgaris* L.var *bengalensis*) is one of the popular leafy vegetables oftropical and sub-tropical regions and is grown widely in India, however, a new introduction in Kerala state. The present study entitled "Productivity of spinach beet as influenced by varieties and nutrient doses" was aimed to assess the suitability of five varieties of spinach beet under protected and open conditions, to standardise the nutrient dose for the crop and to work out the economics of the cultivation.

The present chapter explores the research works done on the influence of variety and nutrient doses on spinach beet under protected and open conditions. As studies on spinach beet are less, those available on other leafy vegetables are also included.

2.1 VARIETAL EFFECTS IN LEAFY VEGETABLES

Dainello *et al.* (1987) and Djurovka *et al.* (1988) stated that yield is the key component of cultivar selection. Rai and Singh (2000) conducted an experiment with nine genotypes of cabbage and found that among the different attributes, gross and net head weight, number of non-wrapper leaves and stalk length mainly contributed to its yield.

Varieties differ in their growth characters and the number, size and weight of leaves are the major yield deciding factors in leafy vegetables. According to Singh *et al.* (2015), the yield in Indian spinach depends on the vegetative growth and it may be expressed in terms of number of leaves per plant, size of leaf and plant height.

2.1.1 Effect of Varieties on Growth and Yield

Significant variations occur in growth and yield among varieties of the broccoli crop (Ngullie and Biswas, 2014) under rainfed mid-hill conditions of Mokokchung district of Nagaland.

Varietal performances are greatly influenced by season (Campbell and Abbott,1982;Adenij*et al.*2009), growing conditions (Sharma *et al.*, 2001; Kotadia *et al.*, 2012; Elavarasan *et al.*, 2013) and management practices (Ohshiro *et al.* 2016).

Devadas *et al.* (1993) compared growth and yield parameters of 12 red and 11 types of green amaranthus and observed that red types have broader, longer leaves, fewer branches, took longer time to bolt and were taller at bolting than green types. Bhardwaj (1996) evaluated twenty divergent genotypes of cabbage and found significant differences for all traits among the twenty five genotypes tested. Among the genotypes, Golden Acre, EC-271632, Express Mail, 83-5 and Pusa Mukta performed well for marketable maturity, head compactness, head size, head weight and per cent compact heads respectively.

Gopalakrishnan (2004) assessed the adaptability of cabbage varieties and recorded maximum yield of 38.28 tha^{-1} in the variety September with an average head diameter of 16.5 cm, closely followed by Sri Ganesh, Hari Rani IAHS 2 and Hybrid 43 which were on par in productivity (25-27 tha^{-1}).

Sharma *et al.* (2006) conducted stability analysis for marketable head yield and its contributing horticultural traits in 11 genotypes of cabbage and documented that genotypes KGAT-III and Pusa Muktha were suitable for higher marketable head yields along with stability for important horticultural attributes.

Ijoyah and Rakotomavo (2007) compared the yield performance of five cabbage varieties and found that variety Gloria Kid YR performed best and was capable of giving satisfactory yield under open field condition compared to the other varieties tested.

Significant variations in yields of varieties with locations were documented in Amaranthus (Varalakshmi *et al.*,2011).

Erum *et al.* (2012) reported significant variations in plant growth characters: plant height, leaf area, plant canopy, number of branches among the varieties of

amaranthus. Similarly Mandal and Dhangrah, (2012) observed wide range of variations in the yield of vegetable amaranthus varieties.

Spinach or palak was found to perform better under saline and alkaline conditions and the variety H 23 yielded 23 per cent more biomass than All Green (Sharma *et al.*, 2001).

Narayanankutty *et al.* (2012) evaluated 28 cabbage varieties and identified NS 43, NS 160 and NS 183 as suitable varieties for cultivation under warm humid tropics of Kerala.

Studies on the performance evaluation of different types of coriander during *rabi* season revealed that Pant Haritma recorded highest green leaf yields (60.10 q ha^{-1}) under the agro climatic conditions of Akola, Maharashtra (Meena and Kale, 2015).

Meena *et al.* (2016) assessed the performance of two palak varieties, All Green and HaritSobha and reported an average yield of 15.5 and 17.7q ha^{-1}, respectively with a yield gap of 1.75 and 2.32q ha^{-1} between local and improved practices for the two varieties.

The field experiment to study the suitability of Indian spinach varieties as intercrop in litchi- papaya based agroforestry system revealed that there was no significant variation in yield among the varieties, but for selection, varieties could be ranked as KS red > Local> KS green, the per hectare yields being 36.32t, 34.61t and 34.00 t respectively (Uddin and Chowhan,2016).

2.1.2 Effect of Varieties on Quality Parameters

Leafy vegetables are rich sources of protein, vitamins such as beta carotene, ascorbic acid, folic acid and riboflavin and minerals including iron, calcium and phosphorus (Aletor *et al.*,2002; Shukla *et al.*,2006; Yadav *et al.*,2013) Although leafy vegetables occupy a very important place in the human diet Anjana *et al.* (2007)

opined that they also constitute the group of foods which contributes maximally to nitrate consumption by living beings .

Khader and Rama (2003) reported the varietal differences in macromineral contents of leafy vegetables and also recorded the varietal differences at different stages of maturity. Calcium and Mg increased as the plant matured from 15 to 30 days, whereas P content decreased continuously as the plant matured from 15 to 45 days and recommended that the best stage of consumption of leafy vegetables is between 15 and 30 days when the mineral contents were the highest. In palak, they observed a continuous increase in Mg and Ca contents and decrease in P contents were recorded from 15 to 45days.

Calderon *et al.* (1991) reported that protein content in leaves of amaranthus varieties varied from 12.74 to 14.65 per cent. According to Prakash and Pal (1991) leaf protein ranged from 14 to 30 g kg^{-1} and carotenoid content from 90 to 200 m kg^{-1} in vegetable amaranthus types.

Hossain and Rahman. (1999) analysed 11 genotypes of local amaranthus (*Amaranthus tricolor*) for the nutritional properties and reported that the genotype Bonefire had highest content of dry matter (10.07 %), protein (12.97 %), Ca (1.54 %), Mg (0.25 %) and Fe (576 ppm).

Gins *et al.* (2000) analysed the chemical composition of *Amaranthus tricolor* leaves and recorded that they contained high amounts of carotenoids (40 mg 100 g^{-1}) and considerable amounts of ascorbic acid.

Kowsalya *et al.* (2001) reported the beta-carotene content of Araikeerai (A*maranthustristis*) as 19900 IU 100 g^{-1} and that of Mullakeerai (*Amaranthusspinosus*) as 13941 IU 100 g^{-1}.

Holubava (2002) evaluated the anti nutrients in six amaranthus genotypes and noted that the genotypes with the highest amount of nitrate also contained the highest amount of oxalic acid.

Evaluating the two amaranthus lines, ArkaSamraksha and Arka Varna, Varalakshmi *et al.* (2011) documented that Arka Samraksha had maximum antioxidant activity (499 mg AEAC units), minimum nitrate content (27.3 mg) and oxalates (1.34 g 100 g^{-1} fresh weight of leaves) and leaf protein (4.0 %). Arka Varna recorded antioxidant activity of 417 mg (AEAC units), nitrate content of 3.82 mg, 1.42 g of oxalates per 100 g fresh weight of leaves and 4.1 % of leaf protein.

Yadav *et al.* (2013) reported higher values for ascorbic acid, carotenoid content and total antioxidant activity in Pusa Bharathi variety of palak, while phenol content was higher for the variety, All Green.

2.2 EFFECT OF NUTRIENTS ON THE PERFORMANCE OF LEAFY VEGETABLES

A balanced application of nutrients is important in realizing good yields in any crop production programme. This assumes significance in vegetables particularly in those species of indeterminate growth habits. Leafy vegetables are mostly harvested by frequent cuttings and hence application of nutrients inadequate quantities is important for the growth of the tender leaves and formation of newer ones.

2.2.1 Effect of Nitrogen on Growth and Yield

The role of nitrogen in promoting vigorous growth in leafy vegetables has been well documented (Tisdale *et al.*, 1990).An ample supply of nitrogen not only helps in the production of succulent leaf matter in leafy vegetables, but also in their seed production.

Field results showed that significantly higher spinach yields were obtained with the ammonium form of fertiliser compared to the nitrate form, with maximum yield on application of 300 kg N ha^{-1} compared to the 150 and 450 kg N ha^{-1} (Goh and Vityakon,1983).

Belichki (1984) suggested that nitrogen is the most important nutrient for growth and yield in spinach, while maximum growth, yield and frequency of harvesting depended on application of N.

Nawawi *et al.* (1986) reported that leaf area plant^{-1}in spinach increased with increase in nitrogen fertilization from 0 to 69 kg N ha^{-1}. Studies on the effect of split application of nitrogen on the growth and yield in clipping type amaranthus, cultivar, CO-3 revealed that application of 60 kg N ha^{-1} in two equal splits, basal and after the fifth clipping, was found to be best for getting maximum plant height, optimum leaf/stem ratio and high green leaf yield (Singh *et al.*, 1986).

Dhillon *et al.* (1987) explored the effect of different doses of nitrogen on yield of spinach grown in an alkaline sandy loam soil and illustrated that the increase in yield was relatively less at 30 kg N ha^{-1} while at 90 kg N ha^{-1},the increase was higher .

Cantliffe (1992) reported that spinach is an important leafy vegetable crop which is highly responsive to fertilizer application and requires a high level of fertility especially nitrogen. Early spring spinach may require larger quantities of fertilizers compared to fall crops.

In amaranthus, linear increase in plant lodging with increase in nitrogen fertilizer rate was noticed in soil with low initial nitrogen(Elbehri *et al.*, 1993). In soil with high amount of residual nitrogen, plant lodging was equally severe across all the rates of nitrogen applied.

Increased leaf area plant^{-1}, LAI and LAD with increased rate of N fertilizers had been documented in amaranthus (Malligawad,1994).

Harahap (1994) reported that nitrogen fertilizer application led to a significant increase in plant height, number of nodes, stem diameter and average internodal length in water spinach. Interaction between cutting frequency and nitrogen levels was also found to be significant.

Jana *et al.* (1999) reported that the highest green yield (114.6 q ha^{-1}) in palak was obtained with 150 kg N ha^{-1} and was significantly superior **to** the rest of the treatments 0, 30, 60 kg N ha^{-1} with lower doses.

Arya and Singh (2001) conducted field experiments during rainy seasons to assess the optimum dose of nitrogen for amaranthus at Ranichauri. They obtained the highest yield (20.31 q ha^{-1}) with 80 kg N ha^{-1} in two split doses during vegetative stage.

Materechera and Medupe (2006) recommended that *Amaranthus hybridus*had potential for production as a green leaf vegetable and nitrogen @ 40 kg ha^{-1} from both organic and inorganic fertilizers was essential for high productivity.

Masinde and Agong (2012) reported that nitrogen deficiency in water spinach exerts its effect on plant growth through reduced leaf area index and hence low light interception and low dry matter production.

2.2.2 Effect of Phosphorus on Growth and Yield

Muhlendyck and Schupan (1963) obtained higher yield in spinach with increased phosphorus application up to 240 kg ha^{-1} and the increase was found to be associated with improvement in market quality and an early maturity .

Regan *et al.* (1968) based on the field experiment on 24 combinations of Ca, P, K and N in spinach revealed that phosphorus stress generally caused reduction in fresh and dry weight of spinach plants. In lettuce the best head growth was recorded when P concentration in soil solution was 0.4ppm (Nishimato *et al.*, 1972).

Ramachandra and Thimmaraju (1983) conducted field experiments in a red sandy loam soil to assess the effect of different levels of nitrogen and phosphorus (0, 50 and 100 kg ha^{-1} respectively) on growth components and yield of *Amaranthus cv.25*and found that application of 100 kg P_2O_5 ha^{-1} increased leaf area index, leaf area duration, net assimilation rate and crop growth rate. Plant height, dry weight and yield were also highest at 100 kg P_2O_5 ha^{-1}.

Kalinowski *et al.* (1992) opined that there was continued additive response of amaranthus to phosphorus up to 80 kg ha^{-1}, the response to P_2O_5 occurred only when initial soil level was below 11 P_2O_5 kg ha^{-1}. This indicated that demand for phosphorus by amaranthus might be similar to other row crops.

Wang and Li (2004) explored the effects of P fertilisation on vegetable growth in different leafy vegetables and documented that the effects were species and sampling-time dependent. The addition of P fertilizer increased yields of green cabbage and rape, while those of spinach and cabbage did not record any significant change.

Nemadodzi (2015) based on his study in baby spinach reported that P application showed significantly increased yields, dry matter and chlorophyll content, with the maximum at 75 kg P ha^{-1} .

2.2.3 Effect Potassium on Growth and Yield

Makus (1990) reported that leaf area, stem weight and leaf blade weight in amaranthus responded linearly to increase levels of applied K_2O. Kalinowski *et al.* (1992), however, based on his study opined that addition of 80 kg K_2O ha^{-1} did not have positive effect on yield of amaranthus. Soundy and Smith (1992) reported a quadratic yield model in lettuce with soil K application, but the applied N and P did not affect K availability.

Yi-Minn*et al.* (2001) observed that potash applied at the rate of 225 kg K_2O ha^{-1}resulted in rapid heading, maturation, better quality and higher income The yield increase was 35 per cent more than zero potash application.

Dzida *et al.* (2011) recommended application of 0.6 g $K \cdot dm^{-3}$ for highest yield of leaf fresh weight and 1.8 g $K \cdot dm^{-3}$ bedding for highest vitamin C content in fresh mass of leaf beet cultivated in green houses.

2.2.4 Effect of Combined Nutrient Application on Growth and Yield

Salaj and Jasa (1965) reported that nitrogen had significant effects on yield of spinach and the highest yield was recorded in the combination of 90 kg N, 27 kg P and 60 kg K ha^{-1}.

Barker (1971) observed marked differences in the dry matter production in spinach with increased levels of N, P and K. Highest yield and dry matter content in spinach was obtained by balanced application of nutrients.

Panda *et al.* (1991) conducted field experiments to assess the effects of NPK on *Amaranthus gangeticus*in acid sandy loam lateritic soils. The results revealed that highest green yield (12.7 t ha^{-1}) and protein (4.9 %) was recorded with full NPK dose as basal application @ 60:20:20 kg ha^{-1}.

Jha and Jana (2009) reported that application of 10 t ha^{-1} of vermicompost along with 100 per cent recommended dose of NPK yielded the significantly highest values for all growth, green and seed yield and quality parameters in All Green variety of palak. The maximum number of leaves was at flower stalk initiation (20.77) and fresh green yield and seed yield were 5.45 and 9.60 t ha^{-1}, respectively.

Padmanabha *et al* . (2009) concluded that combined application of organic (FYM on N basis) and inorganic sources of nutrients @ $N_{150}P_{100}K_{100}$ $kgha^{-1}$ improved the growth and yield of palak.

Anuja and Jayalakshmi (2011) identified application of panchagavya 4 per cent + 100 per cent NPK (75:50:50 kg ha^{-1}) to be the best treatment for increasing yield of palak var. Ooty -1.

2.2.5 Effect of Nutrients on Nutrient Uptake

Peavy and Greig (1972) reported that mineral fertilization brought about higher nitrogen content in leaves as compared to application of organic fertilizers in spinach grown in an alkaline sandy loam soil. The results revealed that N content of leaves increased from 2.97 to3.74 per cent with application of nitrogen. They

observed significant increase in uptake of N by spinach with successive increase in amount of nitrogen applied; uptake of P and K also increased significantly at all levels of applied N.

Nitrogen and phosphorus uptake increased significantly in fenugreek and highest values were recorded when fertilized with 20 kg N and 75 kg P ha^{-1} (Rathore and Manohar, 1989).

Kansal *et al.*(1989) studied the response of spinach to different levels of nitrogen (0, 30, 60 and 90 kg ha^{-1}) and farmyard manure (0, 10 and 20 t ha^{-1}) in a sandy loam soil and reported that the yield, nutrient uptake and ascorbic acid content increased with the combined application of inorganic nitrogen fertilizer and farmyard manure, the maximum being at 90 kg N ha^{-1} + 20 t FYM ha^{-1}.

Higher nitrogen uptake at higher nitrogen rates (25, 50, and 75 kg ha^{-1}) as compared to no nitrogen was reported in amaranthus by Panchal *et al.(* 1991). Similar increases in NPK uptake in amaranthus with increasing N doses of nitrogen were also reported (Malligawad, 1994).

The study conducted by Rajeswari and Shakila (2010) highlighted that the uptake of nitrogen, phosphorus and potassium in palak were highest in the organic treatment in which FYM at 10 t ha^{-1} + vermicompost at 2.5 t ha^{-1} + panchagavya 3 per cent, as foliar spray was applied.

Islam *et al.* (2011) examined the effect of organic manure and chemical fertilizer application on vegetable crops and soil properties in the radish-stem amaranth -Indian spinach cropping pattern in a homestead area of Gazipur district in Bangladesh . In Indian spinach, the total N uptake ranged from 6.64 to 70.6 kg ha^{-1} with the significantly highest N uptake (70.6 kg ha^{-1}) in combination of household waste and reduced fertilizer dose application. P uptake varied from 0.33 to 2.81kg ha^{-1} the K and S uptake from 2.50 to 21.5 kg ha^{-1} and 0.43 to3.35 kg ha^{-1}, respectively. The significantly highest K and S uptake, (21.5 kg ha^{-1} and 3.35 kg ha^{-}

[1]respectively were noted in the treatment of intergrated household waste and reduced fertilizer dose.

Studying the seasonal variations in the response of spinach to elevated ultraviolet-B (UV-B) during summer and winter, Singh *et al.* (2014) observed that the NPK uptake was higher in summer, while NPK use efficiencies were higher during winter. At higher than recommended NPK level, better NPK use efficiencies were displayed during both the seasons.

2.2.6 Effect of Nutrients on Quality Parameters

Higher doses of nitrogen was found to record maximum content of protein, β-carotene, and reducing sugars in spinach (Kansal *et al.*, 1989).

Suresh *et al.* (1996) opined that a well fertilised leafy vegetable crop will be a high yielder and of more nutritive value because of the increased leaf protein content.

Wang *et al.* (2008) reported that application of nitrogen fertilizers *viz.*, ammonium chloride, ammonium nitrate, sodium nitrate and urea significantly increased the yields and nitrate concentrations of Peking cabbage and spinach. Phosphorus fertilization could significantly decrease nitrate concentration in green cabbage, but significantly increased in cabbage and rape at the second harvests.

Fertigation with water soluble fertilizers in coriander showed profound influence on chlorophyll content of leaves and, application at 125 per cent RDF recorded the maximum chlorophyll 'a' of 2.20 and 2.54 mg g^{-1} during first and second season at harvest stages (Rajaraman *et al.*, 2011).

Plant nutrients especially nitrogen and potassium have significant role in deciding yields and quality in palak (Ramakrishna, 2005 ; Gairola *et al.*, 2009). An N: K ratio of 1:1 along with farm yard manure was recommended for palak cultivation, as this combination increased leaf area, per cent dry weight, chlorophyll content index and nitrate reductase activity, whereas, it decreased nitrate content.

Xu *et al.*(2003) explored the variations in leaf concentrations of sugars and vitamin C in organic and chemical fertilizer applied leafy vegetables and recorded that these were significantly higher and nitrate was lower in the organic fertilized than chemical fertilized leafy vegetables.

In lettuce production, Hoque *et al.* (2010) observed increased yields with increased N application rate, but post-harvest quality declined at high levels of N (337 $kgha^{-1}$) and P (225 $kgha^{-1}$). The most economical treatment that recorded the highest yield and best post-harvest quality was with the combination of 225 kg N ha^{-1} and 112 kg P ha^{-1} .

Onyango *et al.* (2011) reported increased yields and nitrate contents in *Amaranthus caudatus* with diammonum phosphate applications and yields saturated at 40 kg N ha^{-1}.

Higher ascorbic acid contents in palak with higher rates of nitrogen application have been reported (Bhore *et al.*, 2000 ; Singh *et al.*,2015).

2.3 EFFECT OF PROTECTED CONDITIONS ON THE PERFORMANCE OF LEAFY VEGETABLES

Protected cultivation can be defined as a cropping technique wherein the micro environment surrounding the plant body is controlled partially / fully as per plant need during their period of growth, to maximize the yield and is resource saving technology (Nair and Barche,2014).

Fruiting vegetables, leafy greens, and herbs have been successfully produced in greenhouses (Hood, 2000).Nagarajan *et al.* (2014) claimed that greenhouse is the most practical method of accomplishing the objectives of protected cultivation.

Protected cultivation has the potential to reduce the stresses, offset the vagaries of weather and permitting year round cultivation to ensure regular supplies in the market (Singh *et al.*, 2005).

Brandenburger *et al.* (2007) opined that greenhouse production of leafy vegetables is an alternative to fruit vegetables in the greenhouses because it allows for multiple short-duration production cycles and a much faster economic return. The suitability of spinach in the rotation cycle for year round vegetable production in polyhouses was also documented.

The environmental conditions inside the polyhouse structure greatly influence the performance of crops (Rajasekhar *et al.*,2013; Smitha and Sunil, 2016).

Dixit (2007) compared the performance of leafy vegetables (spinach, amaranths, fenugreek and coriander) under protected environment and in open field condition. The germination percentage was found 10-20% more under greenhouse condition as compared to open field and greenhouse cultivation could yield 2-3 times greater than that in the open.

Singh *et al.* (2007) reported that protected cultivation of vegetables in peri-urban areas of Northern India provide the best way to increase the productivity and quality of vegetables as well as outweigh unfavourable elements compared to open field conditions. Summer squash - french bean- tomato - spinach was identified as the best off season vegetable combination for round the year utilisation in polyhouses (AICRP, 2009).

Kotadia *et al.* (2012) documented that leafy vegetables, spinach, amaranthus, fenugreek and coriander grown in shade net situation had better plant growth attributes and higher yields compared to open field situation during summer season. Thirty per cent shade net was found ideal for spinach and amaranthus and 75% shade net for fenugreek and coriander.

Studies on screening of leafy coriander cultivars for off season cultivation under shade nets revealed that the variety Ajmer Green was the most suitable cultivar on account of its early germination, leafy characters, late flowering nature and higher green yields (Lal *et al.*, 2015)

Isaac (2015) assessed the performance of five leafy vegetables palak, coriander, lettuce, red and green amaranthus under protected and open condition and reported that palak was the most advantageous in terms of relative equivalent yield of red amaranthus. But, in open field, crop establishment was observed to be very poor as the heavy rains affected the establishment and growth of the leafy crops.

The cited literature reveal that studies on varietal effects and nutrient doses in leafy vegetables, especially spinach beet, under open and protected environments are meagre. The present research work was hence attempted to assess the suitability of varieties in spinach beet and to standardize a nutrient dose for its cultivation in the state both under open and protected condition.

Materials and Methods

3. MATERIALS AND METHODS

The experiment entitled "Productivity of spinach beet as influenced by varieties and nutrient doses" was carried out at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during August-November2015 and 2016. The main objectives of the experiment were to assess the suitability of five varieties of spinach beet under protected and open conditions, to standardize the nutrient doses and to work out the economics of the cultivation.

The materials used and methods followed for the research work are presented in this chapter.

3.1. EXPERIMENTAL SITE

The experiment was conducted in the Instructional Farm attached to College of Agriculture, Vellayani both under protected (polyhouse) and open field conditions. The site is situated at 8.5^0 N latitude, 76.9^0 E longitude, at an altitude of 29 m above MSL.

3.1.1 Soil

Soil samples were collected from the different points of the open field as well as in polyhouse at 0-15 cm depth and analysed for the physio-chemical properties. The data are presented in Table.1

Table 1.Physico - chemical properties of soil prior to experiment

a) Physical properties

Sl.No.	Fractions	Content in soil (%)	Method used
1	Coarse sand	64.08	Bouyoucos hydrometer method (Bouyoucos, 1962)
2	Silt	10.38	
3	Clay	26.54	

b) Chemical Properties.

Sl. No.	Parameters	Content in soil		Method used
		Open	Polyhouse	
1	Available N (kg ha^{-1})	183.14 (low)	226.50 (high)	Alkaline peramanganate method (Subbiah and Asija,1956)
2	Available P (kg ha^{-1})	94.12 (high)	95.47 (high)	Bray colorimetric method (Jackson, 1973)
3	Available K (kg ha^{-1})	211.44 (medium)	268.22 (high)	Ammonium acetate method (Jackson,1973)
4	Organic carbon (%)	0.50 (medium)	0.26 (low)	Walkley and Black rapid titration method (Jackson,1973)
5	Soil reaction (pH)	5.95 (moderately acidic)	5.22 (strongly acidic)	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)
6	Electrical Conductivity (EC)	0.28 (normal)	0.39 (normal)	Digital conductivity meter (Jackson,1973)

The soil of the open field was sandy loam belonging to the taxonomical order Oxisol, moderately acidic in reaction, medium in organic carbon, low in available nitrogen and high in available phosphorus and potassium. In the polyhouse, the soil was strongly acidic, low in organic carbon and high in available nitrogen, phosphorus and potassium.

3.1.2 Climate and Season

The field experiment was laid out during August 2015 under protected condition and in open. The data on weekly mean temperature, relative humidity and rainfall during the cropping seasons were collected from the Department of Agricultural Meteorology, College of Agriculture, Vellayani and are presented in Appendix 1 and 2 and illustrated in Fig. 1 and 2.

As the heavy rains interfered with the crop establishment in 2015, spinach beet in the open was raised in August 2016. The study was conducted as two separate experiments and comparison of the performance of the crop in the open and polyhouse could not be made.

3.1.3 Previous Cropping History

Amaranthus for seed purpose was raised in the polyhouse during previous cropping season, whereas open field was under a bulk crop of vegetable.

3.2 MATERIALS

3.2.1 Details of Protected Structure

The experiment was conducted in the saw toothed type polyhouse of 1000 m^2 area established in the Instructional Farm attached to the College of Agriculture, Vellayani. The top of the polyhouse was covered with 200 micron uv stabilized polythene sheet with provision for natural ventilation. The sides were covered with 50 percent UV stabilised agro shading net of green colour. Foggers were provided for temperature regulation and operated for two minutes, twice daily, in the morning and evening.

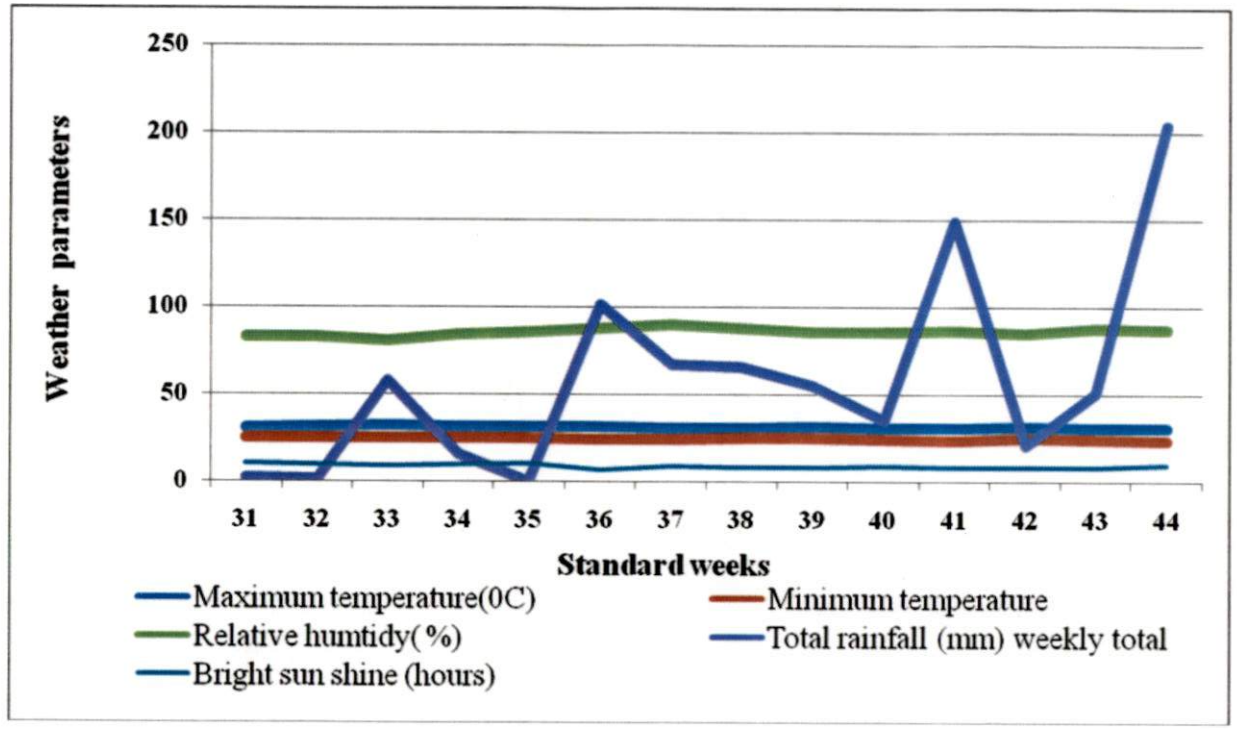


Fig. 1. Weather parameter during the cropping period (August- October 2015)

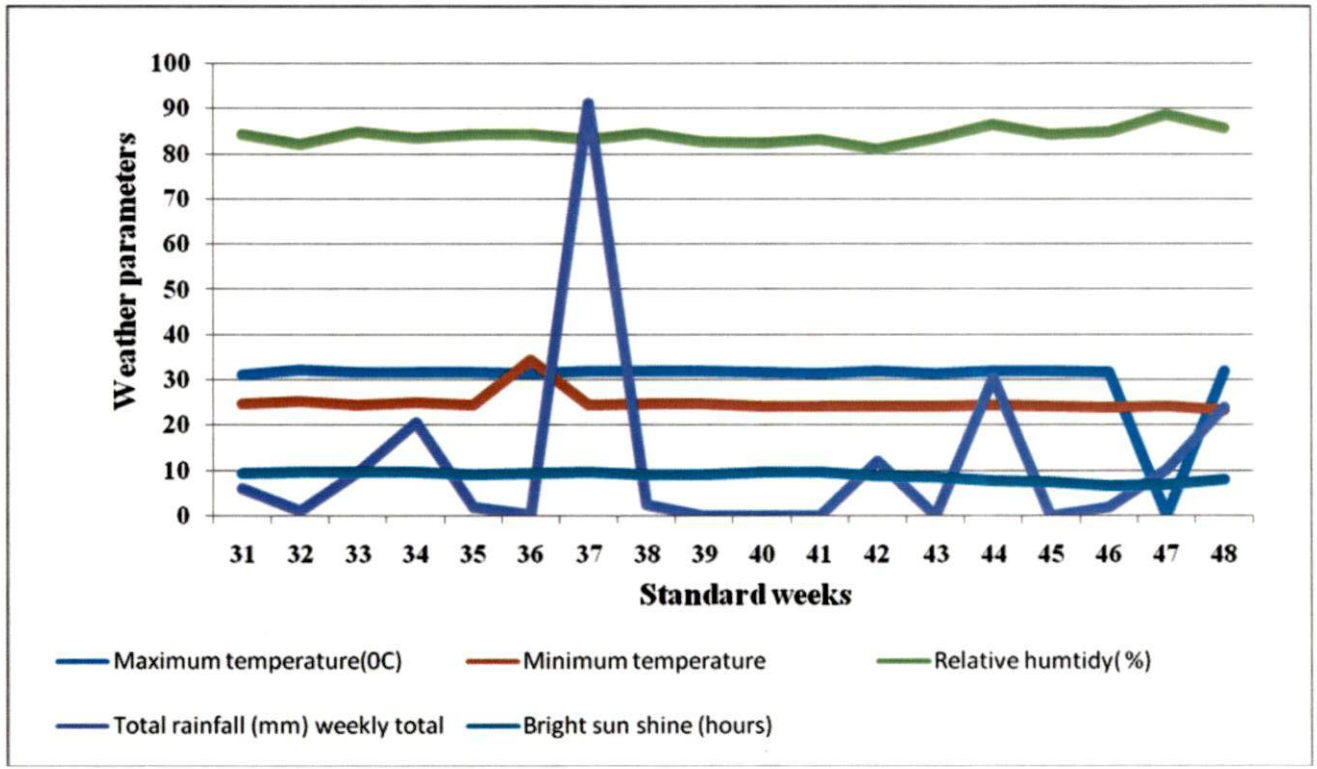


Fig. 2. Weather parameter during the cropping period (August- November 2016)

3.2.2 Crop and Varieties

Five varieties of spinach beet were raised in the open and polyhouse. The varieties included in the study, their characters and sources of seed are detailed in Table 2.

Table 2. Varietal characters and sources of seed

Sl. No	Variety	Character	Source of seed
1	All Green	Stalks and leaves are light green, plants are about 15-20 cm high. Leaves are tender and gives about 6-7 cuttings at 15-20 days interval.	NSC, Palakkad
2	PusaBharathi	Cordate shaped leaves are 25 cm long and 14 cm in breadth. Leaves are smooth and tender, without any red pigment.	IARI, New Delhi
3	Punjab Green	Plants are semi-erect; foliage is shining dark green, thick, long and broad. The leaves are succulent and free from sourness. There is mild purple pigment on the stem	PAU, Ludhiana
4	IndamKolkatta	Hybrid. Plant type is vigorous, foliage color light green and the size of leaf broad and attractive. Stem is succulent and green in colour.	Indo-American Hybrid Seeds Pvt. Ltd., Bengaluru
5	Trendy	F1 Hybrid. Plant type is early maturing and high yielding. Leaves are dark green in colour, very shiny, very soft and tender. Juicy and sweet in taste.	R.K. Seed Farms, New Delhi

3.2.2 Manures and Fertilizers

Well decomposed farm yard manure (0.48% N, 0.18% P_2O_5, 0.5% K_2O) was used as organic source and urea (46% N), rajphos (20% P_2O_5) and muriate of potash (60% K_2O) were the inorganic sources used for the experiment.

3.3 METHODS

3.3.1 Design and Layout

Design : Split plot

Replications : 4

Season : August- November 2015 and 2016

Main plot : 7.5 m x 1.5 m

Sub plot : 2.5 m x 1.5 m

Spacing : 20 cm x10 cm

Treatments:

Main factor : Varieties (V)

V_1 : All Green

V_2 :PusaBharathi

V_3 : Punjab Green

V_4 :Indam Kolkatta

V_5 : Trendy

Sub factor : Nutrient levels (N) N:P:K kg ha^{-1}

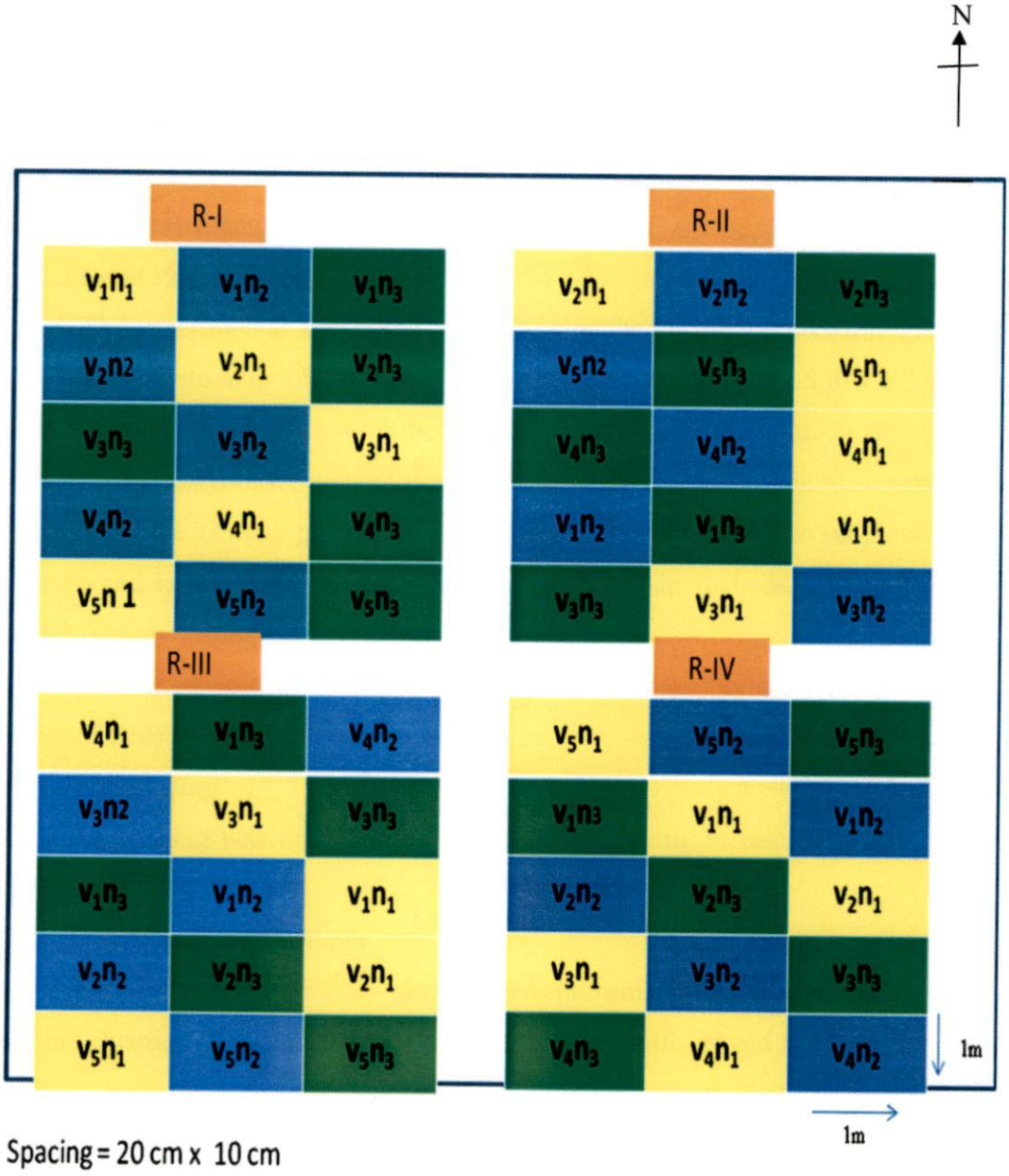
N_1:40:20:40

N_2:60:30:60

N_3:80:40:80

3.3.2 Lay out of Field Experiment

The lay out of the experiment in polyhouse is given in Fig. 3and the same was used for open condition also.



Spacing = 20 cm x 10 cm

Fig.3. Lay out of the experimental field

3.3.3 Crop Management

3.3.3.1 Sowing of Seeds and Seedling Production

Seeds of each variety were sown in pro trays in a potting media of vermicompost, FYM and coir pith in 1:1:1 ratio. The seedlings were raised in the pro trays upto 30 days and were given sprays of *Pseudomonas* @ 2 % twice at 10 day interval and water soluble nutrient spray with19:19:19 @ 0.5%, 15 DAS.

3.3.3.2 Land Preparation

The experimental area in the open was ploughed using a power tiller, levelled and converted into main plots and these were divided into beds of 2.5 m x 1.5 m size with channels in between to form the sub plots as per the layout plan.

In the polyhouse, manual digging was adopted, raised beds were taken and levelled to serve as main plots and each main plot was divided into subplots of 2.5 m length and 1.5 m width. Lime was applied @ 25 gm^{-2} in the beds.

3.3.3.3. Transplanting

One month old spinach beet seedlings of each variety were transplanted in the raised beds at 20 cm x 10 cm spacing.

3.3.3.4 Gap Filling

Gap filling was done one week after transplanting to ensure optimum plant population.

3.3.3.5 Application of Manures

Organic manure (FYM) was applied uniformly to all the treatments @10 t ha^{-1} and chemical fertilizers, as per treatments. One fourth N and K, and full P were given as basal dose and remaining three fourth N and K in three splits as top dressing, after each harvest of the crop.

3.3.3.6 Irrigation

Daily irrigation was practised in the polyhouse and in the open, irrigation was done during non rainy periods.

3.3.3.7 Weeding and Earthing up

Weeding followed by earthing up was done 15 days after transplanting (DAT) and thereafter, earthing up was done after each harvest.

3.3.3.8 Pest and Disease Management

Pseudomonas spray @ 2 per cent was given twice in the main field at two weeks interval from planting. Timely application of plant protection chemicals were adopted adhering to the recommendations, when pest and disease incidences were noticed.

3.3.3.9 Harvest

Harvesting was done when the leaves matured, and the tender ones were left to mature for later harvests.

3.4 OBSERVATIONS

Four representative plants were randomly selected from the net plot area in each treatment leaving the border rows. The plants were labelled for recording observations on growth and yield characters. The average values were used for statistical analysis. The same procedure was followed for recording observations in polyhouse and open.

3.4.1 Growth and Growth Attributes

3.4.1.1 Plant Height

Plant height was taken from the base to the growing tip of the observation plants at 15 days interval until final harvest and the mean height computed and expressed in cm.

3.4.1.2 Number of Leaves Plant-^{1}

The number of leaves plant^{-1} was counted before each harvest and average was worked out.

3.4.1.3 Leaf Area Index (LAI)

The leaf area was computed at each harvest using graph paper method and LAI was worked out using the formula developed by Watson (1947)

Plate.1. Field view of the polyhouse crop of spinach beet

Plate.2. Field view of spinach beet in open field

All Green

Pusa Bharathi

Punjab Green

Indam Kolkatta

Trendy

Plate.3.Varieties of spinach beet used in the experiment

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

3.4.2 Yield and Yield Attributes

3.4.2.1 Days to Harvest

The number of days taken for the first harvest in each treatment was noted as the number of days to harvest.

3.4.2.2 Harvest Interval

The average number of days between two consecutive harvests were recorded in each treatment and expressed as harvest interval.

3.4.2.3 Leaf Yield

Leaf yield plant^{-1}and leaf yield m^{-2} were recorded at each harvest, summed and expressed as total yield in g plant^{-1} and kg m^{-2}.

3.4.2.4 Dry Matter Production (DMP)

Three sample plants in each plot were randomly selected, uprooted, dried under shade and then oven dried at 70 ± 5^{0}C to constant weight and total dry matter production expressed in g plant^{-1}.

3.4.3 Incidence of Pest and Diseases

Observations related to the incidence of pests and diseases in the experimental plots were noted.

3.4.4Shelf Life of Leaves

The shelf life of the harvested leaves in each treatment was assessed as the number of days for which the freshness was retained by keeping leaf samples (5 each) under ambient condition.

3.5 PLANT ANALYSIS

3.5.1 Nutrient contents

3.5.1.1N P K content

The whole plant samples collected from each plot at maximum growth (4th harvest stage) were sun dried and oven dried to constant weight at a temperature of

70 ± 5^{0}C, powdered and digested for nutrient analysis. Nitrogen content was estimated by the modified micro kjeldhal method (Jackson, 1973), phosphorus content was read colorimetrically using vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and potassium by flame photometry method (Jackson, 1973). Nutrient contents were expressed as percentage.

3.5.1.2 Calcium (Ca)

The Ca content in leaves collected at fourth harvest were estimated using Atomic Absorption Spectrophotometer (AAS) after digestion of samples using di-acid mixture and expressed in mg kg^{-1}

3.5.1.3 Magnesium (Mg)

The leaf samples of the fourth harvest were analysed for Mg using AAS after digestion of samples using di-acid mixture and expressed in mg kg^{-1}.

3.5.1.4 Iron (Fe)

The iron content in leaves of the fourth harvest was estimated using AAS after di-acid digestion of the samples and expressed in mg kg^{-1}.

3.5.2Nutrient Uptake

The nutrient content in the plant sample were multiplied with the total dry matter production to work out the nutrient uptake and expressed as g plant^{-1}.

3.5.3 Protein

The protein content in the leaves was calculated by multiplying nitrogen content with the factor 6.25 (Simpson *et al.*, 1965).

3.5.4 Chlorophyll

Chlorophyll content was estimated from fresh fully opened middle leaf at the time of fourth harvest adopting the method described by Sadasivam and Manickam (1996) and expressed in mg g^{-1} leaf on fresh weight basis.

3.5.5 Vitamin A

The total bête-carotene in freshly harvested leaves of the fourth harvest was estimated as per standard procedure (Sadasivam and Manickam,1996) and expressed in I.U.

3.5.6 Vitamin C

The vitamin C content of green leaves was estimated adopting 2, 6 – dichlorophenol indophenol dye method (Sadasivam and Manickam,1996) and expressed in mg 100 g^{-1} of fresh green leaves.

3.5.7 Nitrate

The nitrate content of green leaves was estimated by method described by Nelson *et al.* (1954) and expressed in percentage.

3.6 SOIL ANALYSIS

Soil samples were taken from individual plots of the experimental area in open and polyhouse after the experiment. The samples were shade dried and sieved through a 2 mm sieve and subjected to analyses for the chemical parameters.

3.6.1 Soil properties

3.6.1.1 pH

The pH of the soil samples were determined by preparing soil solution in 1: 2.5 ratio and the reading was taken using pH meter with glass electrode (Jackson, 1973).

3.6.1.2 Electrical Conductivity (EC)

Conductivity meter was used to determine EC of soil samples and expressed as dS^{-1} m (Jackson,1973).

3.6.1.3 Organic Carbon

The soil organic carbon content was estimated using Walkley and Black's rapid titration method (Jackson, 1973) and expressed as percentage.

3.6.1.4 Available Nitrogen

The available nitrogen content in soil was estimated using alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

3.6.1.5 Available Phosphorus

The available phosphorus content in soil was estimated by Bray colorimetric method (Jackson, 1973) and expressed in kg ha^{-1}.

3.6.1.6 Available Potassium

Potassium in soil was extracted with neutral ammonium acetate and estimated using the flame photometer (Jackson,1973). The available potassium in soil was expressed in kg ha^{-1}

3.7 METEOROLOGICAL PARAMETERS

The data on the meteorological parameters in the Department of Agricultural Meteorology, College of Agriculture, Vellayani was collected and presented in Appendix II. The following weather parameters inside the polyhouse were recorded everyday between 1300 and 1315hoursIMT.

3.7.1 Air Temperature

The air temperature was measured with an ordinary dry bulb thermometer and expressed in ^{0}C.

3.7.2 Soil Temperature

Soil temperature at 15 cm depth was measured with the soil thermometer and expressed in ^{0}C.

3.7.3 Relative humidity

Relative humidity was measured with hygrometer and expressed as percentage

3.7.4 Light Intensity

Light intensity was recorded using the lux meter HI 97500 at crop canopy level and expressed in Klux.

3.8 ECONOMIC ANALYSIS

Economics of cultivation was worked out for both the experiments in open as well as polyhouse after taking into account the cost of cultivation for each treatment and prevailing market price of spinach beet.

3.8.1 Net Income

Net income was computed for 10 m^{-2} area as

Net income (₹10 m^{-2}) = Gross income - Total cost of cultivation

3.8.2 Benefit : Cost ratio (B:Cratio)

$$\text{Benefit Cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.9 STATISTICAL ANALYSIS

Data generated from the experiment were subjected to statistical analysis applying ANOVA technique and significance tested by 'F' test (Snedecor and Cochran, 1975). In cases where the effects were found to be significant, critical differences (CD) were calculated at five per cent probability levels.

Results

4. RESULTS

A field experiment was conducted in College of Agriculture Vellayani, Thiruvananthapuram district during August- November 2015 and 2016 to assess the suitability of spinach beet varieties under protected as well as open field conditions, to standardize the nutrient doses and to work out the economics.

The experiment was conducted in polyhouse and open field as two separate experiments and the results are discussed separately.

4.1 UNDER POLYHOUSE CONDITIONS

4.1.1 Growth and Yield Attributes

4.1.1.1 Plant height

The results on the effect of varieties, nutrient doses and their interactions on plant height at different growth stages are presented in Table 3.

Varieties showed significant variations in plant height at all the stages of growth until final harvest except at 45 DAT. The variety Pusa Bharathi (V_2) recorded significantly taller plants at 15, 30, 60, 75 DAT and at final harvest, while at 45 DAT, slightly higher values of 29.45 cm and 29.43 cm were recorded by variety Trendy (V_5) and Indam Kolkatta (V_4) respectively.

The influence of nutrient levels was found to be significant at 15, 30, 45, 75 DAT and at final harvest. Plants were taller at the highest doses of nutrients (N_3- 80:40:80 kg NPK ha^{-1}), a maximum of 29.54 cm at 45 DAT.

The interaction effect of varieties and nutrient doses was found to be significant at 30, 60 and 75 DAT. The interaction v_2n_1 at 30 DAT recorded maximum plant height (29.63 cm) which was on a par with v_3n_3 (27.81 cm) and v_1n_3 (27.53 cm).

Table 3. Effect of varieties, nutrient doses and interaction on plant height at different growth stages in polyhouse, cm

Treatments	Plant height					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	At final harvest
Varieties (V)						
V_1 (All Green)	17.66	25.47	28.70	28.28	29.92	25.64
V_2 (Pusa Bharathi)	25.67	27.72	29.21	29.28	30.34	27.53
V_3 (Punjab Green)	22.26	21.80	27.57	26.60	25.94	25.89
V_4 (Indam Kolkatta)	17.20	19.96	29.43	28.91	26.66	27.61
V_5 (Trendy)	17.47	20.07	29.45	29.33	28.80	27.17
SEm (±)	0.25	0.32	0.445	0.40	0.49	0.47
CD (0.05)	0.782	0.984	-	1.218	1.496	1.462
Nutrient levels (N) kg ha^{-1}						
N_1 (40:20:40)	19.45	22.23	28.51	28.78	28.46	26.39
N_2 (60:30:60)	18.81	21.58	28.56	27.95	27.21	26.30
N_3 (80:40:80)	21.89	25.21	29.54	28.70	29.32	27.61
SEm (±)	0.64	0.59	0.29	0.340	0.35	0.453
CD (0.05)	1.852	1.693	0.838	-	1.005	-
Interactions (vn)						
v_1n_1	16.93	24.93	27.93	27.71	30.52	24.28
v_1n_2	14.67	23.95	28.25	27.75	29.09	25.02
v_1n_3	21.37	27.53	29.93	29.39	30.13	27.61
v_2n_1	27.77	29.63	29.08	29.95	33.49	27.33
v_2n_2	24.23	26.32	28.83	28.63	27.72	27.05
v_2n_3	25.00	27.21	29.73	29.24	29.80	28.23
v_3n_1	20.00	19.07	26.73	26.05	24.06	25.45
v_3n_2	22.03	18.54	26.53	25.09	22.75	25.13
v_3n_3	24.73	27.81	29.45	28.65	31.00	27.10
v_4n_1	17.40	18.37	29.18	28.80	25.30	27.43
v_4n_2	15.57	19.22	29.98	29.46	26.38	27.70
v_4n_3	18.63	22.29	29.13	28.49	28.30	27.70
v_5n_1	15.13	19.18	29.63	31.41	28.94	27.48
v_5n_2	17.53	19.86	29.24	28.81	30.10	26.60
v_5n_3	19.73	21.19	29.48	27.75	27.37	27.43
SEm (±)	1.43	1.31	0.65	0.76	0.78	1.01
CD (0.05)	-	3.881	-	2.253	2.302	-

DAT- Days After Transplanting

At 60 DAT v_5n_1 (31.41cm) and at 75 DAT v_2n_1 (33.49 cm) recorded significantly superior values. Interactions at 45 DAT and at final harvest were found to be non significant.

4.1.1.2 Number of Leaves Plant^{-1}

Perusal of the data on the effect of varieties, nutrient levels and their interaction on number of leaves plant^{-1} (Table 4) revealed that the main effects were significant up to 75 DAT, while the interactions showed significant variations only at 30 DAT.

The variety Punjab Green (V_3) recorded higher number of leaves plant^{-1} at 15, 30 and 60 DAT and on par with Pusa Bharathi (V_2) and All Green (V_1). At 45 DAT the number of leaves plant^{-1}was significantly high in V_2 (7.91)and at 75 days, V_1 recorded the maximum number of leaves plant^{-1} (6.2).

The leaf number plant^{-1} was significantly higher with the highest nutrient level (80:40:80 kg NPK ha^{-1}) and declined with the decrease in nutrient doses. The maximum number of leaves plant^{-1} was recorded at 45 DAT (7.44).

Among the different interactions, v_3n_3 (Punjab Green at 80:40:80 kg NPK ha^{-1}) was significantly superior and registered higher mean value at 30 DAT, while the variations in all other the stages were non significant.

The total number of leaves plant^{-1} was significantly influenced by the varieties and nutrient levels. Maximum number of leaves plant^{-1} was recorded in the variety Punjab Green (36.1) which was on a par with Pusa Bharathi (35.0). Among nutrient levels, it was significantly higher with the highest level of NPK (35.7). The interaction effect was not significant.

4.1.1.3 Leaf Area Index (LAI)

The data on variety, nutrient levels and their interaction effects on LAI presented in Table 5 revealed the effects to be significant at all stages of growth.

Table 4. Effect of varieties, nutrient doses and interaction on number of leaves plant^{-1} in polyhouse

Treatments	Number of leaves						
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	At final harvest	Total number
Varieties (V)							
V_1(All Green)	5.2	6.1	6.0	5.4	6.2	4.7	32.8
V_2 (Pusa Bharathi)	5.5	6.0	7.9	5.3	5.7	4.8	35.0
V_3 (Punjab Green)	5.6	6.4	7.0	6.3	5.6	5.3	36.1
V_4 (Indam Kolkatta)	4.7	5.2	6.7	5.6	5.2	4.9	32.6
V_5 (Trendy)	4.7	5.0	6.3	5.7	5.0	5.1	31.8
SEm (±)	0.2	0.2	0.4	0.2	0.2	0.2	0.9
CD (0.05)	0.72	0.69	1.09	0.55	0.73	-	2.70
Nutrient levels (N) kg ha^{-1}							
N_1 (40:20:40)	4.8	5.6	6.2	5.4	5.7	4.9	32.4
N_2 (60:30:60)	5.2	5.6	6.7	5.5	5.2	4.8	32.9
N_3 (80:40:80)	5.5	6.1	7.4	6.1	5.7	5.1	35.7
SEm (±)	0.2	0.1	0.2	0.2	0.1	0.2	0.5
CD (0.05)	0.45	0.41	0.63	0.47	0.41	-	1.41
Interactions (vn)							
v_1n_1	4.8	6.3	5.2	5.5	7.0	4.8	32.48
v_1n_2	5.5	5.8	6.5	5.0	5.8	4.3	31.84
v_1n_3	5.3	6.2	6.3	5.8	5.8	5.0	34.08
v_2n_1	5.0	5.3	7.7	4.7	5.8	4.2	32.86
v_2n_2	5.3	6.5	7.5	4.7	5.5	4.5	34.03
v_2n_3	6.1	6.2	8.5	6.5	5.7	5.5	38.03
v_3n_1	4.8	5.7	6.5	5.7	5.5	5.2	33.51
v_3n_2	5.7	6.0	7.1	6.0	5.5	5.8	36.04
v_3n_3	6.3	7.6	7.5	7.0	5.8	4.8	38.60
v_4n_1	4.5	5.2	5.5	5.7	5.3	5.0	31.49
v_4n_2	4.5	5.2	6.5	5.5	4.7	5.0	32.03
v_4n_3	5.0	5.2	8.0	5.8	5.5	4.8	34.18
v_5n_1	4.7	5.2	6.0	5.8	4.8	5.3	31.72
v_5n_2	4.7	4.5	6.0	6.0	4.5	4.5	30.35
v_5n_3	4.8	5.3	7.0	5.5	5.7	5.5	33.47
SEm (±)	0.4	0.3	0.5	0.4	0.3	0.4	1.09
CD (0.05)	-	0.95	-	-	-	-	-

DAT- Days After Transplanting

Table 5. Effect of varieties, nutrient doses and interaction on Leaf Area Index (LAI) in polyhouse

	LAI				
Treatments	30 DAT	45 DAT	60 DAT	75 DAT	At final harvest
Varieties (V)					
V_1(All Green)	1.45	2.15	1.95	1.69	1.60
V_2 (Pusa Bharathi)	1.40	2.06	1.87	1.35	1.50
V_3 (Punjab Green)	1.63	2.48	2.37	1.76	1.81
V_4 (Indam Kolkatta)	1.51	2.03	1.87	1.96	1.66
V_5 (Trendy)	1.21	1.79	1.62	1.01	1.39
SEm (±)	0.01	0.02	0.01	0.14	0.02
CD (0.05)	0.027	0.054	0.045	0.434	0.054
Nutrient levels (N) kg ha^{-1}					
N_1 (40:20:40)	1.23	1.84	1.67	1.28	1.34
N_2 (60:30:60)	1.43	2.12	1.81	1.42	1.52
N_3 (80:40:80)	1.66	2.34	2.33	1.97	1.92
SEm (±)	0.01	0.02	0.02	0.11	0.01
CD (0.05)	0.021	0.048	0.044	0.308	0.038
Interactions (vn)					
v_1n_1	1.27	1.85	1.54	1.60	1.30
v_1n_2	1.32	2.04	1.70	1.26	1.38
v_1n_3	1.76	2.56	2.62	2.20	2.12
v_2n_1	1.26	1.82	1.68	0.82	1.36
v_2n_2	1.33	2.10	1.82	1.49	1.46
v_2n_3	1.62	2.25	2.10	1.74	1.67
v_3n_1	1.35	2.16	2.11	0.84	1.54
v_3n_2	1.55	2.66	2.25	1.68	1.70
v_3n_3	1.98	2.62	2.75	2.77	2.20
v_4n_1	1.38	1.84	1.68	2.49	1.47
v_4n_2	1.57	2.12	1.82	1.75	1.68
v_4n_3	1.57	2.14	2.12	1.63	1.82
v_5n_1	0.88	1.54	1.36	0.63	1.04
v_5n_2	1.38	1.70	1.46	0.92	1.38
v_5n_3	1.37	2.13	2.04	1.49	1.77
SEm (±)	0.02	0.04	0.03	0.24	0.03
CD (0.05)	0.049	0.110	0.102	0.705	0.088

DAP- Days After Transplanting

LAI was significantly superior in Punjab Green (V_3) at all stages except at 75 DAT wherein Indam Kolkatta recorded higher value (1.96). LAI of Trendy (V_5) was found to be the lowest at all the stages.

Increasing the nutrient doses was found to increase the LAI of the plant at all stages, the order being $N_3 > N_2 > N_1$. LAI was significantly superior in N_3 compared to the other levels.

The interaction effect of Punjab Green at 80:40:80 kg NPK ha^{-1} (v_3n_3) was significantly superior and recorded the highest LAI during the different stages of growth. It was on par with v_1n_3 at 45 and 75 DAT.

4.1.1.4 Days to Harvest

Table 6 depicts the effect of varieties, nutrient doses and their interactions on days to each harvest and crop duration of spinach beet in polyhouse .

Varieties varied in the number of days taken for harvest. Punjab Green leaves were ready for harvest earlier while Pusa Bharathi was late. The crop duration ranged from 88.33 days (Punjab Green) to 90.47 days (Pusa Bharathi). The four varieties V_1, V_3, V_4 and V_5 were on par with respect to crop duration.

There was no variation in the crop duration due to the different levels of nutrients while interactions were significant for the number of days taken for the third harvest and final harvest. Early harvest was observed in the interaction v_3n_3 under both situations. The crop duration was found the lowest in v_5n_2 (85.92 days) and longest in v_2n_3 (91.42 days).

4.1.1.5 Harvesting Interval

The main effects and interaction effects on harvesting interval are shown in Table 7.

The number of days to the first harvest varied with varieties. Punjab Green, All Green and Indam Kolkatta came to harvest early (27.3, 27.4, 27.8 days respectively). Trendy and Pusa Bharathi took significantly higher number of days compared to Punjab Green. Although significant fluctuations were noted in the

Table 6. Effect of varieties, nutrient doses and interaction on days to harvest and crop duration under polyhouse condition

Days to harvest					
Treatments	First	Second	Third	Fourth	Crop Duration (days)
Varieties (V)					
V_1(All Green)	27.41	43.03	57.33	71.81	88.58
V_2 (Pusa Bharathi)	29.17	44.06	59.67	73.39	90.47
V_3 (Punjab Green)	27.33	41.00	56.33	71.33	88.33
V_4 (Indam Kolkatta)	27.83	42.33	56.54	71.79	88.52
V_5 (Trendy)	28.29	43.34	58.86	73.84	89.06
SEm (±)	0.23	0.35	0.34	0.39	0.38
CD (0.05)	0.721	1.073	1.052	1.201	1.172
Nutrient levels (N) kg ha^{-1}					
N_1 (40:20:40)	27.42	42.04	57.20	71.84	88.40
N_2 (60:30:60)	28.29	43.14	57.88	72.54	88.98
N_3 (80:40:80)	28.31	43.08	58.16	72.92	89.60
SEm (±)	0.30	0.35	0.32	0.33	0.35
CD (0.05)	-	-	-	-	-
Interactions (vn)					
v_1n_1	28.00	43.00	57.00	71.77	89.00
v_1n_2	28.00	44.00	58.00	72.00	88.00
v_1n_3	26.23	42.10	57.00	71.66	88.75
v_2n_1	28.00	42.00	58.00	73.00	90.00
v_2n_2	29.07	44.25	60.00	73.32	90.00
v_2n_3	30.45	45.94	61.00	73.85	91.42
v_3n_1	27.00	40.00	55.00	69.00	86.00
v_3n_2	27.00	41.00	56.00	72.00	90.00
v_3n_3	28.00	42.00	58.00	73.00	89.00
v_4n_1	27.08	42.19	58.00	72.00	88.00
v_4n_2	28.39	43.31	56.40	72.36	91.00
v_4n_3	28.00	41.48	55.22	71.00	86.55
v_5n_1	27.00	43.00	58.00	73.45	89.00
v_5n_2	29.00	43.13	59.00	73.00	85.92
v_5n_3	28.87	43.88	59.59	75.07	92.27
SEm (±)	0.67	0.78	0.71	0.74	0.78
CD (0.05)	-	-	2.121	-	2.317

Table 7. Effect of varieties, nutrient doses and interactions on harvesting interval in polyhouse, days

Harvesting interval					
Treatments	First	Second	Third	Fourth	Final harvest
Varieties (V)					
V_1(All Green)	27.41	15.08	14.67	14.67	16.33
V_2 (Pusa Bharathi)	29.17	15.35	15.00	14.67	16.33
V_3 (Punjab Green)	27.33	14.06	15.33	15.00	17.00
V_4 (Indam Kolkatta)	27.83	14.72	14.53	14.80	16.45
V_5 (Trendy)	28.29	15.45	15.03	15.43	15.16
SEm (±)	0.23	0.09	0.14	0.14	0.17
CD (0.05)	0.721	0.282	0.441	0.442	0.524
Nutrient levels (N) kg ha^{-1}					
N_1 (40:20:40)	27.42	15.03	14.88	14.80	16.40
N_2 (60:30:60)	28.29	15.03	14.72	14.80	16.36
N_3 (80:40:80)	28.31	14.73	15.14	15.14	16.00
SEm (±)	0.30	0.17	0.15	0.13	0.12
CD (0.05)	-	-	-	-	-
Interactions (vn)					
v_1n_1	28.00	15.00	14.00	15.00	17.00
v_1n_2	28.00	16.00	14.00	14.00	16.00
v_1n_3	26.23	14.25	16.00	15.00	16.00
v_2n_1	28.00	15.04	16.00	15.00	17.00
v_2n_2	29.07	15.00	15.00	14.00	16.00
v_2n_3	30.45	16.00	14.00	15.00	16.00
v_3n_1	27.00	14.32	15.00	14.00	17.00
v_3n_2	27.00	13.87	15.00	16.00	18.00
v_3n_3	28.00	14.00	16.00	15.00	16.00
v_4n_1	27.08	15.00	15.00	14.00	16.00
v_4n_2	28.39	15.00	14.58	16.00	16.34
v_4n_3	28.00	14.16	14.00	14.39	17.00
v_5n_1	27.00	15.80	14.38	16.00	15.00
v_5n_2	29.00	15.30	15.00	14.00	15.48
v_5n_3	28.87	15.25	15.70	16.29	15.00
SEm (±)	0.67	0.39	0.33	0.30	0.27
CD (0.05)	-	-	0.981	0.882	0.807

number of days for subsequent harvests in the different varieties, the harvesting interval for third and fourth harvest ranged between 14.1 and 15.3 days while the harvest interval for the final cutting was 17 days in Punjab Green.

Interaction effect was significant for the harvesting interval in the third, fourth and fifth harvests. The harvesting interval in v_5n_3 was the highest for the fourth harvest (16.3 days) and v_3n_2 for the final harvest (18.0 days).

4.1.1.6 Leaf Yield plant^{-1}

Perusal of data on the effect of varieties, nutrient levels and their interactions on leaf yield plant^{-1} (Table8) revealed significant variations with the factors and interactions. The variety Punjab Green (V_3) produced the highest yield of 83.31 g plant^{-1}, significantly superior to the other varieties. Indam Kolkatta (V_4) recorded 76.71 g fresh leaves plant^{-1} and All Green (V_1), 76.70 g plant^{-1}. The lowest yield was recorded in Trendy (68.48 g plant $^{-1}$).

Maximum and significantly superior yield plant^{-1} (80.70 g) was recorded by the nutrient level N_3 (80:40:80 kg NPK ha^{-1}). The leaf yields were lower with the lower levels of nutrients.

Interactions of varieties and nutrient levels influenced leaf yield plant^{-1} significantly. Interaction $v_1n_3$recorded significantly higher yield (88.24 g plant^{-1}) on a par with v_3n_3 (86.27 g plant^{-1}).

4.1.1.7 Leaf Yield m^{-2}

Table 8 illustrates the significant influence of varieties, nutrient doses and their interactions on leaf yield m^{-2}

The variety Punjab Green (V_1) recorded the highest yield (4.78 kg m^{-2}) which was significantly superior to all other varieties. All Green (V_1) recorded the second highest yield of 4.56 kg m^{-2}. The variety Trendy recorded the lowest yield (4.07 kg m^{-2}) and was significantly inferior.

Table 8. Effect of varieties, nutrient doses and interaction on leaf yield in polyhouse

Treatments	Leaf yield (g plant^{-1})	(kg m^{-2})
Varieties (V)		
V_1(All Green)	76.70	4.56
V_2 (Pusa Bharathi)	74.47	4.37
V_3 (Punjab Green)	83.31	4.78
V_4 (Indam Kolkatta)	76.71	4.49
V_5 (Trendy)	68.48	4.07
SEm (±)	0.41	0.06
CD (0.05)	1.27	0.176
Nutrient levels (N) kg ha^{-1}		
N_1 (40:20:40)	70.99	4.21
N_2 (60:30:60)	76.10	4.46
N_3 (80:40:80)	80.70	4.70
SEm (±)	0.33	0.03
CD (0.05)	0.96	0.099
Interactions (vn)		
v_1n_1	66.54	4.11
v_1n_2	75.34	4.51
v_1n_3	88.24	5.06
v_2n_1	72.84	4.29
v_2n_2	75.22	4.38
v_2n_3	75.34	4.44
v_3n_1	80.77	4.58
v_3n_2	82.88	4.76
v_3n_3	86.27	5.01
v_4n_1	72.23	4.26
v_4n_2	75.63	4.44
v_4n_3	82.27	4.76
v_5n_1	62.60	3.79
v_5n_2	71.45	4.18
v_5n_3	71.38	4.24
SEm (±)	0.74	0.08
CD (0.05)	2.20	0.227

Among the different nutrients doses the highest dose of NPK (N_3) recorded the maximum yield (4.70 kg m^{-2}) and was significantly higher than N_2 (4.46 kg m^{-2}) and N_1 (4.21 kg m^{-2}).

The interaction v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) recorded the highest yield (5.06 kg m^{-2}) which was on a par with interaction v_3n_3 (Punjab Green at 80:40:80 kg NPK ha^{-1})which showed a yield of 5.01 kg m^{-2}. The interaction v_5n_1 (Trendy at 40:20:40 kg NPK ha^{-1}) recorded the significantly lowest yield (3.79 kg m^{-2}).

In all the spinach beet varieties, combination with the highest level (N_3)was found to be the best, the yield being in the order Punjab Green > All Green >IndamKolkatta>PusaBharathi> Trendy.

4.1.2 Nutrient Content

The data on nutrient contents in the plant as influenced by the varieties, nutrient levels and their interactions are given in Table 9 and 10 respectively.

4.1.2.1 Nitrogen (N)

Varietal effect on plant nitrogen content was found to be significant. The variety Punjab Green (V_3) showed the highest nitrogen content (3.79%) and the lowest (3.50%) was recorded by Trendy (V_5) .

Nitrogen content was significantly high (3.86%) in N_3 and declined with lowered doses and the lowest nutrient dose resulted in the lowest nitrogen (3.41 %).

Interaction effect was found to be significant. The interactions v_3n_3 resulted superior values (4.12 %) and the lowest value was recorded by the interaction, v_5n_1 (3.32%).

4.1.2.2 Phosphorus (P)

Phosphorus content was significantly high in Punjab Green (1.84 %) and among nutrient levels, N_3 recorded the highest P (1.23 %) and N_1, the lowest (1.18 %)

Table 9. Effect of varieties, nutrient doses and interaction on plant NPK content (%) in polyhouse grown spinach beet

Treatments	N	P	K
Varieties (V)			
V_1 (All Green)	3.59	1.15	4.70
V_2 (Pusa Bharathi)	3.63	1.23	4.29
V_3 (Punjab Green)	3.79	1.84	4.93
V_4 (Indam Kolkatta)	3.60	1.00	4.32
V_5 (Trendy)	3.50	0.81	4.44
SEm (±)	0.02	0.01	0.03
CD (0.05)	0.046	0.017	0.085
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	3.41	1.18	3.60
N_2 (60:30:60)	3.60	1.22	4.87
N_3 (80:40:80)	3.86	1.23	5.15
SEm (±)	0.01	0.01	0.02
CD (0.05)	0.041	0.018	0.063
Interactions (vn)			
v_1n_1	3.38	1.09	3.60
v_1n_2	3.48	1.18	5.12
v_1n_3	3.90	1.18	5.39
v_2n_1	3.42	1.22	2.76
v_2n_2	3.62	1.22	4.87
v_2n_3	3.84	1.24	5.24
v_3n_1	3.50	1.80	4.58
v_3n_2	3.74	1.82	5.00
v_3n_3	4.12	1.90	5.23
v_4n_1	3.41	1.03	3.52
v_4n_2	3.69	1.06	4.54
v_4n_3	3.69	0.92	4.89
v_5n_1	3.32	0.73	3.54
v_5n_2	3.45	0.80	4.80
v_5n_3	3.74	0.89	4.98
SEm (±)	0.03	0.01	0.05
CD (0.05)	0.093	0.042	0.145

Interaction effect was also significant. The interaction v_3n_3 (Punjab Green at 80:40:80 kg NPK ha^{-1}) had maximum P (1.90 %) and was on a par with v_3n_2 (Punjab Green at 60:30:60 kg NPK ha^{-1}) which recorded 1.82 % P.

4.1.2.3 Potassium (K)

Varieties varied significantly in K content and among them, Punjab Green (V_3) showed maximum content (4.93%) and Pusa Bharathi (V_2), the lowest (4.29%).

Nutrient levels significantly influenced K content. N_3 showed the highest content (5.15%), significantly greater than N_2 (4.87%) and N_1 (3.60 %).

All Green at the highest NPK dose recorded the significantly highest K content (5.39 %) which was on a par with v_2n_3 (5.24%) and v_3n_3 (5.23%) and the lowest (2.76 %) was registered in the combination v_2n_1(All Green at 40:20:40 kg NPK ha^{-1}).

4.1.2.4 Iron (Fe)

Variation in Fe content in spinach beet as influenced by varieties, nutrient levels and interactions are shown in Table 10.

The Fe content varied significantly with the varieties. Punjab Green showed the highest Fe content (0.63 mg kg^{-1}) on a par with Pusa Bharathi (0.62 mg kg^{-1}) and All Green (0.60 mg kg^{-1}). Trendy recorded significantly lower values (0.54 mg kg^{-1})

The nutrient dose, N_2 (60:30:60 kg NPK ha^{-1}) recorded the highest Fe content (0.66 mg kg^{-1}) and was significantly superior to other nutrient levels.

Interaction effect of varieties and different nutrients levels was found to be significant The variety PusaBharathi (V_2) in combination with N_2 (60:30:60 kg NPK ha^{-1}) recorded maximum Fe content (0.68 mg kg^{-1}) and on a par with v_4n_2, v_1n_2, v_3n_2, v_5n_2,v_3n_3, v_5n_3,v_1n_3, v_2n_3 and v_3n_1.

4.1.2.5 Calcium (Ca)

The significant influence of varieties, nutrient levels and interactions on calcium content in spinach beet are presented in Table 10.

Table 10. Effect of varieties, nutrient doses and interaction on iron (Fe), calcium (Ca) and magnesium (Mg) content mg kg^{-1} in spinach beet grown in polyhouse

Treatments	Fe	Ca	Mg
Varieties (V)			
V_1 (All Green)	0.60	0.61	0.19
V_2 (Pusa Bharathi)	0.62	0.44	0.17
V_3 (Punjab Green)	0.63	0.55	0.18
V_4 (Indam Kolkatta)	0.52	0.36	0.16
V_5 (Trendy)	0.54	0.53	0.15
SEm (±)	0.002	0.003	0.004
CD (0.05)	0.062	0.010	0.014
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	0.49	0.40	0.14
N_2 (60:30:60)	0.66	0.54	0.17
N_3 (80:40:80)	0.59	0.56	0.21
SEm (±)	0.01	0.004	0.003
CD (0.05)	0.043	0.011	0.008
Interactions (vn)			
v_1n_1	0.54	0.57	0.16
v_1n_2	0.66	0.63	0.17
v_1n_3	0.62	0.64	0.23
v_2n_1	0.53	0.23	0.13
v_2n_2	0.68	0.66	0.16
v_2n_3	0.60	0.44	0.23
v_3n_1	0.60	0.59	0.14
v_3n_2	0.64	0.43	0.17
v_3n_3	0.67	0.64	0.22
v_4n_1	0.47	0.19	0.12
v_4n_2	0.68	0.43	0.18
v_4n_3	0.46	0.46	0.20
v_5n_1	0.33	0.42	0.14
v_5n_2	0.66	0.54	0.15
v_5n_3	0.63	0.62	0.16
SEm (±)	0.03	0.009	0.006
CD (0.05)	0.0978	0.026	0.019

The effect of varieties on Ca content was significant. All Green showed the highest content (0.61 mg kg^{-1}) and Indam Kolkatta recorded the lowest content (0.36 mg kg^{-1}).

Calcium content varied significantly with the nutrient doses applied. N_3 recorded the highest Ca content (0.56 mg kg^{-1}) and was significantly superior to other doses. Lower doses recorded lower Ca content.

Interaction effect of varieties and nutrient levels was found to be significant . The variety V_2 (Pusa Bharathi) in combination with N_2 (60:30:60 kg NPK ha^{-1}) recorded maximum Ca content of 0.66 mg kg^{-1} and on a par with interactions v_1n_3, v_3n_3 and v_1n_3 which recorded 0.64, 0.64 and 0.63 mg kg^{-1}Ca respectively.

4.1.2.6 Magnesium (Mg)

Variations in magnesium content in spinach beet as influenced by the varieties, nutrient levels and interactions are shown in Table 10.

The effect of varieties on Mg content was significant with the variety All Green (V_1) recording the highest value (0.19 mg kg^{-1}) followed by the variety Punjab Green (V_3), 0.18 mg kg^{-1}.

Among nutrient levels, N_3 (80:40:80 kg NPK ha^{-1}) recorded maximum value (0.21 mg kg^{-1}), significantly higher than N_2, 0.17 mg kg^{-1} and N_1, 0.14 mg kg^{-1}

Interaction effect of varieties and nutrient levels was found to be significant. Mg content in the combination with v_1n_3 was maximum (0.23 mg kg^{-1}) and the lowest v_4n_1(0.12 mg kg^{-1}).

4.1.3 Shelf life

The influence of varieties, nutrient levels and their interaction on shelf life of spinach beet leaves under ambient condition are shown in Table 11.

Varieties and nutrient doses did not influence the shelf life of the harvested leaves significantly, but interaction effect was found to be significant.

Leaves harvested in the treatment combination v_3n_3 (Punjab Green at 80:40:80 kg NPK ha^{-1}) recorded highest shelf life of 2.74 days. The shelf life was lowest (1.36 days) for the interaction v_3n_2 (Punjab Green at 60:30:60 kg NPK ha^{-1}).

4.1.4 Chlorophyll

The effect of varieties, nutrient doses and interaction on chlorophyll content of spinach beet were significant (Table 11).

Chlorophyll content in the varieties were significantly different. Punjab Green (V_3) showed maximum chlorophyll content (0.34 mg g^{-1}), which was significantly superior to all other varieties. The content was lowest in IndamKolkatta (0.21 mg g^{-1})

Nutrient levels significantly influenced the chlorophyll content, N_3 showed maximum chlorophyll content (0.31 mg g^{-1}) which was superior than that recorded with the other two nutrient levels N_1 (0.21 mg g^{-1}) and N_2 (0.24 mg g^{-1}).

The interaction effect was also significant. The combination of Punjab Green at N_3 showed maximum content of 0.43 mg g^{-1}, significantly superior to all other interactions. This was followed by the interaction v_3n_2 (0.35 mg g^{-1}).

4.1.5 Protein

The variations in the protein content in spinach beet as influenced by varieties, nutrient doses and interactions are given in Table 11.

The varietal influence on protein content was significant with Punjab Green recording the maximum protein content (23.78 %) followed by Pusa Bharathi (22.66 %) and Indam Kolkatta (22.44 %), where the latter recorded on a par value with Trendy (21.68%).

The nutrient levels also significantly influenced the protein content. The highest dose (N_3) recorded a protein content of 23.81 per cent that was significantly superior to the other two nutrient doses.

The interaction effect was non significant.

Table 11. Effect of varieties, nutrient doses and interaction on shelf life, total chlorophyll and protein content in spinach beet grown in polyhouse

Treatments	Shelf life (days)	Chlorophyll (mg g^{-1})	Protein (%)
Varieties (V)			
V_1 (All Green)	1.61	0.28	22.14
V_2 (Pusa Bharathi)	1.85	0.22	22.66
V_3 (Punjab Green)	2.03	0.34	23.78
V_4 (Indam Kolkatta)	1.75	0.21	22.44
V_5 (Trendy)	1.93	0.23	21.68
SEm (±)	0.15	0.002	0.178
CD (0.05)	-	0.007	0.549
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	1.81	0.21	21.27
N_2 (60:30:60)	1.73	0.24	22.53
N_3 (80:40:80)	1.96	0.31	23.81
SEm (±)	0.10	0.001	0.183
CD (0.05)	-	0.004	0.529
Interactions (vn)			
v_1n_1	1.50	0.27	21.17
v_1n_2	1.68	0.26	21.35
v_1n_3	1.65	0.31	23.9
v_2n_1	1.63	0.18	21.27
v_2n_2	1.99	0.2	22.85
v_2n_3	1.95	0.27	23.86
v_3n_1	2.00	0.24	22.11
v_3n_2	1.36	0.35	23.7
v_3n_3	2.74	0.43	25.54
v_4n_1	1.60	0.18	21.26
v_4n_2	1.88	0.19	22.97
v_4n_3	1.77	0.27	23.08
v_5n_1	2.34	0.21	20.54
v_5n_2	1.75	0.22	21.8
v_5n_3	1.69	0.28	22.69
SEm (±)	0.22	0.003	0.409
CD (0.05)	0.661	0.008	-

4.1.6 Dry Matter Production (DMP)

The variations in DMP as influenced by varieties, nutrient doses and their interactions are shown in Table 12.

The effects were significant for the varieties with Punjab Green (V_3) recording the significantly highest dry matter production of 37.22 g plant^{-1}, followed by All Green (31.34 g plant^{-1}) and Trendy, the lowest (24.40 g plant^{-1}).

Among nutrient levels, the significantly highest DMP was observed in N_3 (30.40 g plant^{-1}) followed by N_2 (28.65 g plant^{-1}) and N_1 (26.96 g plant^{-1}).

Interaction effects were non significant.

4.1.7 Uptake of NPK

The results on the effect of varieties, nutrient doses and their interaction on uptake of nutrients are depicted in Table 12.

The nutrient uptake plant^{-1} was significantly high in Punjab Green (1.41 g N, 0.43 g P and 1.84 g K) followed by All Green (1.13 g N, 0.36 g P and 1.49 g K). The nutrient uptake was lowest in Trendy (0.47 g N, 0.20 g P and 1.09 g K).

Nutrient levels influenced the uptake significantly. The uptake of N, P and K,each followed the order $N_3>N_2>N_1$.

The interaction effect was also significant with v_3n_3 (Punjab Green at 80:40:80 kg NPK ha^{-1}) registering the significantly highest uptake (1.61 g N, 0.46 g P and 2.04 g K).

4.1.8 Vitamin C

Variations in vitamin C content as influenced by varieties, nutrient levels and interactions are presented in Table 13.

Vitamin C content of the varieties varied significantly and Pusa Bharathi showed the significantly highest value (24.47 mg 100 g^{-1}) on a par with Punjab Green (22.81 mg 100 g^{-1}).

Significant differences were observed in vitamin C content with the different levels of nutrients. N_3 recorded the highest vitamin C (25.12 mg 100 g^{-1}) which was

Table 12. Effect of varieties, nutrient doses and interaction on dry matter production and NPK uptake in spinach beet grown in polyhouse, g plant $^{-1}$

Treatments	DMP	N uptake	P uptake	K uptake
Varieties (V)				
V_1 (All Green)	31.34	1.13	0.36	1.49
V_2 (Pusa Bharathi)	25.45	0.93	0.31	1.11
V_3 (Punjab Green)	37.22	1.41	0.43	1.84
V_4 (Indam Kolkatta)	24.95	0.70	0.25	1.09
V_5 (Trendy)	24.40	0.47	0.20	1.09
SEm (±)	0.28	0.01	0.003	0.02
CD (0.05)	0.873	0.034	0.008	0.051
Nutrient levels (N) kg ha^{-1}				
N_1 (40:20:40)	26.96	0.80	0.28	0.99
N_2 (60:30:60)	28.65	0.91	0.31	1.40
N_3 (80:40:80)	30.4	1.07	0.33	1.57
SEm (±)	0.17	0.006	0.002	0.012
CD (0.05)	0.478	0.017	0.007	0.033
Interactions (vn)				
v_1n_1	29.44	1.00	0.32	1.06
v_1n_2	31.10	1.08	0.37	1.59
v_1n_3	33.47	1.31	0.39	1.81
v_2n_1	23.24	0.80	0.28	0.64
v_2n_2	25.50	0.92	0.31	1.24
v_2n_3	27.60	1.06	0.34	1.45
v_3n_1	35.61	1.25	0.40	1.63
v_3n_2	37.00	1.38	0.43	1.85
v_3n_3	39.04	1.61	0.46	2.04
v_4n_1	23.24	0.59	0.24	0.82
v_4n_2	24.94	0.71	0.26	1.13
v_4n_3	26.68	0.80	0.25	1.31
v_5n_1	23.24	0.38	0.17	0.82
v_5n_2	24.73	0.46	0.20	1.19
v_5n_3	25.22	0.58	0.22	1.26
SEm (±)	0.37	0.01	0.01	0.03
CD (0.05)	-	0.038	0.015	0.076

Table 13. Effect of varieties, nutrient doses and interactions on vitamin C, vitamin A and nitrate content of spinach beet in polyhouse

Treatments	Vitamin C (mg 100 g^{-1})	Vitamin A (IU)	Nitrate content (%)
Varieties (V)			
V_1 (All Green)	19.66	18.60	0.106
V_2 (Pusa Bharathi)	24.47	16.93	0.107
V_3 (Punjab Green)	22.81	19.69	0.106
V_4 (Indam Kolkatta)	19.05	17.46	0.105
V_5 (Trendy)	19.94	15.30	0.104
SEm (±)	0.81	0.93	0.001
CD (0.05)	2.501	-	-
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	16.62	16.80	0.105
N_2 (60:30:60)	21.82	17.56	0.105
N_3 (80:40:80)	25.12	18.43	0.107
SEm (±)	0.74	0.75	0.001
CD (0.05)	2.128	-	-
Interactions (vn)			
v_1n_1	14.31	17.19	0.105
v_1n_2	19.92	17.87	0.105
v_1n_3	24.74	20.72	0.109
v_2n_1	19.87	17.65	0.106
v_2n_2	27.84	16.37	0.105
v_2n_3	25.71	16.79	0.110
v_3n_1	16.81	17.60	0.105
v_3n_2	21.19	21.65	0.104
v_3n_3	30.43	19.82	0.109
v_4n_1	14.67	15.72	0.105
v_4n_2	19.26	18.66	0.107
v_4n_3	23.23	18.01	0.105
v_5n_1	17.46	15.83	0.103
v_5n_2	20.86	13.27	0.105
v_5n_3	21.56	16.80	0.104
SEm (±)	1.65	1.67	0.002
CD (0.05)	-	-	-

significantly superior to other doses. Interaction effect was found to be non significant.

4.1.9 Vitamin A

Vitamin A content in spinach beet grown in polyhouse did not record any significant variation with the varieties and nutrient levels. Interaction effect was also non significant (Table 13)

4.1. 10 Nitrate content

The effects of varieties, nutrient levels and their interaction on the nitrate content were found to be non significant (Table 13).

4.1.11 Soil Properties

The effects of varieties, nutrient doses and their interactions on soil chemical properties after the experimentation are shown in Table 14 and 15.

4.1.11.1 Soil pH

The data on soil pH in Table 14 revealed that the varietal influence on pH was not significant. However, the nutrient levels were found to influence the pH significantly. The higher nutrient levels recorded higher values; N_3 recorded 5.34 and remained at par with N_2 (5.33).

The interaction effects were non significant.

4.1.11.2 Electrical Conductivity (EC)

The data on electrical conductivity of soil as influenced by varieties, nutrient levels and their interaction are presented in Table 14 and these were found to be non significant.

4.1.11.3 Organic carbon

The data pertaining to the variations in organic carbon content in soil furnished in Table 14 indicated that the effects were non significant.

Table 14. Effect of varieties, nutrient doses and interactions on soil pH, electrical conductivity and organic carbon in polyhouse

Treatments	Soil pH	Electrical Conductivity (dSm^{-1})	Organic Carbon (%)
Varieties (V)			
V_1 (All Green)	5.22	0.18	0.34
V_2 (Pusa Bharathi)	5.22	0.31	0.38
V_3 (Punjab Green)	5.21	0.14	0.44
V_4 (Indam Kolkatta)	5.36	0.18	0.40
V_5 (Trendy)	5.35	0.27	0.46
SEm (±)	0.07	0.05	0.04
CD (0.05)	-	-	-
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	5.15	0.17	0.46
N_2 (60:30:60)	5.33	0.18	0.39
N_3 (80:40:80)	5.34	0.28	0.36
SEm (±)	0.05	0.04	0.03
CD (0.05)	0.137	-	-
Interactions (vn)			
v_1n_1	5.15	0.14	0.41
v_1n_2	5.40	0.26	0.30
v_1n_3	5.11	0.13	0.30
v_2n_1	5.07	0.14	0.46
v_2n_2	5.18	0.19	0.45
v_2n_3	5.42	0.62	0.22
v_3n_1	5.13	0.14	0.46
v_3n_2	5.28	0.14	0.50
v_3n_3	5.22	0.14	0.38
v_4n_1	5.15	0.24	0.48
v_4n_2	5.34	0.13	0.30
v_4n_3	5.58	0.17	0.42
v_5n_1	5.27	0.26	0.48
v_5n_2	5.42	0.17	0.40
v_5n_3	5.35	0.37	0.50
SEm (±)	0.11	0.09	0.06
CD (0.05)	-	-	-

4.1.11. 4 Available Nitrogen

The varietal effect on available nitrogen content in soil after the experiment was found to be non significant (Table 15).

Among the nutrient doses, N_3 (80:40:80 kg NPK ha^{-1}) recorded significantly higher status of available nitrogen content in soil (204.35 kg ha^{-1}) followed by N_2(194.64 kg ha^{-1}).

The interaction effect was non significant.

4.1.11. 5 Available Phosphorus

The changes in available phosphorus content in soil with the varieties were found to be non significant.

Among the nutrient doses, N_3 recorded significantly superior status of available P (102.94 kg ha^{-1}) followed by N_2 (99.17 kg ha^{-1}) and the least by N_1 (93.52 kg ha^{-1}).

The interaction effect was non significant.

4.1.11.6 Available potassium

The effect of varieties on available potassium content in soil after the experiment was non significant, while that of the nutrient levels were significant. Among nutrient doses, N_3recorded the maximum value (343.28 kg ha^{-1}) and least soil K was recorded by N_1 (276.89 kg ha^{-1}).

The interaction effect was non significant.

4.1.12 Microclimate

The variations in the microclimate (temperature, relative humidity, light intensity and soil temperature) are presented graphically (Fig.4) and Appendix III. The air temperature inside the polyhouse ranged from 31.4to 33.5^{0}C while soil temperature revealed maximum value of 31^{0}C. The relative humidity recorded ranged between 90 and 95 per cent during the cropping period Light intensity measured during noon ranged between 31.1and 54.4 Klux during the cropping period.

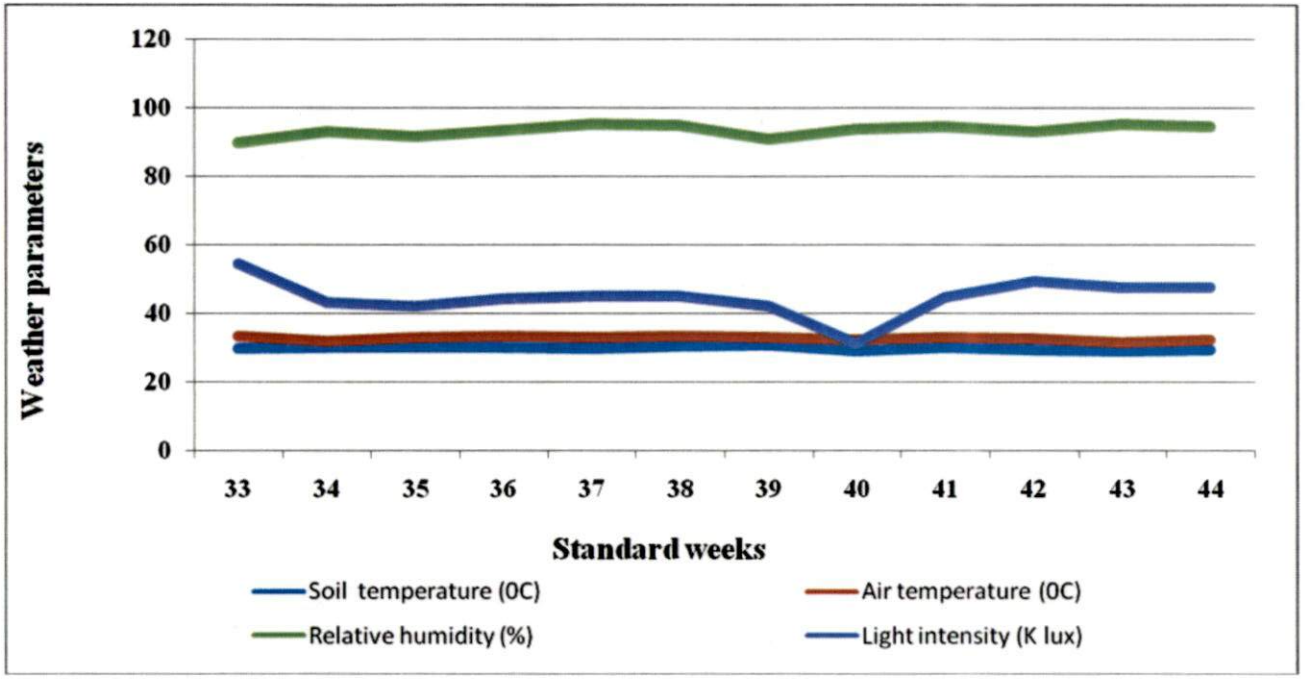


Fig . 4 . Weather data during the cropping period of poly house (2015)

Table 15. Effect of varieties, nutrient doses and interactions on soil available N, P and K status kg ha^{-1} under polyhouse condition

Treatments	Available N	Available P	Available K
Varieties (V)			
V_1 (All Green)	195.77	95.58	341.98
V_2 (Pusa Bharathi)	189.23	93.30	305.91
V_3 (Punjab Green)	191.96	104.88	339.27
V_4 (Indam Kolkatta)	190.25	96.53	289.52
V_5 (Trendy)	202.43	102.43	308.25
SEm (±)	3.92	2.88	12.93
CD (0.05)	-	-	-
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	182.80	93.52	276.89
N_2 (60:30:60)	194.64	99.17	330.79
N_3 (80:40:80)	204.35	102.94	343.28
SEm (±)	2.18	1.47	10.97
CD (0.05)	6.301	4.251	31.682
Interactions (vn)			
v_1n_1	189.44	89.76	334.91
v_1n_2	198.12	95.72	353.49
v_1n_3	199.77	101.27	337.52
v_2n_1	176.46	87.56	252.83
v_2n_2	191.48	90.75	374.94
v_2n_3	199.75	101.58	289.96
v_3n_1	174.52	99.82	326.64
v_3n_2	186.84	108.66	355.12
v_3n_3	214.52	106.15	336.06
v_4n_1	179.22	93.00	214.07
v_4n_2	187.97	96.67	317.08
v_4n_3	203.56	99.91	337.41
v_5n_1	194.38	97.47	255.99
v_5n_2	208.77	104.03	315.78
v_5n_3	204.14	105.77	352.99
SEm (±)	4.87	3.29	24.53
CD (0.05)	-	-	-

4.1.13 Economic Analysis

4.1.12.1 Net Income

The net income realized with the cultivation in 10 m^2area is presented in Table 16. Perusal of data showed that Punjab Green (V_3) recorded the highest net income (₹881.59)and was significantly superior to other varieties.

Among the nutrient levels, N_3 recorded the significantly highest net income (₹835.54)among the three levels.

Varieties x nutrient level interaction effects revealed that the interaction,v_1n_3, *ie.*, All Green combination with 80:40:80 kg NPK ha^{-1}, recorded the highest net income (₹1045.29) but on a par with Punjab Green at 80:40:80 kg NPK ha^{-1} (₹ 1015.45). The lowest income was registered by v_5n_1,*ie.,* Trendy at 40:20:40 kg NPK ha^{-1}(₹450.04).

4.1.12.2 Benefit : Cost Ratio (B:C ratio)

The data on B :C ratio as influenced by varieties, nutrient levels and their interaction are presented in Table 16.

Among the different varieties, Punjab Green (V_3) registered the highest B:C ratio of 1.44 and was on a par with All Green (V_1) that recorded a value of 1.38; but, significantly superior to all other varieties.

The effect of nutrient levels was found to be significant and among the nutrient levels, N_3 (80:40:80 kg NPK ha^{-1}) recorded superior value (1.42) compared to N_2 and N_1(1.33 and 1.27 respectively).

Interaction effect of All Green (V_1) at 80:40:80 kg NPK ha^{-1}(N_3) resulted in significantly superior B: C ratio (1.52) which was on a par with Punjab Green (V_3) at N_3combination (1.51).

4.2 UNDER OPEN CONDITIONS

4.2.1 Growth and Yield attributes

Table 16. Effect of varieties, nutrient levels and interactions on net income and B:C ratio in polyhouse cultivation of spinach beet

Treatments	Net income (₹ $10m^{-2}$)	B:C ratio
Varieties (V)		
V_1(All Green)	748.52	1.38
V_2 (Pusa Bharathi)	635.21	1.32
V_3 (Punjab Green)	881.59	1.44
V_4 (Indam Kolkatta)	671.86	1.33
V_5 (Trendy)	450.04	1.22
SEm (±)	34.27	0.02
CD (0.05)	105.597	0.053
Nutrient levels (N) (kg ha^{-1})		
N_1 (40:20:40)	531.03	1.27
N_2 (60:30:60)	665.76	1.33
N_3 (80:40:80)	835.54	1.42
SEm (±)	20.59	0.01
CD (0.05)	59.472	0.031
Interactions (vn)		
v_1n_1	480.74	1.24
v_1n_2	719.52	1.36
v_1n_3	1045.29	1.52
v_2n_1	589.49	1.30
v_2n_2	640.78	1.32
v_2n_3	675.37	1.34
v_3n_1	764.11	1.38
v_3n_2	865.20	1.44
v_3n_3	1015.45	1.51
v_4n_1	535.52	1.27
v_4n_2	646.29	1.32
v_4n_3	833.79	1.41
v_5n_1	285.32	1.14
v_5n_2	456.99	1.22
v_5n_3	607.83	1.30
SEm (±)	46.04	0.02
CD (0.05)	136.287	0.068

4.2.1.1 Plant Height

The mean data on the effect of varieties, nutrient levels and their interactions on plant height of spinach beet cultivated in the open field are shown in Table 17.

Varieties showed significant variations in plant height at the different stages of growth upto final harvest, except at 60 DAT. Pusa Bharathi recorded significantly taller plants in the early stages, 15 and 30 DAT (21.28 and 24.60 cm respectively) and All Green at 45DAT (26.42 cm) and at final harvest (24.18 cm).

The influence of nutrient levels was found to be significant at 15, 30, 45 DAT and at harvest. The highest dose N_3 (80:40:80 kg NPK ha^{-1}), resulted in taller plants and the shortest plants were noticed in N_1 (40:20:40 kg NPK ha^{-1}). Although non significant at 60 DAT, the plant height was the highest in N_3 treatment .

The interaction effect of varieties and nutrient levels was found to be significant only at 45 DAT. Maximum plant height was recorded in v_1n_1 (29.40 cm) on par with v_3n_3 (27.08 cm) and significantly superior to other interactions at this stage.

4.2.1.2 Number of Leaves Plant^{-1}

The data on the effect of varieties, nutrient levels and their interaction on number of leaves plant^{-1} (Table 18) revealed that the varieties had significant influence at 30 and 60 DAT, while it remained non significant at 15, 45 DAT and at final harvest.

The total number of leaves plant^{-1} was the highest in All Green (27.1) and significantly superior to all other varieties.

The effect of nutrient levels was significant at 15 and 45 DAT. The leaf number plant^{-1} was significantly the highest with the highest nutrient level, 80:40:80 kg NPK ha^{-1} (26.2). The number was found to be less with the lower NPK levels.

Variations due to interaction effects in leaf number were significant only at 30 DAT. The interaction v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) was significantly superior and registered 7.06 leaves plant^{-1} which was on a par with v_2n_2 (Pusa

Table 17.Effect of varieties, nutrient doses and interactions on plant height in open, cm

Treatments	Plant height				
	15 DAT	30 DAT	45 DAT	60 DAT	At final harvest
Varieties (V)					
V_1(All Green)	15.18	22.31	26.42	25.23	24.18
V_2 (Pusa Bharathi)	21.28	24.60	25.94	24.85	22.54
V_3 (Punjab Green)	19.18	19.18	22.17	25.53	24.01
V_4 (Indam Kolkatta)	15.32	17.30	23.18	24.02	22.32
V_5 (Trendy)	15.47	17.05	25.48	25.47	23.98
SEm (±)	0.25	0.36	0.40	0.41	0.45
CD (0.05)	0.771	1.112	1.241	-	1.401
Nutrient levels (N) kg ha^{-1}					
N_1 (40:20:40)	16.91	19.54	24.78	24.69	22.88
N_2 (60:30:60)	16.42	18.69	23.56	24.80	23.21
N_3 (80:40:80)	18.53	22.04	25.57	25.57	24.13
SEm (±)	0.45	0.60	0.39	0.30	0.33
CD (0.05)	1.311	1.732	1.121	-	0.962
Interactions (vn)					
v_1n_1	14.60	21.73	29.40	25.83	23.90
v_1n_2	13.09	20.80	23.95	25.25	24.43
v_1n_3	17.85	24.41	25.90	25.53	24.20
v_2n_1	23.15	26.40	26.55	23.98	20.53
v_2n_2	20.00	23.19	25.08	24.50	23.08
v_2n_3	20.70	24.21	26.20	26.08	24.03
v_3n_1	17.45	16.95	20.46	25.28	24.15
v_3n_2	19.11	16.11	18.98	24.93	23.50
v_3n_3	20.98	24.48	27.08	25.48	24.38
v_4n_1	14.90	16.20	22.08	23.00	21.53
v_4n_2	14.98	16.62	23.03	23.45	21.53
v_4n_3	16.08	19.09	24.45	25.60	23.90
v_5n_1	14.45	16.43	25.44	25.35	24.30
v_5n_2	14.91	16.73	26.75	25.88	23.50
v_5n_3	17.06	17.99	24.25	25.18	24.15
SEm (±)	1.01	1.34	0.86	0.66	0.74
CD (0.05)	-	-	2.561	-	-

DAT- Days After Transplanting

Table 18. Effect of varieties, nutrient doses and interactions on number of leaves plant^{-1} in open condition

Treatments	Number of leaves plant^{-1}					
	15 DAT	30 DAT	45 DAT	60 DAT	At final harvest	Total number
Varieties (V)						
V_1(All Green)	5.51	6.11	5.09	5.41	4.98	27.1
V_2 (Pusa Bharathi)	4.86	5.67	5.17	4.93	4.91	25.5
V_3 (Punjab Green)	5.19	5.44	5.01	4.83	4.50	25.0
V_4 (Indam Kolkatta)	4.66	4.89	4.91	5.34	4.50	24.3
V_5 (Trendy)	4.56	4.85	4.64	5.15	4.76	24.0
SEm (±)	0.23	0.22	0.20	0.11	0.16	0.4
CD (0.05)	-	0.689	-	0.331	-	1.27
Nutrient levels (N) kg ha^{-1}						
N_1 (40:20:40)	4.66	5.30	4.77	5.10	4.75	24.6
N_2 (60:30:60)	5.00	5.36	4.84	5.00	4.59	24.8
N_3 (80:40:80)	5.21	5.51	5.29	5.30	4.85	26.2
SEm (±)	0.14	0.14	0.15	0.18	0.14	0.4
CD (0.05)	0.418	-	0.430	-	-	1.05
Interactions (vn)						
v_1n_1	4.80	5.49	4.75	5.49	5.26	25.8
v_1n_2	5.48	5.77	5.25	5.00	4.45	26.0
v_1n_3	6.25	7.06	5.26	5.75	5.23	29.6
v_2n_1	4.78	5.04	4.72	5.00	4.99	24.5
v_2n_2	5.02	6.25	5.27	4.76	5.25	26.6
v_2n_3	4.78	5.72	5.51	5.02	4.50	25.5
v_3n_1	4.79	6.00	4.82	4.74	4.75	25.1
v_3n_2	5.28	5.56	4.98	4.74	4.00	24.6
v_3n_3	5.50	4.74	5.24	5.00	4.77	25.2
v_4n_1	4.49	4.99	5.05	5.24	3.99	23.8
v_4n_2	4.51	4.98	4.21	5.28	4.49	23.5
v_4n_3	4.99	4.71	5.49	5.51	5.00	25.7
v_5n_1	4.46	4.97	4.50	5.01	4.74	23.7
v_5n_2	4.70	4.26	4.48	5.20	4.78	23.4
v_5n_3	4.53	5.31	4.94	5.23	4.76	24.8
SEm (±)	0.32	0.32	0.33	0.40	0.31	0.8
CD (0.05)	-	0.939	-	-	-	-

DAT- Days After Transplanting

Bharathi at 60:30:60 kg NPK ha^{-1}), 6.25 leaves $plant^{-1}$ and least number of 4.26 leaves $plant^{-1}$ was observed in the combination v_5n_2 (Trendy at 60:30:60 kg NPK ha^{-1}).

The interaction effect on the total number of leaves $plant^{-1}$ was non significant.

4.2.1.3 Leaf Area Index (LAI)

Table 19 depicts the influence of variety, nutrient levels and interaction on LAI. The LAI, in general, increased with age and was highest at 45 DAT and thereafter declined.

The LAI at 30 DAT was significantly influenced by varieties and the variety Indam Kolkatta recorded the highest LAI (0.66) on a par with Pusa Bharathi (V_2) and All Green (V_1), the values being 0.64 and 0.63 respectively. The other varieties showed significantly lower values and the lowest was in Trendy (V_5).

At 45, 60 DAT and at final harvest, the variety All Green recorded highest LAI while Trendy showed the lowest.

Among the nutrient levels, N_3 (80:40:80 kg $NPKha^{-1}$) registered the highest LAI at all the stages of growth. LAI at 60:30:60 and 40:20:40 kg NPK ha^{-1} were significantly lower and on a par with each other.

Interaction effects were significant at all stages and the combined effect of All Green at the highest NPK dose (v_1n_3) recorded maximum value at all stages.

4.2.1.4 Days to Harvest

The variations in the number of days to each harvest in the different varieties at varying doses of NPK were non significant (Table 20). The duration of the varieties in the open ranged from 67.49 (Indam Kolkatta) to 69.40 days (Pusa Bharathi) after transplanting.

4.2.1.5 Harvesting Interval

The effect of varieties, nutrient levels and their interaction on harvesting interval of spinach beet are shown in Table 21.

Table 19. Effect of varieties, nutrient doses and interactions on Leaf Area Index (LAI) at different stages in open condition

	LAI			
Treatments	30 DAT	45 DAT	60 DAT	At final Harvest
Varieties (V)				
V_1(All Green)	0.63	1.06	1.18	0.90
V_2 (Pusa Bharathi)	0.64	1.04	0.96	0.81
V_3 (Punjab Green)	0.58	0.98	0.92	0.77
V_4 (Indam Kolkatta)	0.66	0.99	0.94	0.74
V_5 (Trendy)	0.50	0.89	0.80	0.70
SEm (±)	0.01	0.02	0.01	0.01
CD (0.05)	0.029	0.051	0.038	0.031
Nutrient levels (N) kg ha^{-1}				
N_1 (40:20:40)	0.53	0.92	0.83	0.67
N_2 (60:30:60)	0.60	0.96	0.91	0.75
N_3 (80:40:80)	0.68	1.09	1.14	0.93
SEm (±)	0.01	0.02	0.01	0.01
CD (0.05)	0.029	0.058	0.027	0.041
Interactions (vn)				
v_1n_1	0.45	1.05	1.05	0.77
v_1n_2	0.66	0.91	1.13	0.85
v_1n_3	0.78	1.21	1.35	1.07
v_2n_1	0.64	0.92	0.77	0.74
v_2n_2	0.56	0.98	0.85	0.80
v_2n_3	0.70	1.21	1.28	0.90
v_3n_1	0.44	0.91	0.84	0.65
v_3n_2	0.63	0.99	0.91	0.64
v_3n_3	0.66	1.04	1.02	1.03
v_4n_1	0.71	0.92	0.84	0.68
v_4n_2	0.64	1.05	0.91	0.76
v_4n_3	0.63	1.01	1.06	0.79
v_5n_1	0.38	0.80	0.68	0.52
v_5n_2	0.48	0.88	0.73	0.69
v_5n_3	0.62	0.99	1.00	0.89
SEm (±)	0.02	0.05	0.02	0.03
CD (0.05)	0.068	0.142	0.058	0.102

DAT- Days After Transplanting

Table 20.Effect of varieties, nutrient doses and interactions on days to harvest and crop duration in open condition

Treatments	Days to harvest			
	First	Second	Third	Crop duration
Varieties (V)				
V_1(All Green)	29.28	42.44	56.44	68.44
V_2 (Pusa Bharathi)	29.99	43.40	57.40	69.40
V_3 (Punjab Green)	28.04	41.60	55.60	67.60
V_4 (Indam Kolkatta)	28.49	41.49	55.49	67.49
V_5 (Trendy)	29.32	41.76	55.76	67.76
SEm (±)	0.4	0.45	0.45	0.45
CD (0.05)	1.228	-	-	-
Nutrient levels (N) kg ha^{-1}				
N_1 (40:20:40)	27.78	41.78	55.78	67.78
N_2 (60:30:60)	28.36	42.36	56.36	68.36
N_3 (80:40:80)	28.27	42.27	56.27	68.27
SEm (±)	0.36	0.36	0.36	0.36
CD (0.05)	-	-	-	-
Interactions (vn)				
v_1n_1	28.73	42.73	56.73	68.73
v_1n_2	28.53	42.53	56.53	68.53
v_1n_3	28.05	42.05	56.05	68.05
v_2n_1	28.03	42.03	56.03	68.03
v_2n_2	29.72	43.72	57.72	69.72
v_2n_3	30.45	44.45	58.45	70.45
v_3n_1	27.30	41.30	55.30	67.30
v_3n_2	27.51	41.51	55.51	67.51
v_3n_3	28.00	42.00	56.00	68.00
v_4n_1	27.08	41.08	55.08	67.08
v_4n_2	28.39	42.39	56.39	68.39
v_4n_3	27.00	41.00	55.00	67.00
v_5n_1	27.74	41.74	55.74	67.74
v_5n_2	27.67	41.67	55.67	67.67
v_5n_3	27.87	41.87	55.87	67.87
SEm (±)	0.80	0.80	0.80	0.80
CD (0.05)	-	-	-	-

Varietal variations in the number of days for subsequent harvest was significant for the first and second harvest. Punjab Green (V_3) and Indam Kolkatta (V_5) were ready for first harvest in 28 and 28.5 days after planting. Subsequent harvests were taken at 12.7 to 14.5 days interval in the different varieties.

The variations due to different doses of nutrient for all harvests and interaction of variety and nutrient were non significant, except for the last harvest.

4.2.1.6 Leaf Yield plant^{-1}

Perusal of data (Table 22) revealed significant variations in leaf yield plant $^{-1}$ with varieties, nutrient levels and their interactions.

The variety All Green (V_1) produced the highest yield 72.77 g plant^{-1}, significantly superior to variety Pusa Barathi (V_2) 65.74 g plant^{-1}, Indam Kolkatta (V_4) 65.63 g plant^{-1} and Punjab Green (V_3) 63.27 g plant^{-1}. The lowest yield was recorded in Trendy (V_5), 58.45 g plant $^{-1}$.

The yield plant^{-1} varied significantly with the different levels of nutrients, Maximum and significantly superior yield (69.96 g plant^{-1}) was recorded with the nutrient level N_3 followed by N_2 (64.96 g plant^{-1}) and N_1 (60.60 g plant^{-1}).

Variety and nutrient interactions influenced the leaf yield plant^{-1} significantly. Pusa Bharathi at 80:40:80 kg NPK ha^{-1} (v_2n_3) recorded the significantly highest yield (76.99 g plant^{-1}) on a par with v_1n_3 (74.47 g plant^{-1}). Irrespective of variety, the highest dose of NPK gave maximum per plant yields in spinach beet under open conditions.

4.2.1.7 Leaf Yield m^{-2}

The variations in the yield of spinach beet as influenced by varieties, nutrient doses and their interaction are given in Table 22.

The varietal influence on the leaf yield m^{-2} was significant. The variety, All Green (V_1) recorded maximum yield (3.9 kg m^{-2}) which was significantly superior to all other varieties. Pusa Bharathi (V_2) recorded the second highest yield (3.68 kg m^{-2}),

Table 21. Effect of varieties, nutrient doses and interactions on harvesting interval in open condition

Harvesting interval (days)				
Treatments	First	Second	Third	Final harvest
Varieties (V)				
V_1 (All Green)	29.28	14.50	13.17	13.34
V_2 (Pusa Bharathi)	29.99	14.39	13.58	13.66
V_3 (Punjab Green)	28.04	12.73	14.00	13.38
V_4 (Indam Kolkatta)	28.49	12.92	12.97	13.35
V_5 (Trendy)	29.32	13.88	13.32	13.77
SEm (±)	0.4	0.30	0.43	0.30
CD (0.05)	1.228	0.919	-	-
Nutrient levels (N) kg ha^{-1}				
N_1 (40:20:40)	28.59	13.76	13.31	13.65
N_2 (60:30:60)	29.19	13.98	13.37	13.35
N_3 (80:40:80)	29.29	13.31	13.54	13.49
SEm (±)	0.28	0.27	0.28	0.22
CD (0.05)	-	-	-	-
Interactions (vn)				
v_1n_1	29.23	13.77	12.97	13.77
v_1n_2	29.78	15.76	12.64	12.50
v_1n_3	28.84	13.97	13.90	13.74
v_2n_1	28.97	14.29	14.19	14.50
v_2n_2	29.99	14.87	13.94	13.24
v_2n_3	31.00	14.00	12.62	13.25
v_3n_1	27.36	13.05	13.53	12.50
v_3n_2	28.37	12.62	14.35	14.25
v_3n_3	28.38	12.53	14.12	13.38
v_4n_1	28.52	13.25	13.50	13.13
v_4n_2	28.08	13.32	12.58	14.27
v_4n_3	28.88	12.18	12.84	12.64
v_5n_1	28.85	14.45	12.38	14.34
v_5n_2	29.75	13.31	13.34	12.50
v_5n_3	29.37	13.87	14.24	14.45
SEm (±)	0.64	0.60	0.62	0.50
CD (0.05)	-	-	-	1.468

Table 22. Effect of varieties, nutrient doses and interactions on leaf yield in open condition

Treatments	Leaf yield (g plant^{-1})	(kg m^{-2})
Varieties (V)		
V_1(All Green)	72.77	3.93
V_2 (Pusa Bharathi)	68.75	3.67
V_3 (Punjab Green)	63.27	3.46
V_4 (Indam Kolkatta)	65.63	3.60
V_5 (Trendy)	63.31	3.42
SEm (±)	0.49	0.06
CD (0.05)	1.518	0.168
Nutrient levels (N) kg ha^{-1}		
N_1 (40:20:40)	63.58	3.48
N_2 (60:30:60)	65.49	3.64
N_3 (80:40:80)	71.17	3.73
SEm (±)	0.34	0.05
CD (0.05)	0.978	0.129
Interactions (vn)		
v_1n_1	70.63	3.83
v_1n_2	73.22	3.96
v_1n_3	74.47	4.02
v_2n_1	64.08	3.30
v_2n_2	65.18	3.55
v_2n_3	76.99	4.14
v_3n_1	61.86	3.39
v_3n_2	62.64	3.43
v_3n_3	65.32	3.56
v_4n_1	61.32	3.46
v_4n_2	64.28	3.79
v_4n_3	71.30	3.56
v_5n_1	60.04	3.41
v_5n_2	62.11	3.47
v_5n_3	67.79	3.38
SEm (±)	0.76	0.10
CD (0.05)	2.240	0.311

on a par with Indam Kolkatta V_4 (3.61 kg m^{-2}) and the variety Trendy (V_5), recorded the lowest leaf yield (3.42 kg m^{-2}).

The effect of the nutrient levels was also significant. The highest dose of NPK resulted in a significantly superior yield (3.73 kg m^{-2}), on a par with N_2 (3.60 kg m^{-2}) and significantly higher than N_1 (3.48 kg m^{-2}).

Interaction effect of varieties and nutrient doses on leaf yield m^{-2} was found to be significant. The interaction v_3n_3 (Pusa Bharathi at 80:40:80 kg NPK ha^{-1}) recorded a yield of 4.14 kg m^{-2} which was on a par with v_1n_3 (4.02 kg m^{-2}) and significantly superior to all other combinations. All the varieties recorded higher yields at the highest level of nutrients.

4.2.2 Nutrient Content

4.2.2.1 Nitrogen (N)

The varieties and nutrient doses exerted significant influence on nitrogen content in spinach beet (Table 23).

All Green (V_1) recorded the highest nitrogen content (3.05 %) followed by Trendy (2.82 %) and Pusa Bharathi (2.79 %). Punjab Green recorded the lowest nitrogen content (2.34 %).

Significantly higher values were recorded for the higher levels of nutrient tested. A maximum value of 3.05 per cent was recorded for N_3.

The interaction effect was found to be non significant.

4.2.2.2 Phosphorus (P)

The influence of variety, nutrient levels and their interaction on phosphorus content in spinach beet are presented in Table 23.

Phosphorus content was the highest in variety Trendy (0.90 %) followed by Pusa Bharathi (0.86 %) and Indam Kolkatta (0.82 %)

The higher level of nutrients (N_3) recorded maximum phosphorus content (1.34 %) and was significantly superior to the other two levels.

Interaction effect was non significant.

Table .23. Effect of varieties, nutrient doses and interactions on NPK content (%) in spinach beet grown under open condition

Treatments	N	P	K
Varieties (V)			
V_1(All Green)	3.05	0.80	4.31
V_2 (Pusa Bharathi)	2.79	0.86	3.89
V_3 (Punjab Green)	2.34	0.78	4.53
V_4 (Indam Kolkatta)	2.63	0.82	3.92
V_5 (Trendy)	2.82	0.90	4.04
SEm (±)	0.048	0.005	0.028
CD (0.05)	0.148	0.016	0.085
Nutrient levels (N)) kg ha^{-1}			
N_1 (40:20:40)	2.42	0.46	3.20
N_2 (60:30:60)	2.71	0.69	4.47
N_3 (80:40:80)	3.05	1.34	4.75
SEm (±)	0.077	0.005	0.022
CD (0.05)	0.222	0.014	0.063
Interactions (vn)			
v_1n_1	2.39	0.40	3.20
v_1n_2	3.29	0.43	4.72
v_1n_3	3.46	1.56	4.99
v_2n_1	2.40	0.43	2.36
v_2n_2	2.60	0.55	4.47
v_2n_3	3.36	1.59	4.84
v_3n_1	2.26	0.38	4.18
v_3n_2	2.29	0.46	4.60
v_3n_3	2.48	1.50	4.83
v_4n_1	2.44	0.54	3.12
v_4n_2	2.58	1.42	4.14
v_4n_3	2.89	0.52	4.49
v_5n_1	2.62	0.56	3.14
v_5n_2	2.77	0.62	4.41
v_5n_3	3.08	1.53	4.58
SEm (±)	0.172	0.011	0.049
CD (0.05)	-	0.032	0.145

4.2.2.3 Potassium (K)

The influence of varieties, nutrient levels and their interactions on potassium content are depicted in Table 23.

Varietal effect on potassium content was found to be significant. The variety Punjab Green(V_3) recorded maximum value (4.53%) and the least was recorded by Pusa Bharathi (V_2) , 3.89 per cent.

Nutrient levels significantly influenced the potassium content. The highest nutrient dose, N_3 recorded significantly superior K content (4.75%) followed by N_2 (4.47 %) and the lowest nutrient dose (N_1)resulted in the lowest value (3.20%) .

The influence of interactions was also significant. The interaction, v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) resulted in maximum K content (4.99 %) which was on a par with v_2n_3 (Pusa Bharathi at 80:40:80 kg NPK ha^{-1}) that recorded 4.84 % K.

4.2.2.4 Iron (Fe)

Fe content in spinach beet varied significantly with the varieties and nutrient levels, while interaction effects were non significant (Table 24).

Punjab Green (V_3) showed the highest value (0.66 mg kg^{-1}) on par with Pusa Bharathi and Trendy (0.61 mg kg^{-1} and 0.59 mg kg^{-1} respectively). All Green recorded significantly lower Fe content(0.53 mg kg^{-1}).

The nutrient dose, N_2 (60:30:60 kg NPK ha^{-1}) recorded the highest Fe (0.63 mg kg^{-1}) and was significantly superior to other doses. Interaction effect was non significant.

4.2.2.5 Calcium (Ca)

Nutrient levels alone caused significant variation in the Ca content in spinach beet grown in open condition (Table 24).

The highest nutrient level (N_3 - 80:40:80 kg NPK ha^{-1}) recorded the highest Ca content of 0.60 mg kg^{-1} and it was significantly superior to the other levels. Interaction effect was found to be non significant.

Table 24. Effect of varieties, nutrient doses and interactions on iron (Fe), calcium (Ca) and magnesium (Mg) content mg kg^{-1} in open condition

Treatments	Fe	Ca	Mg
Varieties (V)			
V1 (All Green)	0.53	0.57	0.20
V2 (Pusa Bharathi)	0.61	0.56	0.17
V3 (Punjab Green)	0.66	0.54	0.16
V4 (Indam Kolkatta)	0.56	0.55	0.19
V5 (Trendy)	0.59	0.52	0.14
SEm (±)	0.02	0.03	0.01
CD (0.05)	0.074	-	0.016
Nutrient levels (N)) kg ha^{-1}			
N1 (40:20:40)	0.52	0.51	0.17
N2 (60:30:60)	0.63	0.53	0.19
N3 (80:40:80)	0.61	0.60	0.15
SEm (±)	0.018	0.024	0.004
CD (0.05)	0.053	0.068	0.012
Interactions (vn)			
v1n1	0.44	0.58	0.19
v1n2	0.59	0.48	0.24
v1n3	0.55	0.64	0.17
v2n1	0.53	0.56	0.16
v2n2	0.65	0.56	0.17
v2n3	0.64	0.57	0.17
v3n1	0.67	0.51	0.17
v3n2	0.66	0.51	0.18
v3n3	0.65	0.60	0.14
v4n1	0.47	0.48	0.21
v4n2	0.59	0.52	0.21
v4n3	0.62	0.64	0.16
v5n1	0.51	0.44	0.14
v5n2	0.64	0.59	0.15
v5n3	0.61	0.54	0.13
SEm (±)	0.041	0.053	0.009
CD (0.05)	-	-	0.028

4.2.2.6 Magnesium (Mg)

Mg content in spinach beet as influenced by the varieties, nutrient levels and interactions are presented in Table 24.

The effect of varieties on Mg content was significant and All Green recorded the significantly highest content (0.20 mg kg^{-1}) which was on a par with Indam Kolkatta(0.19 mg kg^{-1}).

Among the nutrient levels, N_2 (60:30:60 kg NPK ha^{-1}) recorded maximum value (0.19 mg kg^{-1}),significantly higher than N_3(0.15 mg kg^{-1}) and N_1(0.17 mg kg^{-1}).

Interaction effect of varieties and nutrient levels was found to be significant. The highest Mg content was observed in v_1n_2*ie*., All Green at 60: :30:60 kg NPK ha^{-1} (0.24 mg kg^{-1}) compared to the other interactions.

4.2.3 Shelf Life

The data on influence of varieties, nutrient levels and their interaction on shelf life of spinach beet leaves are given in Table 25.

Varietal variations in the shelf life of the harvested leaves alone were significant. All Green showed higher shelf life (2.05 days) and Indam Kolkatta, the least (1.34 days).

4.2.4 Chlorophyll

The result on the effect of varieties, nutrient doses and interaction on chlorophyll content are presented in Table 25.

The variety, All Green recorded maximum chlorophyll content (0.33 mg g^{-1}) which was significantly superior to all other varieties. The lowest content was assessed in Punjab Green leaves (0.26 mg g^{-1}) .

The chlorophyll content varied significantly with the nutrient levels, the NPK level of N_3 recorded the highest value (0.31 mg g^{-1}) which was superior to the other two nutrient levels.

The interaction effect was also significant. The combination of All Green at 80:40:80kg NPK ha^{-1}showed maximum content (0.35 mg g^{-1}), significantly superior

Table 25. Effect of varieties, nutrient doses and interactions on shelf life, chlorophyll and protein content of spinach beet grown in open condition

Treatments	Shelf life (days)	Chlorophyll (mg g^{-1})	Protein (%)
Varieties (V)			
V_1 (All Green)	2.05	0.33	19.04
V_2 (Pusa Bharathi)	1.77	0.30	17.42
V_3 (Punjab Green)	1.95	0.26	14.65
V_4 (Indam Kolkatta)	1.34	0.28	16.46
V_5 (Trendy)	1.84	0.29	17.64
SEm (±)	0.11	0.001	0.30
CD (0.05)	0.33	0.004	0.926
Nutrient levels (N)) kg ha^{-1}			
N_1 (40:20:40)	1.68	0.27	15.13
N_2 (60:30:60)	1.96	0.29	16.91
N_3 (80:40:80)	1.73	0.31	19.09
SEm (±)	0.08	0.001	0.48
CD (0.05)	-	0.004	1.386
Interactions (vn)			
v_1n_1	2.22	0.31	14.93
v_1n_2	1.92	0.31	20.57
v_1n_3	2.01	0.35	21.63
v_2n_1	1.61	0.29	14.99
v_2n_2	1.82	0.31	16.25
v_2n_3	1.87	0.31	21.02
v_3n_1	1.8	0.25	14.11
v_3n_2	2.16	0.26	14.32
v_3n_3	1.88	0.29	15.52
v_4n_1	1.02	0.27	15.22
v_4n_2	1.89	0.29	16.10
v_4n_3	1.12	0.30	18.04
v_5n_1	1.75	0.25	16.40
v_5n_2	2.00	0.30	17.30
v_5n_3	1.77	0.30	19.23
SEm (±)	0.18	0.003	1.07
CD (0.05)	-	0.009	3.176

to other interactions. This was followed by the interaction v_1n_2 (0.32 mg g^{-1}), on a par with v_1n_1 (0.31 mg g^{-1}).

4.2.5 Protein

The variations in protein content in spinach beet as significantly influenced by varieties, nutrient levels and interaction are given in Table 25.

The varietal influence on protein content was significant with All Green recorded the maximum protein content (19.04 %) followed by variety Pusa Bharathi (17.12 %).

Nutrient levels significantly influenced the protein content, the highest level of 80:40:80 kg NPK ha^{-1} recorded the highest protein content (18.82%) and was significantly superior to the other two NPK doses. The lowest content was with the lowest dose (15.13%).

Among interactions, v_1n_3 recorded the significantly highest protein content (21.63%) on a par with v_2n_3(21.02%).

4.2.6 Dry matter production (DMP)

There was significant variation in the dry matter production with varieties, nutrient doses and their interactions (Table 26).

The variety All Green (V_1) recorded the significantly highest DMP (20.21 g $plant^{-1}$) and was on a par with Pusa Bharathi (V_2) that recorded dry matter yield of 20.09 g $plant^{-1}$.

The DMP was highest (21.02 g $plant^{-1}$) with the highest dose of nutrients and the lowest (16. 53 g $plant^{-1}$) with N_1.

Interaction effect was also significant. The interaction v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) recorded maximum value (24.16 g $plant^{-1}$) which was significantly superior to all other interactions. The lowest DMP was recorded by the interaction v_4n_1 (Indam Kolkatta at 40:20:40 kg NPK ha^{-1}), 14.33 g.

Table 26. Effect of varieties, nutrient doses and interactions on dry matter production and NPK uptake of spinach beet in open condition, g plant^{-1}

Treatments	DMP	N uptake	P uptake	K uptake
Varieties (V)				
V_1 (All Green)	20.21	0.63	0.18	0.89
V_2 (Pusa Bharathi)	20.09	0.56	0.18	0.79
V_3 (Punjab Green)	18.03	0.42	0.14	0.82
V_4 (Indam Kolkatta)	17.86	0.48	0.15	0.72
V_5 (Trendy)	17.20	0.49	0.16	0.71
SEm (±)	0.12	0.010	0.002	0.006
CD (0.05)	0.375	0.031	0.004	0.019
Nutrient levels (N)) kg ha^{-1}				
N_1 (40:20:40)	16.53	0.39	0.07	0.51
N_2 (60:30:60)	18.81	0.51	0.13	0.84
N_3 (80:40:80)	21.02	0.65	0.28	1.00
SEm (±)	0.07	0.014	0.001	0.005
CD (0.05)	0.203	0.042	0.004	0.015
Interactions (vn)				
v_1n_1	16.19	0.39	0.06	0.52
v_1n_2	20.27	0.67	0.09	0.96
v_1n_3	24.16	0.84	0.38	1.21
v_2n_1	18.50	0.44	0.08	0.44
v_2n_2	20.07	0.52	0.11	0.90
v_2n_3	21.14	0.71	0.34	1.02
v_3n_1	17.28	0.39	0.07	0.72
v_3n_2	18.61	0.43	0.09	0.86
v_3n_3	18.21	0.45	0.27	0.88
v_4n_1	14.33	0.35	0.08	0.45
v_4n_2	17.45	0.45	0.25	0.72
v_4n_3	21.79	0.63	0.11	0.98
v_5n_1	14.19	0.37	0.08	0.45
v_5n_2	17.64	0.49	0.11	0.78
v_5n_3	19.78	0.61	0.30	0.91
SEm (±)	0.16	0.032	0.003	0.012
CD (0.05)	0.464	0.095	0.008	0.035

4.2.7 Uptake of NPK

The results on the effect of varieties, nutrient doses and their interactions on uptake of nutrients, N, P and K are shown in Table 26.

4.2.7.1 Uptake of Nitrogen

The highest N uptake (0.63 g plant^{-1}) was observed in the variety All Green (V_1) and significantly superior to all other varieties. The uptake was significantly the highest in N_3(0.65 g plant^{-1}) and lowest (0.39 g plant^{-1}) in N_1.

The interaction effect was also significant with v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) registered maximum uptake (0.84 g plant^{-1}), significantly superior to all other interactions. Interaction v_4n_1 (Indam Kolkatta at 40:20:40 kg NPK ha^{-1}) recorded the lowest uptake (0.35 g plant^{-1}).

4.2.7.2 Uptake of Phosphorus

The variation was significant for varieties, nutrient doses and interactions. All Green and Pusa Bharathi ($V_1$and V_2) recorded significantly higher phosphorus uptake (0.18 g plant^{-1}), and the lowest value (0.14 g plant^{-1}) was recorded by variety Punjab Green.

Nutrient levels also influenced the P uptake significantly. N_3 (80:40:80 kg NPK ha^{-1}) recorded the highest value, 0.28 g plant^{-1} and N_1 (40:20:40 kg NPK ha^{-1}), the lowest uptake (0.07 g plant^{-1}).

Phosphorus uptake varied significantly with the interactions. Interaction v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) registered maximum uptake (0.38 g plant^{-1}) which was significantly superior to the uptake in all other interactions.

4.2.7.3 Uptake of Potassium

Potassium uptake also recorded a similar trend as nitrogen and phosphorus uptake. It was significantly superior in the variety All Green (0.89 g plant^{-1}) and at the highest dose (1.00 g plant^{-1}).

The interaction effect of v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) registered maximum value (1.21 g $plant^{-1}$) and v_5n_1 (Trendy at 40:20:40 kg NPK ha^{-1}), the least value (0.45 g $plant^{-1}$).

4.2.8 Vitamin C

The variations in vitamin C content in spinach beet as influenced by varieties, nutrient levels and interactions are shown in Table 27.

Vitamin C content of varieties varied significantly and All Green showed the highest content (30.21 mg 100 g^{-1}), significantly superior to Pusa Bharathi (28.16 mg 100 g^{-1}), Punjab Green (24.52 mg 100 g^{-1}), Trendy (27.64 mg 100 g^{-1}) and Indam Kolkatta (26.92 mg 100 g^{-1}).

The nutrient levels brought about significant variations in vitamin C content. N_3 (80:40:80 kg NPK ha^{-1}) recorded the highest vitamin C content (29.93 mg 100 g^{-1}) and was significantly superior to other doses.

Interaction effect was also found to be significant. Interaction v_1n_3 (All Green at 80:40:80 kg NPK ha^{-1}) recorded maximum content (31.70 mg 100 g^{-1}) which was on a par with the interaction v_2n_3 (Pusa Bharathi at 80:40:80kg NPK ha^{-1}), 31.37 mg 100 g^{-1} and significantly superior to other interactions.

4.2.9 Vitamin A

The influence of varieties, nutrient levels and interactions on Vitamin A content are presented in Table 27.

Vitamin A content was significantly influenced by varieties; variety All Green recorded maximum vitamin A (23.53 IU) which was on a par with Pusa Bharathi (23.13 IU). The least value was recorded by Indam Kolkatta (19.87 IU).

The effects of variety x nutrient level interaction were non significant.

4. 2.10 Nitrate

The influence of varieties, nutrient doses and their interaction on the nitrate content are depicted in Table 27.

Table 27. Effect of varieties, nutrient doses and interactions on vitamin C, vitamin A, and nitrate content of spinach beet grown in open condition

Treatments	Vitamin C (mg $100g^{-1}$)	Vitamin A (IU)	Nitrate (%)
Varieties (V)			
V_1 (All Green)	30.31	23.53	0.107
V_2 (Pusa Bharathi)	28.16	23.13	0.110
V_3 (Punjab Green)	24.52	20.90	0.109
V_4 (Indam Kolkatta)	26.92	19.87	0.108
V_5 (Trendy)	27.64	20.96	0.110
SEm (±)	0.27	0.49	0.001
CD (0.05)	0.823	1.518	-
Nutrient levels (N)) kg ha^{-1}			
N_1 (40:20:40)	25.49	21.38	0.107
N_2 (60:30:60)	27.10	21.43	0.108
N_3 (80:40:80)	29.94	22.22	0.112
SEm (±)	0.26	0.34	0.001
CD (0.05)	0.743	-	0.002
Interactions (vn)			
v_1n_1	29.66	23.19	0.106
v_1n_2	29.56	23.07	0.104
v_1n_3	31.71	24.32	0.112
v_2n_1	24.13	23.29	0.108
v_2n_2	28.98	23.58	0.109
v_2n_3	31.37	22.51	0.114
v_3n_1	22.06	20.62	0.106
v_3n_2	22.73	20.84	0.108
v_3n_3	28.79	21.24	0.113
v_4n_1	26.60	19.77	0.106
v_4n_2	26.22	20.36	0.108
v_4n_3	27.94	19.49	0.111
v_5n_1	25.01	20.02	0.108
v_5n_2	28.03	19.32	0.112
v_5n_3	29.88	23.55	0.110
SEm (±)	0.58	0.77	0.001
CD (0.05)	1.702	-	-

Varietal effect was found to be non significant. Nutrient levels registered significant influence on nitrate content. The highest nutrient dose (N_3) recorded highest value (0.112 %) followed by N_2(0.108%) and N_1(0.107 %).

Interaction effects were found to be non significant.

4.2.11 Soil properties

4.2.11.1 Soil pH

Data on soil pH presented (Table 28) revealed that there was no significant variation in soil reaction with varieties, nutrient levels and their interaction.

4.2.11.2 Electrical Conductivity (EC)

The effect of different varieties, nutrient levels and their interactions on electrical conductivity are shown in Table 28. Perusal of the data revealed that the varieties, nutrient levels and their interaction did not register any significant effect on EC.

4.2.11.3 Organic carbon

The data pertaining to variations in soil organic carbon content is furnished in Table 28 and it was evident that varieties, nutrient levels and their interactions exerted non significant influence on organic carbon status in soil

4.2.11.4 Available nitrogen

Available nitrogen content in soil after the experiment did not vary significantly with varieties (Table 29). However, the status increased with increase in NPK levels. The interaction effect was not significant.

4.2.11.5 Available phosphorus

The available phosphorus content in soil after the experiment is given in Table 29. Nutrient levels alone had significant influence and the soil P status (96.90 kg ha^{-1}) was significantly highest with the highest dose.

4.2.11.6 Available potassium

The changes in available potassium content in soil with different varieties and nutrient levels are presented in Table 29. As in the case of available N and P, K

Table 28. Effect of varieties, nutrient doses and interaction on soil pH, electrical conductivity and organic carbon content in open condition.

Treatments	Soil pH	Electrical Conductivity (dSm^{-1})	Organic Carbon (%)
Varieties (V)			
V_1 (All Green)	5.26	0.15	0.45
V_2 (Pusa Bharathi)	5.21	0.14	0.49
V_3 (Punjab Green)	4.88	0.13	0.39
V_4 (Indam Kolkatta)	4.90	0.13	0.45
V_5 (Trendy)	4.98	0.14	0.40
SEm (±)	0.099	0.01	0.02
CD (0.05)	-	-	-
Nutrient levels (N) kg ha^{-1}			
N_1 (40:20:40)	5.01	0.13	0.47
N_2 (60:30:60)	5.07	0.14	0.46
N_3 (80:40:80)	5.06	0.15	0.38
SEm (±)	0.081	0.01	0.03
CD (0.05)	-	-	-
Interactions (vn)			
v_1n_1	5.27	0.13	0.35
v_1n_2	5.42	0.15	0.58
v_1n_3	5.08	0.16	0.42
v_2n_1	5.19	0.13	0.46
v_2n_2	5.20	0.13	0.55
v_2n_3	5.25	0.15	0.46
v_3n_1	5.02	0.12	0.51
v_3n_2	4.80	0.13	0.34
v_3n_3	4.82	0.14	0.32
v_4n_1	4.89	0.13	0.51
v_4n_2	4.87	0.11	0.43
v_4n_3	4.93	0.16	0.42
v_5n_1	4.70	0.12	0.51
v_5n_2	5.03	0.16	0.42
v_5n_3	5.23	0.14	0.25
SEm (±)	0.182	0.01	0.07
CD (0.05)	-	-	-

Table 29. Effect of varieties, nutrient doses and interaction on soil available N, P and K in open condition, kg ha^{-1}

Treatments	Available N	Available P	Available K
Varieties (V)			
V_1(All Green)	193.24	94.74	313.92
V_2 (Pusa Bharathi)	197.86	93.54	345.49
V_3 (Punjab Green)	188.51	92.81	343.72
V_4 (Indam Kolkatta)	193.67	93.58	303.55
V_5 (Trendy)	181.91	94.16	319.91
SEm (±)	3.44	0.40	10.47
CD (0.05)	-	-	-
Nutrient levels (N)) kg ha^{-1}			
N_1 (40:20:40)	181.54	89.28	296.90
N_2 (60:30:60)	187.27	95.12	331.74
N_3 (80:40:80)	204.31	96.90	347.32
SEm (±)	2.26	0.68	8.20
CD (0.05)	6.537	1.958	23.684
Interaction (vn)			
V_1N_1	189.96	94.44	284.61
V_1N_2	193.48	94.28	354.21
V_1N_3	196.28	95.50	302.93
V_2N_1	191.72	86.73	328.94
V_2N_2	187.53	96.03	330.40
V_2N_3	214.34	97.86	377.15
V_3N_1	178.64	87.76	337.64
V_3N_2	181.24	93.47	323.30
V_3N_3	205.66	97.21	370.24
V_4N_1	176.49	87.99	264.01
V_4N_2	197.72	96.17	307.08
V_4N_3	206.81	96.57	339.57
V_5N_1	170.90	89.47	269.30
V_5N_2	176.39	95.63	343.70
V_5N_3	198.44	97.37	346.73
SEm (±)	5.06	1.52	18.34
CD (0.05)	-	-	-

status was significantly influenced by nutrient levels alone. A significant increase in K was recorded with increasing levels of NPK and the highest status of 347.32 kgha^{-1} was recorded in N_3.

4.2.12 Economic Analysis

4.2.12.1 Net Income

The data on net income realized with the cultivation in open field is presented in Table 30. Perusal of data on net income computed for 10 m^2 revealed that the variety All Green (V_3) could fetch the highest net income (₹ 371.38) and was significantly superior to the net income from the other tested varieties.

Among the nutrient levels, N_3 (80:40:80 kg NPK ha^{-1}) recorded the highest net income (₹ 318.67) followed by N_2 (₹150.36) and the lowest was computed in N_1 (₹ 101.97).

Varieties x Nutrient level interaction revealed that the combination v_1n_3 (Pusa Bharathiat 80:40:80 kg NPK ha^{-1}) produced the highest net income (₹495.39 10 m^2) which was significantly superior to all other combinations. The net income was lowest inv_2n_1 (Pusa Bharathi at 40:20:40 kg NPK ha^{-1}).

4.2.12.2 Benefit : Cost Ratio (B:C)

The variations in B: C ratio with varieties, nutrient levels and their interaction are presented in Table 30.

Among the different varieties All Green (V_1) registered the highest B:C ratio of 1.19 and it was significantly superior to all other varieties

Of the three nutrient doses tested, N_3 (80:40:80 kg NPK ha^{-1}) recorded maximum B: C ratio (1.16) compared to N_2 (1.08) and N_1 (1.05).

Interaction effect of Pusa Bharathi at 80:40:80 kg NPK ha^{-1} resulted in maximum B:C ratio of 1.25 which was on a par with All Green at 80:40:80 kg NPK ha^{-1} (1.21).

Table 30.Effect of varieties, nutrient levels and interaction on net income and B:C ratio of spinach beet grown under open conditions

Treatments	Net income (₹ha^{-1})	B:C ratio
Varieties (V)		
V_1(All Green)	371.38	1.19
V_2 (Pusa Bharathi)	220.04	1.11
V_3 (Punjab Green)	86.02	1.04
V_4 (Indam Kolkatta)	146.30	1.07
V_5 (Trendy)	127.93	1.01
SEm (±)	12.17	0.006
CD (0.05)	37.494	0.019
Nutrient levels (N)) kg ha^{-1}		
N_1 (40:20:40)	101.97	1.05
N_2 (60:30:60)	150.36	1.08
N_3 (80:40:80)	318.67	1.16
SEm (±)	11.28	0.006
CD (0.05)	32.570	0.016
Interactions (vn)		
v_1n_1	310.57	1.16
v_1n_2	385.21	1.19
v_1n_3	418.36	1.21
v_2n_1	21.68	1.01
v_2n_2	143.04	1.07
v_2n_3	495.39	1.25
v_3n_1	45.88	1.02
v_3n_2	66.90	1.03
v_3n_3	145.27	1.07
v_4n_1	60.45	1.03
v_4n_2	85.06	1.04
v_4n_3	293.39	1.15
v_5n_1	71.27	1.03
v_5n_2	71.58	1.03
v_5n_3	240.93	1.12
SEm (±)	25.22	0.012
CD (0.05)	74.639	0.037

Discussion

5. DISCUSSION

The experiment on "Productivity of spinach beet as influenced by varieties and nutrient doses" to assess the suitability of spinach beet varieties under protected and open conditions, to standardize the nutrient doses and to work out the economics was undertaken at College of Agriculture, Vellayani during 2015 and 2016. The results of the experiment are discussed briefly in this chapter.

5.1 INFLUENCE OF VARIETIES ON THE PERFORMANCE OF SPINACH BEET IN POLYHOUSE AND OPEN CONDITIONS

5.1.1 Growth and yield

Varieties differ in their genetic potential and, their productivity can vary in response to management practices. Spinach beet is a leafy vegetable suited to tropical and sub tropical climates. The results of the study revealed that the growth and yield attributes of spinach beet cultivated under protected and open conditions in general, varied significantly with the varieties

The variations among varieties in plant height (leaf height) under protected conditions (polyhouse) were significant at all stages except at 45DAT. Pusa Bharathi recorded significantly taller plants compared to other varieties. In the open field condition, taller plants were observed in All Green. This variation among varieties could be attributed due to the genetic variability in morphological characters of the varieties. Varalakshmi (2004) reported significant variations in plant height in vegetable Amaranthus accessions and had attributed this to the genetic nature of the plants.

Comparing the plant heights in the open and polyhouse, plants exhibited comparatively greater plant heights in the polyhouse compared to that in the open. The differential behavior of the varieties in the open and polyhouse could be

attributed to the environmental differences. The lower light intensities in the polyhouse (34- 51.39 K lux) compared to that in the open (82 - 93 K lux) might have encouraged elongation. Smitha and Sunil (2016) observed similar variations in cucumber grown in polyhouse and opined that this was due to lower light intensities. Low light intensities retarded the destruction of auxin (IAA) which encouraged cell division and cell expansion in the apical portion, leading to greater plant height. These results are supported by earlier research findings (El-Aidy *et al.*, 1988; Abou Habid *et al.*,1994; Ramesh and Arumugam,2010).

Yield attributes in spinach beet included in the study were leaf size, leaf number, LAI and number of harvests. Varieties differed significantly in yield both in the polyhouse and open conditions.

The highest yield (83.31g plant^{-1} and 4.78 kg m^{-2}) was recorded in the variety Punjab Green in the polyhouse which was significantly superior to all other varieties(Fig.5). Tender leaves constitute the economic part of spinach beet. Mean data on the total number of leaves plant $^{-1}$ (36.1) and LAI were significantly higher for Punjab Green. The LAI for Punjab Green remained significantly superior to other varieties at all stages (Table 5). It was the highest at 45 DAT indicating maximum growth of the crop in the polyhouse. All Green recorded the second highest yield (4.56 kg m^{-2}) and the least was noticed in Trendy (4.05 kg m^{-2}).

The variety All Green was found to be the highest yielder under open condition (72.77g plant^{-1}, 3.93 kg m^{-2}). The number of leaves produced plant $^{-1}$ (27.1) and LAI computed were also the highest in this variety. The higher yield recorded can thus be related to the above observations.

The varietal performance varied with the growing condition. In general, yield of spinach beet was more in the polyhouse compared to that in the open. The differences in leaf number and yield recorded among varieties might be due to the inherent characters of the individual varieties and microclimatic variations in growing environment. Similar observations on the wide variation in vegetative growth among

varieties were reported by earlier investigators (Damato, 2000 ;Abou El-Magd *et al.*, 2006). It is assumed that the lower solar radiation throughout the different growth stages in the polyhouse promoted leaf expansion which is needed for better light interception. This is in agreement with findings of Watson (1952). Leaf Area Index (LAI) is a measure of the photosynthetic area of the plant per unit area of land. Lower solar radiation within the polyhouse and rain shelter was the most important factor that influenced height and LAI in the crops grown in these structures (Kotadia *et al*, 2012; Smitha and Sunil, 2016) and it was interpreted that this led to greater vegetative vigour, better photosynthate accumulation and increased biomass production in protected structures when compared to the crops in the open field. This is in confirmation with the reports of Heuvelink (1999) and Rajasekar *et al.* (2013).

Irrespective of the varieties, crop duration was more in the polyhouse (87 to 90 days) while in the open field, duration was lesser (67 to 69 days). However, first harvest could be taken in 27 to 29 days both in the open and polyhouse. As the two experiments were conducted in two different years (2015 and 2016), a statistical comparison on the performances under the two growing conditions could not be made. Nevertheless, it can be presumed that the favorable microclimate for vegetative growth, high rate of carbon dioxide utilization, protection from the abiotic stresses and thus the favourable environment would have prolonged the spinach beet growth in the polyhouse resulting in increased crop duration.

Temperature, light and humidity play a vital role for the growth and development of crops. Misra and Pathania (2000) opined that in a protected environment, shading reduces light intensity and cools the microclimate inside the greenhouse. It is interpreted that the CO_2 released by the plants during night hours also gets trapped inside, which leads to increased photosynthesis during daytime. Sirohi and Behera (2000) added that the evaporation from the soil and plants also raises the humidity inside. All these had a bearing on the growth and yielding ability of the crop. Monitoring the temperature, relative humidity and light intensity inside

the polyhouse, it was found that the former two were greater and light intensity was lower than in the open field which would have been favorable for the growth of spinach beet (Fig.4).The variations noticed is in concurrence with that reported by Agarwal *et al.* (2003). The period from August to October in 2015 experienced heavy rains , a total of 826.3 mm during the three months (Fig 1). The heavy rainfall that occurred during the first month (Fig.1) affected the crop establishment and early stage of crop in the open field which affected the performance of the crop outside during this season. Hence, the crop was re-sown in 2016.

Comparing the microclimate in the polyhouse with that outside during the cropping period in the two conditions, open RH was 5.5 to 12.5 per cent greater, temperature 2- 4^0 C higher and light intensity 25 to 55 K lux less in the (Fig. 3). Crops cultivated in the open conditions are subjected to the unexpected changes in weather elements and have to supersede the effects so as to yield substantially. In this respect also the crop in the polyhouse was in an advantageous position.

Differential behavior of varieties under open and polyhouse conditions have been documented by Wani *et al.* (2011) in tomato. In their study, the varieties that recorded the highest yield in the polyhouse could only be the third highest yielder in the open field.

5.1.2 **Shelf life, quality and nutrient uptake in spinach beet**

There was no significant variation among varieties in the shelf life of leaves from the polyhouse under ambient conditions, while when grown in the open, All Green had a significantly better shelf life (2.05 days) compared to the other varieties. Retention of moisture and hence turgidity is an important determinant of the better shelf life of green leaves. Potassium content and uptake has paramount importance in this aspect and Table 26.illustrates the significantly highest uptake of K (0.89 g $plant^{-1}$) in All Green among the varieties grown in the open. The higher K content might have improved the water relations in the leaf leading to better turgidity and shelf life.

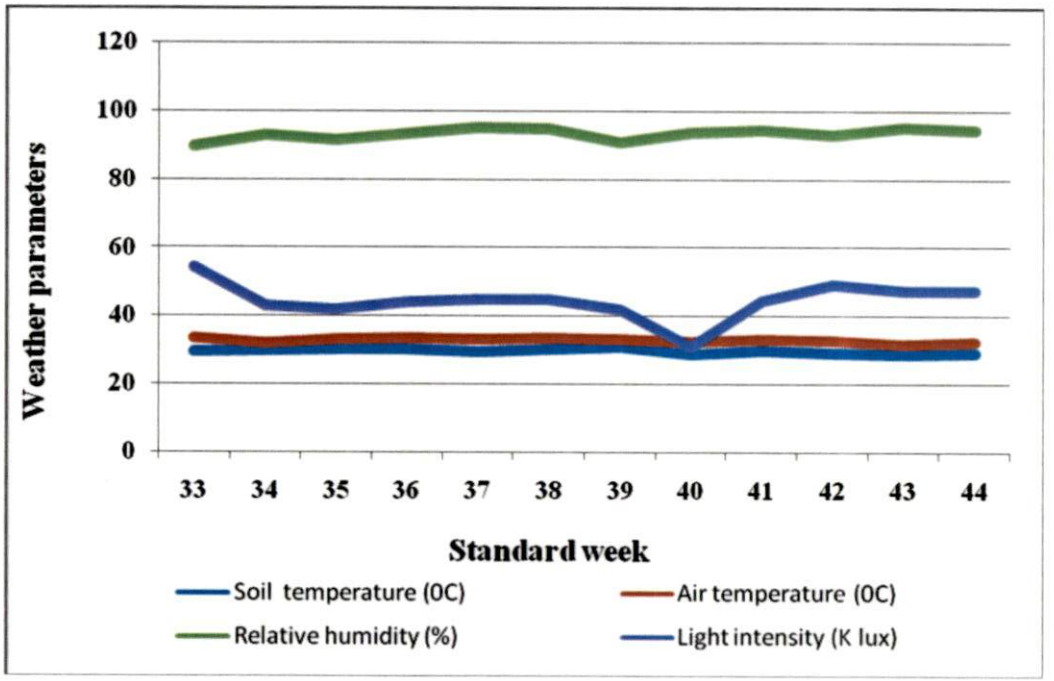


Fig. 4. Weather data during the cropping period in polyhouse (2015)

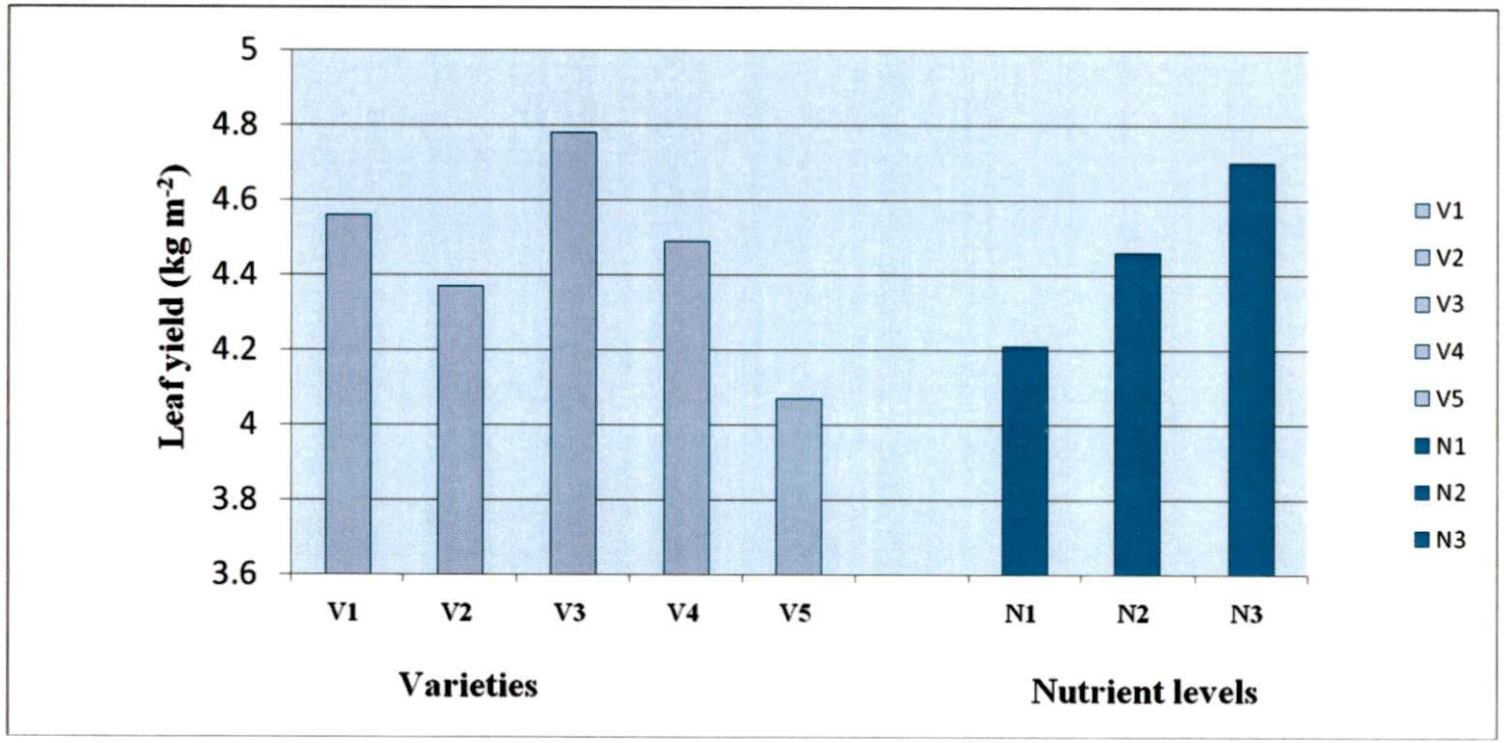


Fig .5. Effect of varieties and nutrient doses on leaf yield in polyhouse

Spinach beet is widely regarded as a protective food which enriches human diet with additional nutritive values. Green colour is a quality trait in leafy vegetables. Chlorophyll that is responsible for the green colour was significantly high in the leaves of variety Punjab Green in polyhouse and the variety All Green in the open (Fig.6 & 7). This corresponds to the higher N and Mg contents recorded by the two varieties in the specified growing condition. Tisdale *et al.* (1990) have documented the significant role of nitrogen and magnesium in chlorophyll development and photosynthesis. It is well known that the photosynthetic activity in plants is based on the quantity of chloroplast pigment, which is directly proportional to the amount of photosynthetic area of the leaves. The higher chlorophyll content also contributed to the higher photosynthate production and higher yields in these varieties.

Corresponding to the nitrogen content, the crude protein content was significantly the highest in the variety Punjab Green in polyhouse and All Green in open. Prakash (1999) had reported crude protein in All Green variety to range from 25 to 42 per cent. The high protein content in spinach beet upholds its nutritive value among vegetables.

According to Anjana and Iqbal (2007), although leafy vegetables occupy a very important place in the human diet, it constitutes a group of foods which contributes maximally to nitrate consumption by human beings. This was based on their earlier study on samples of leafy vegetables collected from the local markets of Delhi which had revealed that a significant number of spinach and chenopodium samples contained nitrate in concentrations higher than the Acceptable Daily Intake (ADI) limit which is 0-3.7 mg kg^{-1} body weight. In this regard, the nitrate content in the spinach beet varieties assume importance. The results of the present study indicated that the nitrate content in the varieties was in the range 0.104-.0.107 per cent in polyhouse and 0.107-0.110 per cent in open, but, there was no significant variation among the varieties in each condition.

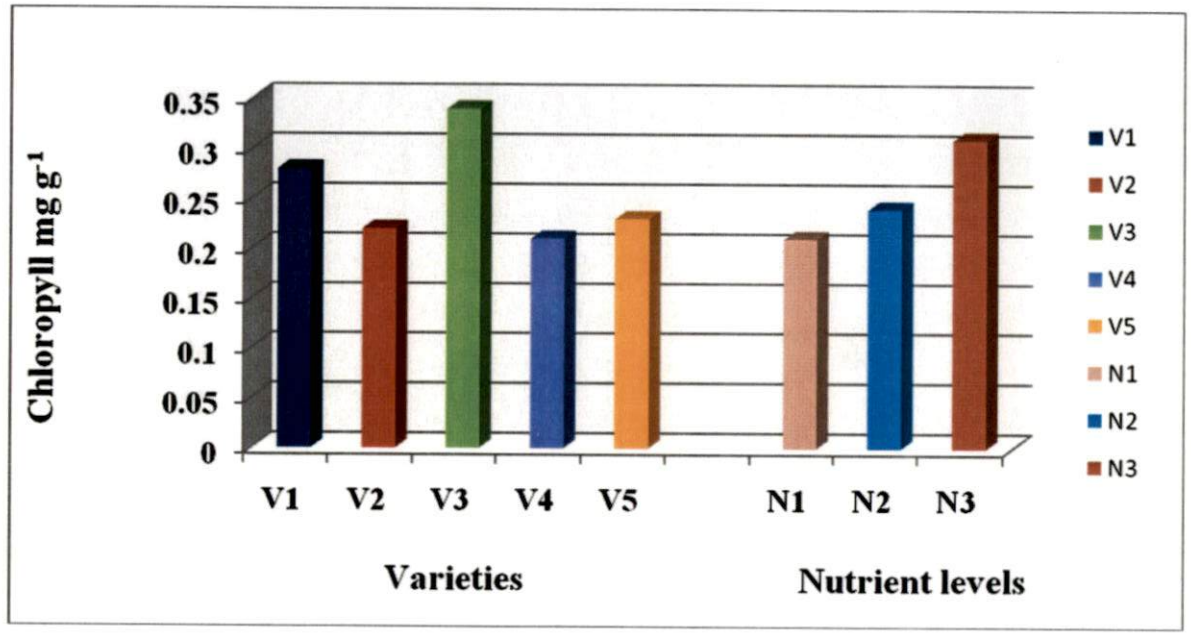


Fig. 6. Effect of varieties and nutrient doses on chlorophyll content of spinach beet in polyhouse

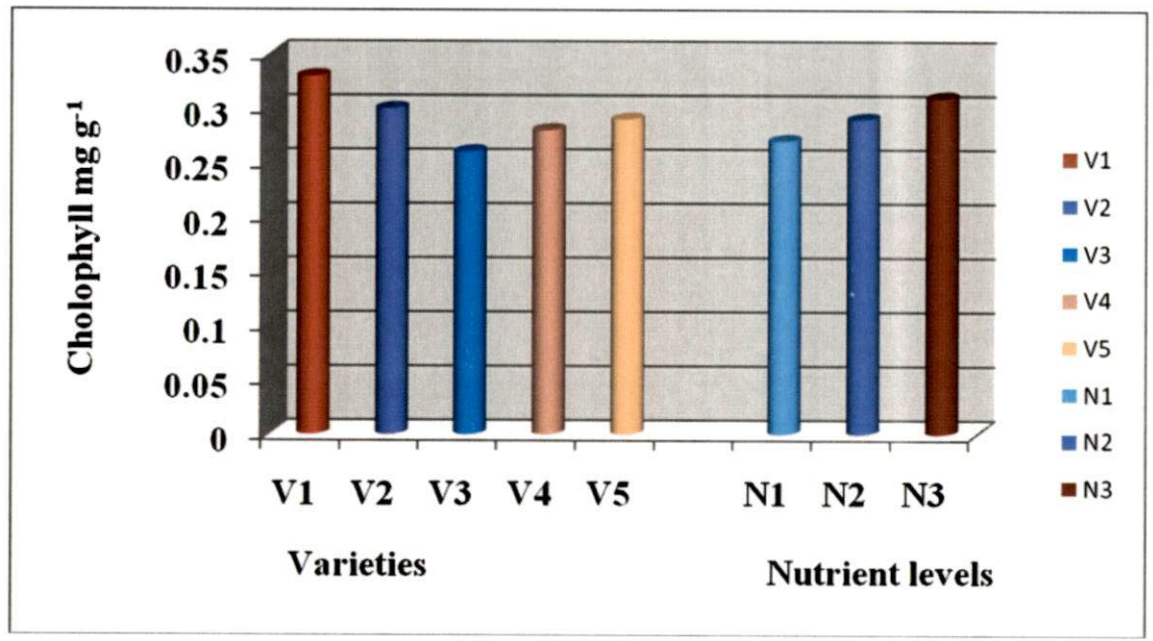


Fig. 7. Effect of varieties and nutrient doses on chlorophyll content in spinach beet under open condition

Spinach beet is rich in vitamin A and vitamin C. Biochemical analysis of the leaf samples and statistical analysis of the data revealed that the varieties did not record any significant difference in vitamin A content in the polyhouse, while in the open, the varieties showed variations that were significant. All Green recorded the significantly highest content (23.53 IU). The report that on fresh weight basis, β-carotene concentration increased in spinach and lettuce when exposed to high light intensity (Oyama *et al.*,1999) supports the observation recorded in this study, the values of vitamin A being more in the open (19.87 to 23.53 IU) compared to that in polyhouse crop (15.30 to 19.69 IU) .

Varieties varied significantly in their vitamin C (ascorbic acid) content, Pusa Bharathi showed the highest value (24.47 mg 100 g^{-1}) on a par with Punjab Green (22.81 mg 100g^{-1}). In the open, All Green recorded significantly higher vitamin C content (30.31 mg 100 g^{-1}) and was on par with that in Pusa Bharathi.

Comparison of ascorbic acid content in spinach beet grown in the open and polyhouse revealed higher content in the former (26.92-31.31 mg 100 g^{-1}) while in the polyhouse it ranged from 19.05- 24.47 mg 100 g^{-1} among the varieties. Oyama *et al.* (1999) and Weerakkody (2003) reported that ascorbic acid concentration generally increased with increased exposure to light, particularly in leafy greens. Exposure of fruits to light accelerated the ascorbic acid synthesis in tomato (Shinohara *et al.*, 1987). The ascorbic acid content of tomato fruits was low in lower clusters and remarkably high in the upper most fourth cluster of tomato plants. Further, Shinohara (1982) established a close relationship between the light conditions and the ascorbic acid content in different vegetables. In general, it is concluded that lower the light intensity, lower the content of ascorbic acid in plant tissues (Weston and Barth, 1997; Lee and Kader, 2000). Thangam and Thamburaj (2008) also reported decrease in ascorbic acid content in tomato with shade.

Regarding nutrient uptake, the higher NPK uptake observed in the variety Punjab Green followed by All Green in the polyhouse corresponded to the better

plant growth characters and higher yields and hence DMP observed in these varieties. In open field, the uptake were found to be the highest in All Green and between the growing conditions, polyhouse crop recorded comparably higher values. It is interpreted that the microclimate in the polyhouse was ideal for the growth of spinach beet and this resulted in better root distribution, absorption, foliar growth, nutrient content and higher DMP. The Fe, Ca and Mg content in spinach beet varied significantly among varieties both in the open and polyhouse. Varieties ,PusaBharathi and Punjab Green recorded higher Fe, Ca and Mg in the polyhouse, and All Green in open condition.

5.1.3 Economics

Analysis of the economics of cultivation revealed significant differences in net returns and B:C ratio among varieties(Fig. 8).The variety Punjab Green recorded the highest net returns and B:C ratio followed by All Green in polyhouse and the hybrids proved to be the least profitable. The better growth and yield characters contributed to the higher yields in Punjab Green and All Green and hence the highest returns. In Indam Kolkatta and Trendy, the low yields coupled with the high cost of hybrid seeds, contributed to the lower net returns and B: C ratios.

As the experiment was done in an existing polyhouse and no maintenance and drip installation cost were accounted to work out the cost of cultivation. The cost of cultivation in polyhouse for 10 m^2 was computed taking into account the cost of inputs and labour charges alone. The inclusion of depreciation costs would render the profits as loss.

In the open, net returns and B:C ratio of All Green were significantly the highest (Fig. 9).The better growth in All Green was manifested in the yields recorded and hence better returns.

On comparison of the cultivation in open and polyhouse, net returns were higher in the polyhouse crop on account of the higher yields realized. Many of the research workers attempting studies in polyhouse cultivation have reported several

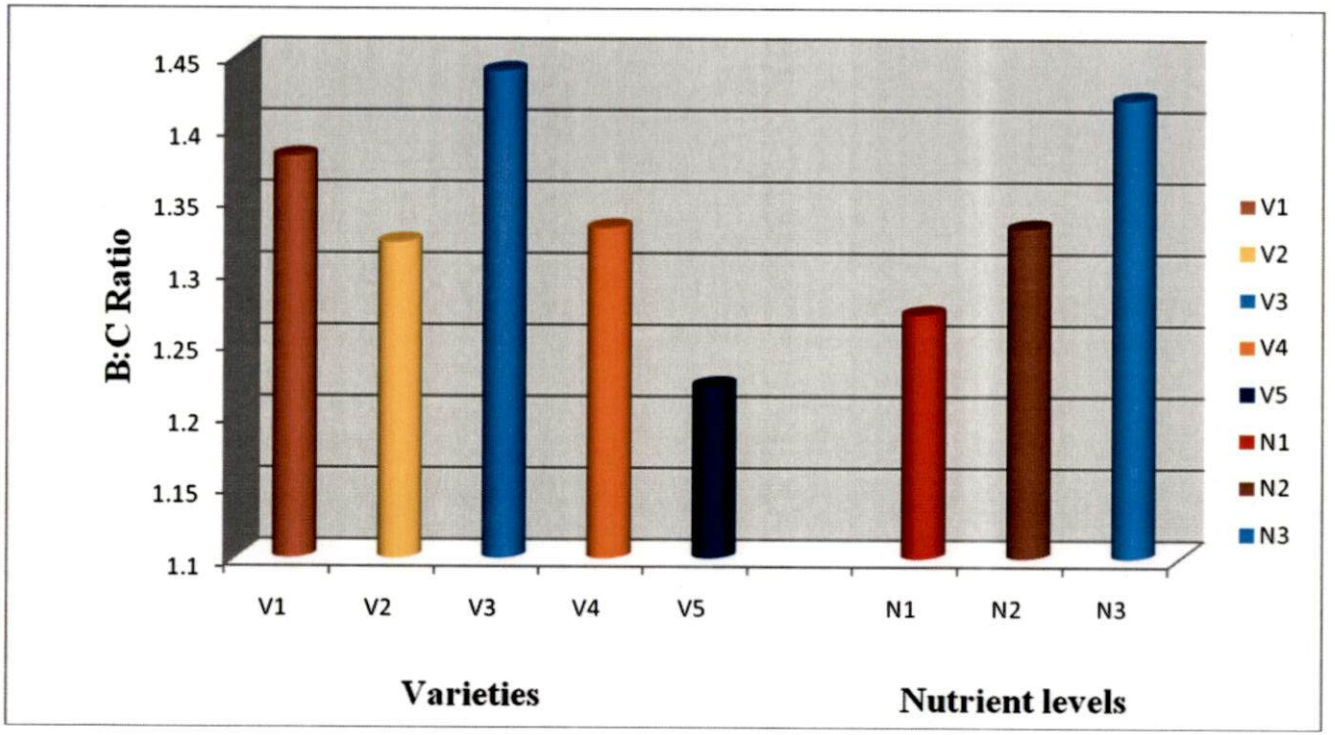


Fig. 8. B:C Ratio as influenced by varieties and nutrient levels in polyhouse

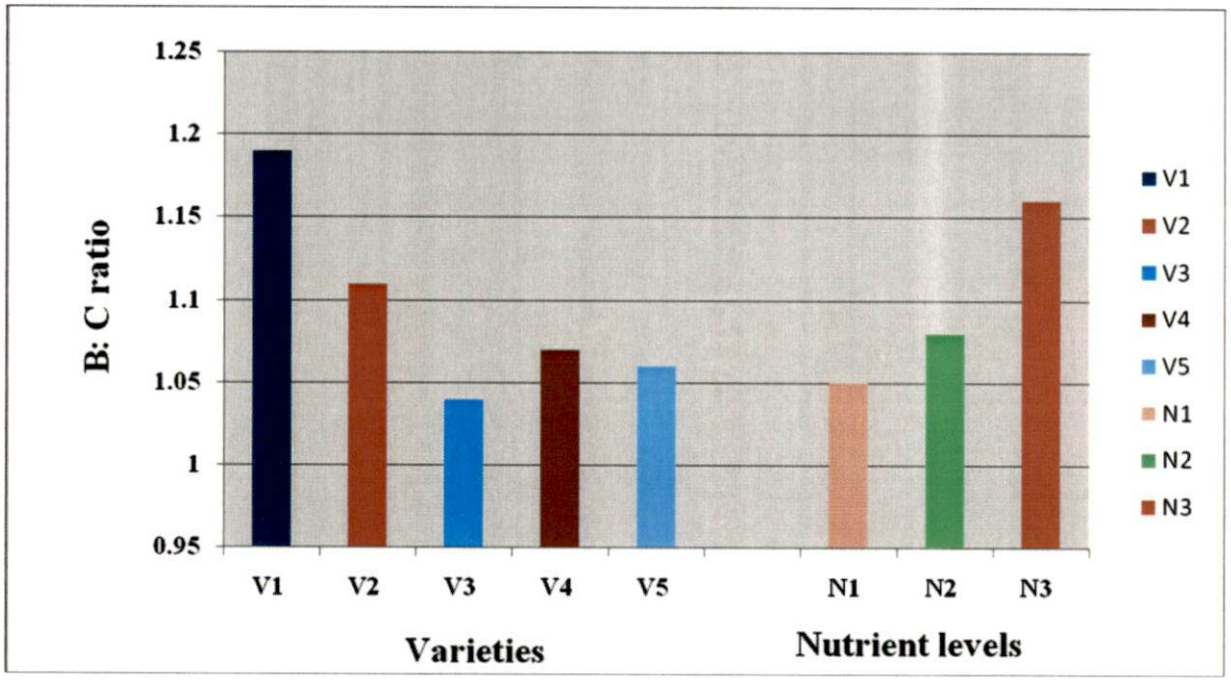


Fig. 9. B:C ratio as influenced by varieties and nutrient levels in open field condition

fold increases in yields that have resulted in better net returns and B:C ratios compared to the open (Vattakunnel, 2014; Kumar *et al.*, 2015; Athira, 2017). Based on this experiment, All Green, proved to be a promising variety suited for both open and polyhouse cultivation, the yield being 3.93 and 4.56 kg m^{-2} respectively and corresponding B: C ratios being 1.19 and 1.38.

5.2 INFLUENCE OF NUTRIENT LEVELS ON THE PERFORMANCE OF SPINACH BEET IN POLYHOUSE AND OPEN

5.2.1 Growth and yield

Optimum crop growth and yield depend on adequate availability of the different plant nutrients (Averbeke *et al.*,2007). Spinach beet being a leafy vegetable responds well to nutrient applications, especially N.

In the present study, NPK levels were found to significantly influence the plant height, taller plants were observed with higher doses at 15, 30, 45, 75 DAT and at final harvest in the polyhouse. The influence of nutrient doses in the open field condition also recorded almost similar trend. In both conditions, plants were the tallest at the highest level of NPK (80:40:80 kg ha^{-1}). Leaf Area Index (2.33; 1.09 at 45 DAT) and number of leaves $plant^{-1}$ (35.7; 26.2) in polyhouse and open, respectively were significantly higher in the highest NPK level. Higher nutrient doses promoted growth and this was expressed as increased plant height and leaf area. The progressive increase in the leaf area index with increased N fertilisers applied was also noticed by Ramchandra (1978), Tambe (1989) in amaranthus and Etman (1992) in spinach.

Balanced application of major nutrients is critical for plant growth and this of great significance in leafy vegetables in which the vegetative parts form the economic produce. Tambe (1989) observed that application of N, P, K together could improve the nutritive quality as well as the yields of leafy greens of amaranthus. Based on the investigation on the influence of different manures on spinach beet, Madhavi (2007)

elucidated that the number of leaves plant^{-1}, total leaf weight plant^{-1} and total yield at harvest were the highest with the application of recommended dose of fertilizers @ 80 : 40 : 50 kg NPK ha^{-1}. Magen (2008) emphasized that to obtain high yields of good quality, plants should be supplemented with nutrients especially N, P and K in appropriate proportion. In the present study, the NPK ratio of 2:1:2, that was recommended for spinach cultivation (Gairola *et al.*, 2009) was maintained in the treatments. The per plant and total yield in polyhouse (4.70 g plant^{-1}; 80.71 kg m^{-2}) and open (71.17 g plant^{-1} ; 3.73 kg m^{-2}) were significantly the highest in the highest level of N, P and K. Positive effects of N (Jana *et al.*, 1999), P (Nemadodzi, 2015) and K (Dzida *et al.*, 2011) in spinach beet cultivation have been documented. Chakraborty *et al.* (2015) reported significantly superior number of leaves, LAI, number of branches and yield in palak with 300:200:300 kg NPK ha^{-1}.Singh *et al.* (2015) also documented the significant influence of the highest dose of N on plant growth, leaf yield and quality traits of spinach beet var. All Green.

The trend of spinach beet in polyhouse recording better growth and yields compared to the open with varied NPK levels remained similar to that of the varieties performing comparatively better in the polyhouse.

5.2.2 **Shelf life, quality and nutrient uptake in spinach beet**

The different nutrient levels did not influence the shelf life of leaves either in the open or polyhouse. Chlorophyll content was the highest in 80:40:80 kg NPK ha^{-1} applied plots under both growing conditions. Nitrogen plays a significant role in chlorophyll synthesis and hence the higher content (Fig. 10) contributed to the higher chlorophyll in the treatment which received the highest level of nitrogen. It is also assumed that the ensured balanced nutrition in N_3 (80:40:80 kg NPK ha^{-1}) might have resulted in well developed leaves with greater chlorophyll content. The observation on chlorophyll content is in line with the findings of Kumar (2011).

The NPK uptake were significantly higher with the highest dose of NPK tried. Nutrient uptake is a positive function of dry matter yield (Ramakal *et al.* 1988).

Islam *et al.* (2011) have documented better nutrient uptake in palak with integrated (organic + chemical) nutrient management.

Onyango *et al.* (2011) stated that the mineral nutrient supplied to the crop not only decides the productivity, but also the nutritional value of the crop. The authors have elucidated the significant roles of the three major nutrients- nitrogen governs plant growth by virtue of being a major constituent of chlorophyll, protein, amino acids and photosynthetic activity; phosphorus plays a significant role in root growth, enhances utilization of soil nutrients and water by plants, and finally increase crop yields while potassium activates plant physiology, improves quality, increases disease resistance, prevents lodging and makes the plants capable of surviving moisture stress.

Better absorption as illustrated in the nutrient content (Fig.10) favourably affected the qualitative factors in spinach beet. Protein, vitamin A, C and Ca content were the highest at the highest NPK level, while Fe and Mg showed fluctuations. The trend in protein content indicated that higher amounts of N applied played a key role in enhancing the protein content of crop as nitrogen is a constituent of protein. The protein content was significantly reduced in the treatment receiving the lowest level of nitrogen. Similar results were reported by Ahmed (1992) in spinach and Prakash (1999) in spinach beet. Reports on higher ascorbic acid content with higher doses of N have been documented (Rajput *et al.,* 1989). Similarly increased beta carotene content of vegetables at increased levels of nitrogen have also been reported (Mozafar, 1993; Flores *et al.,* 2004). In accordance with the present study results, Maurya and Goswami (1985) also reported the highest carotene content with balanced NPK application.

The observations bring to focus the fact that based on the yield and nutritional factors, 80 :40 :80 kg NPK ha^{-1} is the best dose for cultivation of spinach beet in the open and polyhouse conditions.

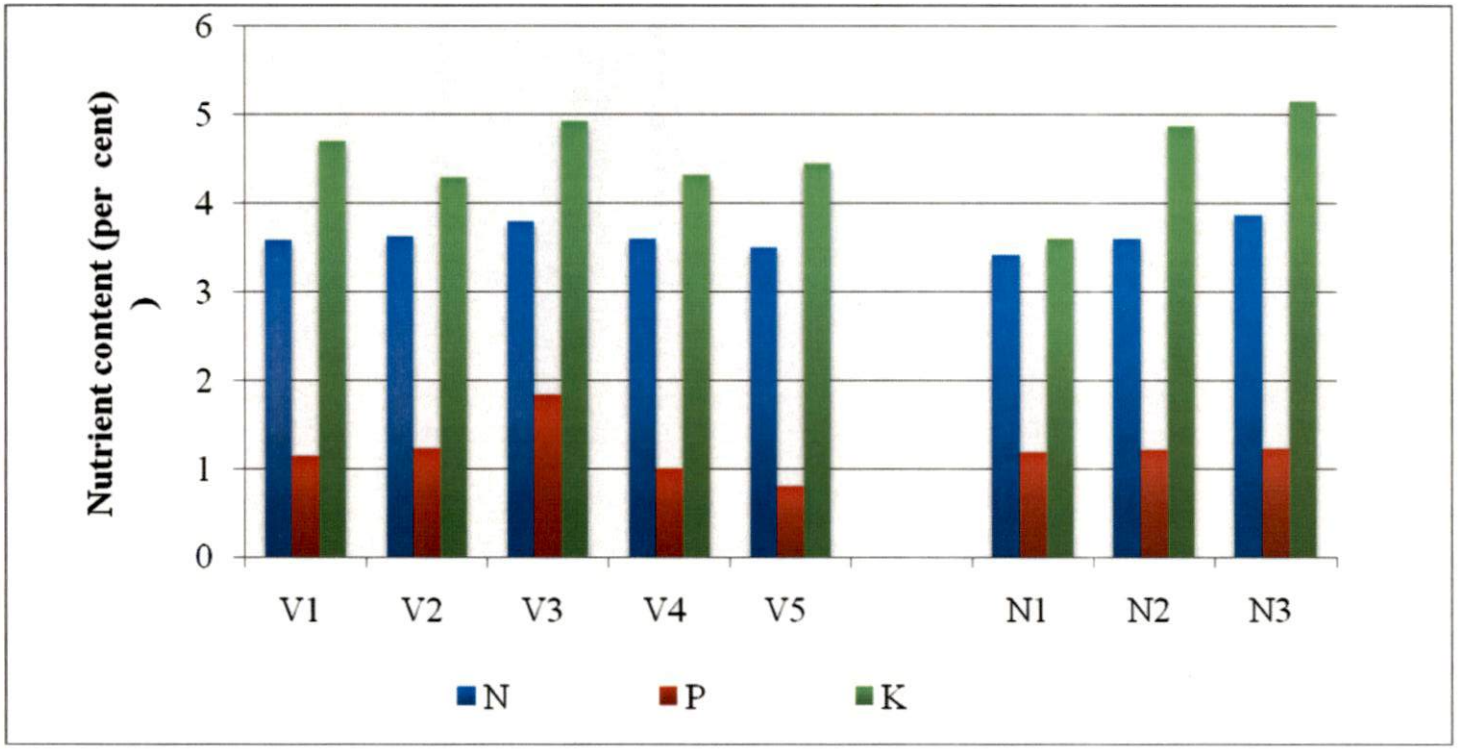


Fig.10. Effect of varieties and nutrient doses on plant NPK content in polyhouse

Leafy vegetables are known to contain nitrates in levels that when consumed can cause severe pathologies in humans (Wang and Li, 2004). The nitrate level in spinach leaves were found to increase with increased NPK application, the trend being the same under both growing conditions and in the open was significantly the highest at 80:40:80 kg NPK ha^{-1}. A similar observation of increased nitrate content with increased N application was reported in lettuce (Liu *et al.*, 2014).Leafy vegetables respond well to increased N application. Nevertheless, when applied in excess, some of the N taken up, will accumulate as nitrate in the vacuoles instead of being converted to amino-nitrogen (Martinoia *et al.,* 1981; Demsar *et al.,* 2004). This accumulated foliar nitrate poses a health risk when consumed in large quantities and is often subject to regulation. Therefore, the benefits of increased yield and increased protein content of leafy vegetables arising from nitrogenous fertilisation need to be balanced against the risk of excessive nitrate contents. Integration with organic manures has been recommended as a viable option to reduce the nitrate contents in leaves (Rajeswari and Shakila, 2010).

5.2.3 Soil properties

Significant increase in the available N, P and K status in soil were observed with higher NPK levels both in the polyhouse and the open field. Nevertheless, available N decreased from the initial status in contrast to P and K, wherein increases were noticed. The economic produce in spinach beet is the leaves and N is known to have a superior role in vegetative growth, especially in the number of leaves, size of leaves, chlorophyll and protein content. The uptake values were higher for N and hence the increased absorption in addition to that supplemented by the different levels might have decreased the soil N status. The decline in N was more in the lower nutrient level confirming the reason stated. The P and K supplied through the chemical fertilizers would have been more than the requirement and uptake of P and K, and hence added to the soil status.

5.2.4 Economics

All management factors being same, the variation in the cost of cultivation was mainly due the differences in the cost of fertilizer input at the different levels of N, P and K. The gross returns was the highest in the NPK dose of 80:40:80 kg ha^{-1}on account of the higher yield (Fig.9). The net returns and benefit cost ratios were in the order $N_3>N_2>N_1$.The pattern was same both in the open and polyhouse. The higher returns with the highest NPK levels in spinach beet has been reported by Kumar (2011).

5.3 INTERACTION EFFECT OF VARIETIES AND NUTRIENT LEVELS ON THE PERFORMANCE OF SPINACH BEET IN POLYHOUSE AND OPEN CONDITION

The interaction effects of varieties and nutrient levels did not always follow the same trend as observed in individual effects of variety and nutrient level. The results are discussed below

5.3.1 Performance of Spinach Beet in Polyhouse

The combination of All Green and 80 :40:80 kg NPK ha^{-1} was found to record the significantly the highest yield (5.06 kg m^{-2}), on a par with Punjab Green at 80 :40:80 kg NPK ha^{-1} (5.01kg m^{-2}) and is depicted in Fig. 11. Although the total leaf number $plant^{-1}$ and LAI were higher for Punjab Green at 80:40:80 kg NPK ha^{-1}, the interaction effect revealed All Green at the highest NPK level to yield better. Net returns computed for 10 m^{-2} were also maximum for All Green and 80:40:80 kg NPK ha^{-1}combination (₹. 1045.3),but, on a par with Punjab Green at 80:40:80 kg NPK ha^{-1} (₹. 1015.5). This is illustrated in Fig.12. The higher yield was responsible for the maximum returns realized. Nitrogen and P content were higher in Punjab Green $+N_3$combination and K, in All Green + N_3. Owing to the higher DMP, the NPK uptake recorded higher values in Punjab Green at 80:40:80 kg NPK ha^{-1}. Chlorophyll contents and shelf life were also significantly higher in this combination. Among the

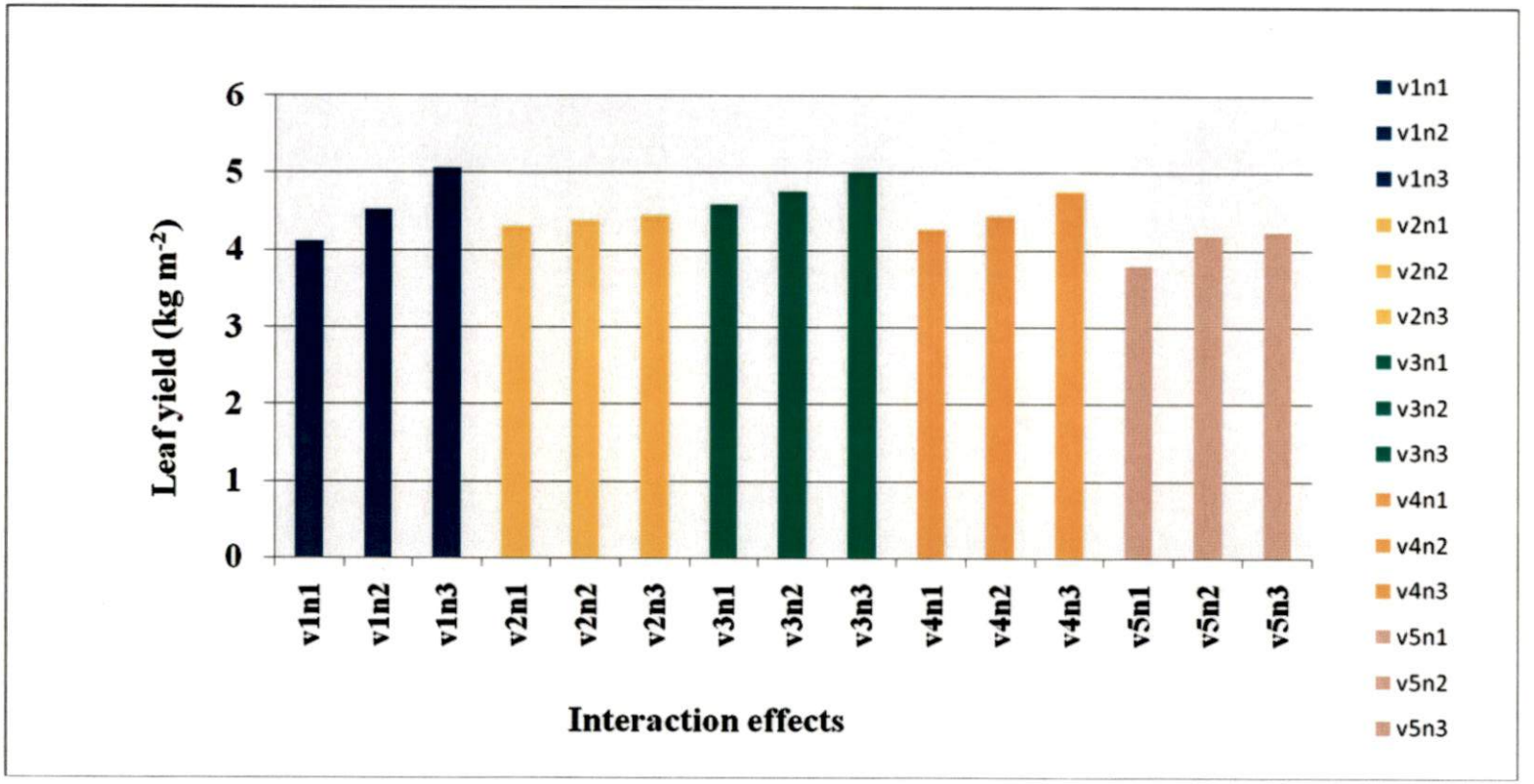


Fig 11. Interaction effect of varieties and nutrient doses on leaf yield in polyhouse

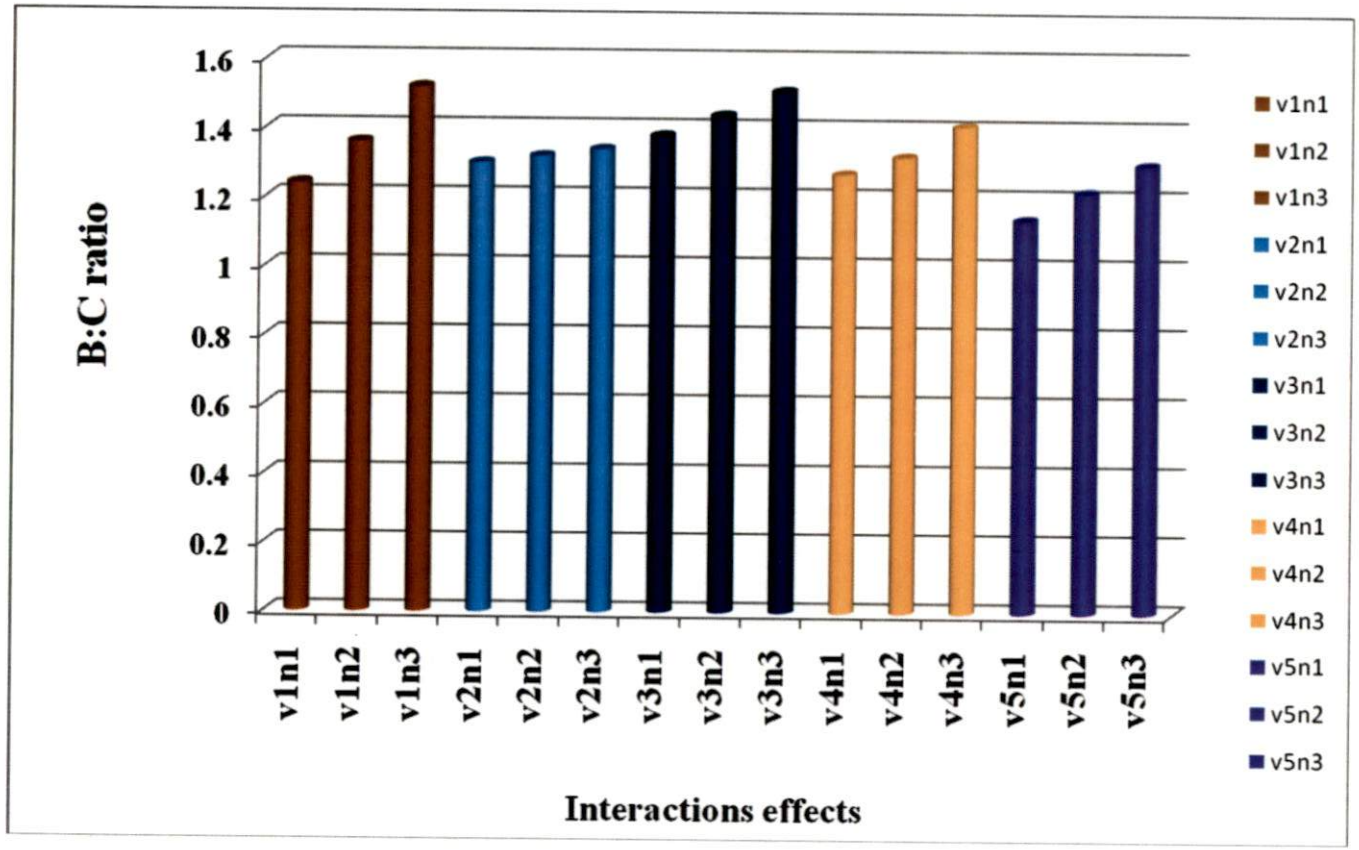


Fig.12. B:C ratio as influenced by variety x nutrient level interaction in polyhouse

quality parameters, the influence was not significant except in Fe, Ca and Mg content which were higher in v_2n_2 (Fe and Ca) and v_1n_3 (Mg). The interaction effects on the soil properties were non significant.

5.3.2 Performance of Spinach Beet in Open Field

Yields were significantly the highest in the combination Pusa Bharathi at 80:40:80 kg NPK ha^{-1}(4.14 kg m^{-2}) followed by All Green + 80:40:80 kg NPK ha^{-1}(4.02 kg m^{-2}),despite the individual effects of the latter variety being better. Maximum net returns (₹. 495.39 for 10 m^{-2})and B: C ratio (1.25) were obtained for the Pusa Bharathi + 80:40:80 kg NPK ha^{-1}(v_2n_3) combination (Fig.13). All Green + 80:40:80 kg NPK ha^{-1}had significantly higher N and K content and P content was higher in v_2n_3. NPK uptake was the highest in All Green + 80:40:80 kg NPK ha^{-1}.

The interaction effect on soil properties, organic carbon, available N, P and K were not significant.

The results of the study revealed that among the five varieties tested, Punjab Green recorded significantly higher yields in the polyhouse and variety All Green in the open. Among the nutrient levels, the dose of 80 :40:80 kg NPK ha^{-1} was superior, both in the open and polyhouse. Taking into account the economics of cultivation, the combination, All Green + 80:40:80 kg NPK ha^{-1} was the most profitable for cultivation of spinach beet in the polyhouse while PusaBharathi + 80:40:80 kg NPK ha^{-1}, in the open condition.

Although statistical comparisons could not be made, it could be summarized that polyhouse cultivation of spinach beet is more profitable than open cultivation. The higher yield in the polyhouse might be attributed to the favourable microclimate that promoted vegetative growth under protected condition The leaves being the economic part ,increased leaf size and number in the polyhouse led to the higher yields in this growing condition. Further, the crop was protected from the direct effects of the weather elements, especially high temperatures and rainfall, that would otherwise have affected the crop when grown in the open.

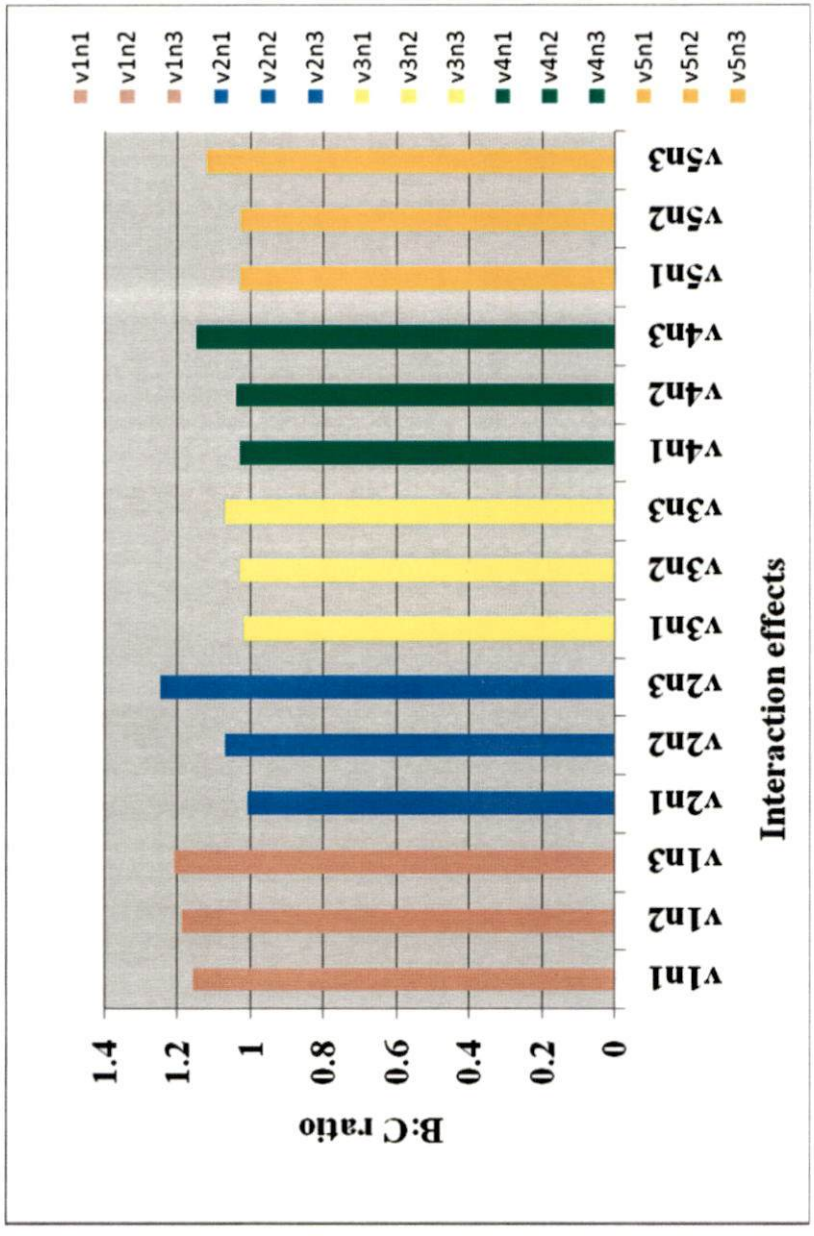


Fig13. B:C ratio as influenced by variety x nutrient level interaction in open field

Year round cultivation is possible in polyhouse with proper temperature and moisture regulation. The crop failure experienced during the open cultivation of spinach beet clearly demonstrates the suitability of the crop only during low rainy months *ie*., during October to February. A temporary protection should be provided during the heavy rainy days that may coincide during this period in southern Kerala. Being a short statured crop (maximum height 31 cm), the high soil temperature will also affect the crop growth and hence summer months could not be recommendable in spinach beet under open field condition.

Summary

6. SUMMARY

The experiment entitled "Productivity of spinach beetas influenced by varieties and nutrient doses" was undertaken at College of Agriculture, Vellayani to assess the suitability of five varieties of spinach beet under protected and open conditions, to standardize the nutrient doses and to work out the economics of cultivation.

The experiment was laid out in split plot design in the Instructional Farm attached to the College of Agriculture Vellayani under protected and open conditions as two separate experiments during August-November 2015 and 2016, respectively. The treatments included five varieties (V_1: All Green; V_2: Pusa Bharathi; V_3: Punjab Green; V_4: Indam Kolkatta; V_5: Trendy) in main plots and three nutrient levels (N_1: 40:20:40 kg NPK ha^{-1}; N_2: 60:30:60 kg NPK ha^{-1}; N_3: 80:40:80 kg NPK ha^{-1}) in sub plots with four replications.

The salient results of the study are summarized in this chapter

6.1 SPINACH BEET UNDER POLYHOUSE CONDITION

The results revealed that the varieties, levels of NPK and their interaction had significant influence on the growth, yield and economics of cultivation of spinach beet

- Among the five varieties, Punjab Green was superior in terms of number of leaves $plant^{-1}$ and LAI which resulted in significantly higher yield. Maximum yield was recorded by Punjab Green (4.78 kg m^{-2}) followed by All Green (4.56 kg m^{-2}). The highest NPK level of 80:40:80 kg ha^{-1} registered significantly taller plants, higher number of leaves $plant^{-1}$, LAI and yield (4.7 kg m^{-2}). Interaction effects were also significant - v_1n_3 (All Green at 80:40:80 kg ha^{-1}) recorded maximum yield (5.06 kg m^{-2}) followed by v_3n_3, Punjab Green at 80:40:80NPK kg ha^{-1}(5.01 kg m^{-2}).

- Varieties had significant influence on DMP and NPK uptake. The DMP was significantly high in the variety Punjab Green (37.22 g plant^{-1}) and was on par with All Green (31.34 g plant^{-1}). The NPK uptake was also the highest in Punjab Green. The DMP and nutrient uptake varied significantly with the nutrient levels and increased in the order $N_3 > N_2 > N_1$. The interaction effect of Punjab Green at 80:40:80 kg NPK ha^{-1} recorded significantly superior N,P and K uptake.
- The shelf life of the leaves kept under ambient conditions did not show any significant variation with either the variety or nutrient level but the interaction effect was significant. Punjab Green with the highest NPK level (80:40:80 kg NPK ha^{-1}) recorded increased shelf life (2.74 days).
- Chlorophyll content varied significantly among varieties and nutrient levels. It was significantly high for the variety Punjab Green and the highest NPK level. The interaction effect of the two individual effects recorded significantly higher chlorophyll content compared to the other interactions.
- Assessing the varietal effects on quality parameters, protein, vitamin A and Fe content were significantly the highest in Punjab Green while vitamin C was highest in Pusa Bharathi. Ca and Mg were significantly higher in All Green and Punjab Green respectively. Variations in nitrate contents were non significant. The NPK level of 80:40:80 kg ha^{-1} registered the significantly highest protein, vitamin C, Ca and Mg content. The influence on vitamin A and nitrate contents were non significant. Interaction effects were significant for mineral contents alone.
- The soil chemical properties did not differ significantly with varieties, whereas available NPK status in soil increased significantly with higher levels of NPK application and the highest status was observed with N_3 (80:40:80 kg NPK ha^{-1}).

- Maximum net returns and B:C ratio (computed for 10 m^2) were realized with the variety Punjab Green (₹ 881.59 and 1.44) and among nutrient levels, N_3 was most economical (₹ 835.54 and 1.42). Interaction effects of All Green and Punjab Green at 80:40:80 kg NPK ha^{-1} proved superior in terms of net returns and B:C ratio for cultivation of spinach beet under protected condition.

6.2 SPINACH BEET UNDER OPEN CONDITION

- In the open, among the five varieties tested, All Green was found to record significantly taller plants with the highest number of leaves (27.1 $plant^{-1}$). Significantly superior LAI and yield were registered in All Green. The highest yield recorded in All Green was 3.93 kg m^{-2} and the lowest in Trendy (3.42 kg m^{-2}). The effect of NPK levels was significant in LAI, number of leaves $plant^{-1}$ and yield, the values increasing with increase in the doses. Among nutrient levels, N_3 (80:40:80 kg NPK ha^{-1}) showed significantly superior growth attributes and yield. The interaction, Pusa Bharathi + 80:40:80 kg NPK ha^{-1}, was significantly superior in yield (4.14 kg m^{-2}) remained at par with All Green + 80:40:80 kg NPK ha^{-1} (4.02 kg m^{-2}).
- The varieties did not differ significantly in their crop duration (67 – 69 days) and interaction effects were also non significant.
- Shelf life varied with varieties and it was observed that All Green leaves could be retained fresh under ambient conditions for the highest number of days (2.05). Effect of NPK levels and interactions were non significant.
- Chlorophyll content was the highest in the variety All Green (0.33 mg g^{-1}), highest NPK level (0.31mg g^{-1}) and their interaction (0.35 mg g^{-1}).
- Dry matter production and NPK uptake were significantly the highest in All Green and increased with increasing doses of NK applied as

treatments. Interaction effects were also significantly superior for the above combination.

- Varieties exerted significant differences in vitamin A, vitamin C, protein and mineral content. Protein content, vitamins A, C, Ca and Mg were thehighest in variety All Green, while Fe content was highest in Punjab Green. Among nutrient levels, variations were significant and the highest NPK level registered the highest values for vitamin C, Ca and protein. The interactions were significant for vitamin C, protein and Mg, All Green at 80 :40:80 kg NPK ha^{-1} recorded the highest values for the former two parameters while All Green at 60 :30:60 kg NPK ha^{-1} showed the highest content of Mg.
- Nutrient levels significantly influenced the nitrate content, maximum (0.112 %), being with the highest level N_3.
- The effect of NPK doses was significant on soil properties, available NPK in soil increased significantly with increase in NPK levels.
- Economic analysis showed that among varieties, maximum net returns and benefit cost ratio were realized with the variety, All Green (₹ 371.38 for 10 $m^{-2}$and 1.19) and among nutrient levels, 80:40:80 kg NPK ha^{-1} was superior (₹ 318.67 10 m^{-2} and 1.16). Interaction effects revealed that the combination of Pusa Bharathi and 80:40:80 kg NPK ha^{-1} to be the most profitable (B:C ratio – 1.25) followed by All Green + 80:40:80 kg NPK ha^{-1}(B:C ratio – 1.21) .

Based on the study it could be concluded that

- Punjab Green is the most suitable variety of spinach beet for polyhouse cultivation and All Green, for open cultivation
- NPK @ 80:40:80 kg ha^{-1} is the most suitable nutrient dose for both conditions irrespective of the variety.

- Considering the economics, the combination of All Green & 80:40:80 kg NPK ha^{-1} is the most profitable for polyhouse cultivation and Pusa Bharathi + 80:40:80 kg NPK ha^{-1}, for open conditions.
- In the absence of the most suited variety, All Green can be recommended for cultivation in polyhouse and in open at a nutrient dose of 80:40:80 kg NPK ha^{-1}.

Future line of work

- Examine the possibility of organic nutrition in spinach beet
- Explore the effect of foliar nutrition
- Evaluate the suitability of spinach beet for vertical farming in different structures

References

7. REFERENCES

Abou El-Magd M. M, El-Bassiony A. M., and Fawazy Z. F. 2006. Effect of organic manure with or without chemical fertilizers on growth, yield and quality of some varieties of broccoli plants. *J. Appl. Sci. Res.* 2(10): 791-798.

Abou-Habid, A. F., Salch, M. M., Shanan, S. A., and Elabd, A. M. 1994. A comparative study between different means of protection on the growth and yield of winter tomato crop. *Acta Hortic.* 366: 105-112.

Adeniji, O. T., Swai, I., Oluoch, M.O., Tanyongana, R., and Aloyce, A. 2009. Evaluation of head yield and participatory selection of horticultural characters in cabbage. *Afr. Crop Sci. Conf. Proc.* 9: 475-481

Agrawal, N. N., Mehta, H. G., Sharma, A., Dixit, P., Dubey. 2003. Cultivation of cole crops under protected environment. *Karnataka J. Agric. Sci.* 16 (2): 332-334.

Ahmed, A. H. H. 1992. Physiological studies on the nitrogen and phosphorus deficiencies in spinach plants (*Spinacia oleracea* L.). 1. Growth and organic compounds. *Bull. Faculty Agric., Univ. Cairo*. 42 (1):87-110.

AICRP [All India Coordinated Research Project]. 2009. *Highlights of research and achievements during X Plan period* (2002-2007). All India Coordinated Research Project on Applications of Plastics in Agriculture,CIPHET, Ludhiana, 42p.

Aletor, O., Odhodia, A. A., Ipinmoroti,K.O. 2002. Chemical composition of common leafy vegetables and functional proportion of their leaf protein concentrate *Food Chem.* 78: 63-68.

Anjana, U. S. and Iqbal, M. 2007. Nitrate accumulation in plants, factors affecting the process, and human health implications - A review. *Agron. Sust. Dev.* 27: 45-57.

Anjana, U. S., Iqbal, and M., Abrol, Y. P. 2007. Are nitrate concentrations in leafy vegetables within safe limits? *Current Sci.* 92 (3): 355-360.

Anuja, U. S. and Jayalakshmi, L. 2011.Effect of foliar application of organic nutrients and inorganic fertilizers on NPK uptake, post harvest soil available nutrients and yield performance of palak (*Beta vulgaris* L. var. *bengalensis*). *Asian J. Hortic.* 6(2): 423-426.

Arya, M. P. S. and Singh, R. V. 2001. Response of amaranth (*Amaranth hypochondriacus*) to levels and time of nitrogen application. *Indian J. Agron.* 46: 186-189.

Athira, R. C. 2017. Standardization of fertigation schedule and spacing for bell pepper (*Capsicum annum*. L.) in polyhouse. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 72p.

Averbeke, V. W., Juma, K. A., and Tshikalange, T. E 2007. Yield response of African leafy vegetables to nitrogen, phosphorus and potassium: The case of *Brassica rapa* L. subsp. *chinensis* and *Solanum retroflexum* Dun. In: *Proceedings of the International Symposium on the Nutritional Value and Water Use of Indigenous Crops for Improved Livelihoods*, 19- 20 September 2006, University of Pretoria,Pretoria, South Africa. Available on website http://www.wrc.org.za

Barker, A. V., Peck, N. H., and MacDonald, G. E. 1971. Nitrate accumulation in vegetables. I. Spinach grown in upland soil. *Agron. J.* 63 : 126-129.

Belichki, I. 1984. Effect of fertilizer on growth of spinach. *Acta Hortic.* 14(2): 210-214.

Bhardwaj, V. 1996. Genetic variability and correlation studies in cabbage (*Brassica oleracca var. capitata* L). M. Sc. thesis. Y. S. Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh, 142p.

Bhore, M. R., Prabhu, T., and Sajindranath, A. K. 2000. Effect of sowing dates and nitrogen levels on growth, leaf yield and quality of palak. *South Indian J. Hortic.* 53(1-6): 340-344.

Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agron. J.* 54: 464-465

Brandenburger, L. P., Wells, L. K., and Haigh, M. M. 2007. Yield and quality characteristics of spring spinach grown in Oklahoma. *Hortic.Technol.* 14: 602– 605.

Calderon, E., Gonzalez, J. M., and Bressani, R. 1991.Agronomic, physical, chemical and nutritional characteristics of fifteen amaranth varieties. *Turrialba* 41: 458-464.

Campbell, T. A. and Abbott, J. A. 1982. Field evaluation of vegetable amaranth (*Amaranthus* spp.). *Hortic. Sci.*17: 407-409.

Cantliffe, D. 1992. Nitrate accumulation in vegetable crops as affected by photoperiod and light duration (beets, radish, spinach, beans). *J. Am. Soc. Hort. Sci.* 97: 414 – 418.

Chakraborty, S., Mandi, A., and Panda, D. 2015. Effect of nutrients and spacing on growth and seed yield of palak (*Beta vulgaris* var. *bengalensis). Environ. Ecol.* 33(1B): 410-415.

Dainello, F. J., Heineman, R. R., and Black, M. C. 1987. Bolting and yield characteristics of processing spinach varieties in the Texas winter garden. *Texas Agr. Expt. Sta.PR* 4508:1–9.

Damato, G. 2000. Late sowing dates and high plant density in six cultivars of broccoli for processing. *Acta Hortic.*533: 267-274.

Demsar, J., Osvald, J., and Vodnick, D. 2004. The effect of light-dependent application of nitrate on the growth of aeroponically grown lettuce (*Lactuca sativa* L.). *J. Am. Soc. Hortic. Sci.* 129: 570 – 575.

Devadas, V. S., Gopalakrishnan, P. K., and Peter, K. V. 1993. A comparison of red and green amaranthus for growth and yield parameters. *S. Indian Hortic.* 41 : 43-46

Dhillon, S., Singh, B., and Kansal, B. D. 1987. Effect of different level of nitrogen on yield and chemical composition of spinach *(Spinacea oleracea* L.). *J. Res. Punjab Agric. Univ.* 24(1): 31-36.

Dixit, A. 2007. Performance of leafy vegetables under protected environment and open field condition. *Asian J. Hort.* 2 (1) : 197-200.

Djurovka, M., Lazic, B., and Markovic. V. 1988. General characteristics of spinach varieties suitable for industrial processing. *Acta Hortic.* 220:159–164.

Dzida, K., Jarosz, Z., and Michalojc, Z. 2011. The effect of diversified potassium fertilization on the yield and chemical composition of *Beta vulgaris* L. *Acta Sci. Pol., Hortorum Cultus* 10(4) : 263-274

El-Aidy, F., El-Afry, M., and Ibrahim, F. 1988. The influence of shade nets on the growth and yield of sweet pepper. In: *Proceedings International Symposium on Integrated Management Practice* , AVRDC, Taiwan.p 32-34.

Elavarasan, K., Pushpalatha, P. B., John, J.P., Sheela, K. B., and Narayanankutty, C. 2013. Studies on the performance of different genotypes of cabbage grown in plains and higher altitude of Kerala. *Int. Lett. Nat. Sci.* 2(3): 317-320.

Elbehri, A., Putnam, D. H., and Schmitt, M. 1993. Nitrogen fertilizer and cultivar effects on yield and nitrogen use efficiency of grain amaranth. *Agron. J.* 85 (1): 120-128.

Erum, S., Naeemulla, M., Masood, S., Qayyum, A., and Rabbani, M.A. 2012. Genetic divergence in amaranthus collected from Pakistan. *J. Anim. Plant Sci.* 23(2): 193-200.

Etman, A. 1992. Response of spinach to soil and foliar urea application. *Ann. Agri. Sci.(Cairo).* 38(2): 667-673.

Flores, P., Navarro, J. M., Garrido, C., Rubio, J. S., and Martinez, V. 2004. Influence of Ca_2^+, K^+ and NO_3^- fertilization on nutritional quality of pepper. *J. Sci. Food Agric.* 84: 569–574.

Gairola, S., Umar, S., and Suryapani, S. 2009. Nitrate accumulation, growth and leaf quality of Spinach beet (*Beta vulgaris* Linn.) as affected by NPK fertilization with special reference to potassium. *Indian J. Sci. Technol.* 2(2): 237-240.

Gins, M. S., Lozovskaya, E. L., Gins, V. K., Konokov, P. F., and Tkacheva, T. V. 2000. The biochemical composition and antioxidant properties of introduced vegetable plants. *Russian Agric. Sci.* 5: 25-28.

Goh, K. M. and Vityakon, P. 1983. Yield of spinach and beetroot as affected by rates and forms of nitrogenous fertilizers. *N. Z. J. Agric. Res.* 26(3): 349-356.

GOI [Government of India]. 2016. *Statistical Year Book India 2016* – Horticulture. Ministry of Statistics and Programme implementation, Government of India. Available at http://www.mospi.gov.in/statistical-year-book-india/2016/178.

GOK [Government of Kerala]. 2016. *An Analytical Study on Agriculture in Kerala* [on-line]. Available: http://spb.kerala.gov.in/pdf/a_s_06042016.pdf [05 Jan. 2016].

Gopalakrishnan, T. R. 2004. *Three Decades of Vegetable Research in Kerala Agricultural University.* Kerala Agricultural University, Thrissur, 131p.

Harahap , D. 1994. Nitrogen effect on water convolvulus. *ARC Training*. p 24-67.

Heuvelink, E. 1999. Evaluation of a dynamic simulation model for tomato crop growth and development. *Ann. Bot.* 83(4): 413-422.

Holubava, K. 2002 Content of nitrate and oxalic acid in biomass of selected genotypes of amaranth (*Amaranthus* spp.). *Agricultura Trop. et. Subtropica.* 35: 59-63.

Hood, K. 2000. Budget for greenhouse tomatoes. *Mississippi St. Univ. Ext. Serv. Publ.* p. 2257.

Hoque, M. M., Ajwal, H., and Othman, M. 2010. Yield and post harvest quality of lettuce in response to nitrogen, phosphorus, and potassium fertilizers. *Hortic. Sci.* 45(10): 1539–1544.

Hossain, S. I. and Rahman, M. M. 1999. Response of amaranth genotypes (*A. tricolor* L.) to stem production. *Ann. Bangladesh Agric.* 9: 105-112.

ICMR [Indian Council of Medical Research).].2011. Report of the Expert Committee of ICMR. Available: http://nutritiononfoundationof india.res.in/PPT-2011/seven 17-18teen/Dr.b-sesikeran.pdf.

Ijoyah, M. O. and Rakotomavo, H. 2007. Yield performance of five cabbage varieties compared with local variety under open condition in Seychelles. *J. Sustain. Dev. Agric. Environ.* 3: 76-80.

Isaac, S. R. 2015. Performance evaluation of leafy vegetables in naturally ventilated polyhouses. *Int. J. Res. Stud. Agric. Sci.* 1(3): 1-4.

Islam, M. M., Karim, A. J. M. S., Jahiruddin, M., Nik, M., Majid, M. G., Miah, M., Ahmed, M., and Hakim, M. A. 2011. Effects of organic manure and chemical fertilizers on crops in the radish-stem amaranth- Indian spinach cropping pattern in homestead area. *Asian J. Crop Sci.* 5(11):1370-1378.

Jackson, M. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, 498p.

Jana, J. C., Thapa, U., and Maity, T.K. 1999. Green and seed yield of palak (*Beta vulgaris* L. var. *bengalensis* Hort.) as affected by nitrogen fertilization and cutting management. *Veg. Sci.* 26(1): 61-63.

Jha, M. K. and Jana, J. C. 2009.Evaluation of vermicompost and farmyard manure in integrated nutrient management of spinach (*Beta vulgaris* var. *bengalensis*). *Indian J. Agric. Sci.* 79(7): 538-541.

Kalinowski, L. S., Navaparo, J. P., Concha, A. I. R., Hermoza, G. C., Pachego, R. A., Choquevilla, Y. C., and Jara, E. V. 1992. Grain amaranth research in Peru. *Food Rev. Int.* 8(1): 87-124.

Kansal, B. D., Singh, B., Bajaj, K. L .1989. Effect of different levels of nitrogen and farmyard manure on yield and quality of spinach (*Spinacea oleracea* L.). *Plant Food Hum. Nutr.* 31(2): 163-170.

Khader, V. and Rama, S. 2003. Selected mineral content of common leafy vegetables consumed in India at different stages of maturity. *Plant Foods Hum. Nutr.* 53: 71-81.

Kotadia, H. R., Patil, S. J., Bhalerao, P. P., Gaikwad1, S. S., and Mahant, H. D. 2012. Influence of different growing conditions on yield of leafy vegetables during summer season. *The Asian J. Hortic.* 7: 300-302

Kowsalya.S., Chandrasekhar. D., and Balasasirekha, R. 2001. Beta- carotene retention in selected green leafy vegetables subjected to dehydration. *Indian J. Nutr. Dietet.* 38: 374-383.

Kumar, P. Chauhan, R.S., and Grover, R.K. 2015. Comparative economics of cucumber cultivation under polyhouses and open field conditions in Haryana. *Indian J. Econ. Dev.* 3 (7) : 2-4

Kumar, P. V. 2011. Studies on the effect of integrated nutrient management practices on growth, leaf yield and quality of palak (*Beta vulgaris* var. *bengalensis* Hort.) . M. Sc. (Hort.) thesis, Andhra Pradesh Horticultural University, Andhra Pradesh, 118p.

KVK [Krishi Vigyan Kendra]. 2014. Newsletter. Krishi Vigyan Kendra, Ernakulam, No.13, p.5.

Lal, S., Rana, M. K., and Partap, P. S. 2015. Seed yield of fenugreek genotypes as influenced by date of sowing and green cuttings. *Haryana J. Hortic. Sci.* 32(3-4): 265–269.

Lee, S. K. and Kader, A. A. 2000. Preharvest and post harvest factors influencing vitamin C content of horticultural crops. *Post harvest Biol. Technol.* 20: 207–220.

Liu , W. C., Sung, Y., Chen, B., and Lai, H. 2014. Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (*Lactuca sativa* L.) . *Int. J. Environ. Res. Public Health.*11: 4427-4440.

Madhavi, Y. 2007. Studies on the effect of different levels of vermicompost, castor cake, poultry manure and bio fertilizers on growth yield and quality of Indian spinach (*Beta vulgaris* var. *bengalensis* Hort.). M.Sc. (Hort.) thesis, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad, 137p.

Magen, H. 2008. Balanced crop nutrition: Fertilizing for crop and food quality. *Turk J. Agric.* 32: 183–193.

Makus, D. J. 1990. Composition and nutritive value of vegetable amaranth as affected by stage of growth, environment and method of preparation. In: *Proceedings of Fourth National Amaranth Symposium: Perspectives on Production Processing and Marketing*, University of Minnesota, St Paul, Minnesota (USA) : 35-41.

Malligawad, L. H., Patil, V. C., and Biradar, D. P.1993. Effect of nitrogen fertigation, plant density and planting geometry on grain amaranth cultivar. *Agron. Abstr., Annual meeting*, November 7-12, 1993 140 p.

Malligawad. L. H. 1994. Studies on the effect of plant density, planting geometry and nitrogen fertilization on grain amaranthus. Ph.D. Thesis ,University of Agricultural Sciences , Dharawad.160p

Mandal, J. and Dhangrah, V. K. 2012. Screening vegetable amaranth under summer condition in red and lateritic belt of West Bengal. *Environ. Ecol.* 30 (4A): 1430-1433.

Martinoia, E., Heck, U., and Wienecken, A. 1981.Vacuoles as storage compartments for nitrate in barley leaves. *Nat.* 289: 292-294.

Masinde, W. and Agong, S. G. 2012. The influence of nitrogen application on growth and mineral content of two African night shade species (*Solanum* spp.) cultivated in Kenya. *J. Agric. Sci. Tech.* 14(2): 44

Materechera.S.A and Medupe.M. L. 2006. Effect of cutting frequency and nitrogen from fertilizer and cattle manure on growth and yield of leaf amaranthus (*Amaranthus hybridus*) in a South African Semi-Arid Environ. *Biol. Agric. and Hortic, An Int.J. for Sustain. Prod. Syst.* Vol. 23 (3):251-262.

Maurya K.R. and Goswami, R.K. 1985. Effect of NPK fertilizers on the growth and yield of carrot. *Prog. Hort.*17 (3): 211-217.

Meena, Vijendra,K., Subramanian, S., Dipti, N.V., and Simta, K. 2016. Intoduction of palak (*Spinacia oleracea* L.) in Ernakulam district of Kerala through front line demonstration and on farm testing. *Agric. Sci. Digest.*, 36 (2): 130-133

Meena, Y.K., and Kale, V.S. 2015. Performance of different genotypes of coriander under agro climatic conditions of Akola, Maharashtra region. *Book of Abstract* for national Seminar on Hi-tech Hoticulture for Enhancing Productivity, Quality and Rural Prosperity, Ajmer, 19-20 January 2015:124

Misra, R.L. and Pathania, N.S., 2000. For north Indian conditions, Hi-tech greenhouse and production strategies for cut-flowers. *Indian Hortic* 43 (1): 8-11.

Mozafar, A. 1993. Nitrogen fertilizer and the amount of vitamins in plants: a review. *J. Plant Nutr.*16: 2479–2506.

Muhlendyck, E. and Schupan, W. 1963. The effect of phosphorus manuring on yield and market quality of vegetables. *Gartenbawsis.* 28:139-151.

Nagarajan, M., Senthilvel, S., and Planysamy, D. 2014. Material substitution in green house construction. *Kisan World.* 11:57-58.

Nair, R. and Barche, S. 2014. Protected cultivation of vegetables – present status and future prospects in India. *Indian J. Appl. Res.* 4 (6) : 245-247.

Narayanankutty, C., Gopalakrishnan, T. R., and Peter, K. V. 2012. Cabbage and cauliflower production in warm humid tropics of Kerala. In: *Proceedings of Fifth Indian Horticulture Congress*, 6-9 November 2012, New Delhi: 214.

Nawawi, M., Santosa, W. I., and Notodlejo, S. 1986. The effect of shading and nitrogen fertilizer application on yield of spinach. *Agrivita* .8/9 (2/1): 17-18.

Nelson, J.L., Kurtz, L.T., and Bray, R.H. 1954. Rapid determination of nitrate and nitrites *Anal. Chem.* 26 (6):1081-1085

Nemadodzi, L. E. 2015. Growth and development of baby spinach (*Spinacia oleracea* L.) with reference to mineral nutrition, M.Sc. (Ag) thesis, University of South Africa, South Africa , 96p.

Ngullie, R. and Biswas, P. K. 2014. Performance of different varieties of broccoli under rainfed mid-hill conditions of Mokokchung district of Nagaland. *Int. J. Farm Sci.* 4(2): 76-79.

Nishimato, R. K., Fox, R. L., and Parvin, P. E. 1972. Response of vegetable crops to phosphorus concentrations in soil solution. *Soc. Hort. Sci.* 102: 705-709.

Ohshiro,M., Hossain.A.Md., Nakamura,I., Akamine.H., Tamaki.M., Bhowmik. P. C., and Nose. A. 2016. Effects of soil types and fertilizers on growth, yield, and quality of edible *Amaranthus tricolor* lines in Okinawa, Japan, *Pl. Prod. Sci.* 19(1): 61-72.

Onyango,C. M., Harbinson, J., Shibairo1, S. I., and Imungi, J. K. 2011. Effect of organic and inorganic fertilisers on yield and quality of amaranth in sub-Saharan Africa. *Afr. Crop Sci. Conf. Proc.* 10:. 489 - 494

Oyama, H., Shinohara, Y., and Ito, T. 1999. Effects of air temperature and light intensity on β- carotene concentration in spinach and lettuce. *J. Japan. Soc. Hortic. Sci.* 68(2): 414-420.

Padmanabha, K., Umesh, M. R., Krishnappa, K. S., and Manjunatha, M. H. 2009.. Effect of organic and inorganic nutrient sources on growth and yield components of palak (*Beta vulgaris* var. *bengalensis* Hort.) *Int. J. Agric. Sci.* 5(1): 270-272.

Panchal, D. B., Patel, R. B., and Dalal, K . C . 1991. Effect of nitrogen and phosphorus on grain and nutrient uptake by amaranthus. *Gujarat Agric. Univ. Res. J.* 16 (2): 71-72.

Panda, J.M., Sahu, S. K., and Nayak, J. K. 1991. Effect of nitrogen, phosphorus and potash on growth, yield and quality of kosala (*Amaranthus gangeticus*L.). *Orissa J. Hortic.*19 (1& 2): 64-68.

Peavy, W. and Greig. J. 1972. Organic and mineral fertilizers compared by yield, quality, and composition of spinach. *J. Amer. Soc. Hortic. Sci.* 97(6): 718-723.

Prakash, D. and Pal, M. 1991. Nutritional and antinutritional composition of vegetable and grain leaves. *J. Sci. Food Agric.* 57: 573-583.

Prakash, P. B. 1999. Effect of nitrogen, farmyard manure and vermicompost on growth, yield, quality and shelf-life of spinach beet cv. All green. M. Sc. (Ag.) thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, 42 p.

Rai. N. and Singh, A. K. 2000. Genetic variability, heritability and advance studies in cabbage. *J. Appl. Biol.*10 (1): 8-11.

Rajaraman, G., Paramaguru, P., Aruna, P., Sudagar, I.P. and Ragothaman, G. 2011. Fertigation studies on leaf area and chlorophyll content in coriander (*Coriandrum sativum* L.) *The Asian J. Hortic.* 6(1) : 46-49

Rajasekar, M., Arumugam, T., and Kumar, R. S. 2013. Influence of weather and growing environment on vegetable growth and yield. *J. Hortic. For.* 5(10): 160-167.

Rajeswari, R. and Shakila, A. 2010. Effect of organic manures on nutrient uptake of palak (*Beta vulgaris* L. var. *bengalensis*). *Asian J. Hort.* 4 (2): 405-407.

Rajput, B. P., Mehta, V. B., Chavan, A. S., and Sananse, S. I. 1989. Effect of different levels of nitrogen on yield of palak (*Beta vulgaris* L.) varieties under coastal saline condition. *J. Indian Soc. Coastal Agric.* Res. 7: 37-40.

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

Ramakal, K. S., Khera, A. P., Bhatia, R. N., Gupta, S. P., and Duhan, B. S. 1988. Effect of combined application of FYM and inorganic fertilizer on grain yield and soil fertility status in bajra wheat crop sequence. *Haryana J. Agron.* 4(1): 42-47.

Ramakrishna, M. 2005. Effect of nutrient management practices on yield and quality of spinach (*Beta vulgaris* L.) grown on alfisol. M.Sc. (Ag.) thesis, Acharya N. G. Ranga Agricultural University, Rajendranagar, 87p.

Ramchandra, H. A. 1978. Effect of different levels of N and P on growth, yield and quality attributes of amaranthus (*Amaranthus gaugeticus* L.) *Mysore J. Agri. Sci.* 12(3): 526-527.

Ramesh, K. S. and Arumugam, T. 2010. Performance of vegetables under naturally ventilated polyhouse condition. *Mysore J. Agric. Sci.* 44(4): 770-776.

Rathore, P. S. and Manohar, S. S. 1989. Effect of date of sowing levels of nitrogen and phosphorus on growth and yield of fenugreek. *Madras Agric. J.* 76(11): 647-648.

Regan,W.S., Lambeth,V. N., and Brown, J. R., 1968. Fertilization inter relationship on yield and oxalic acid content of spinach beet. *Proc. Amer.soc.Hortc.sci*, 93: 485-491

Sadasivam,S., and Manickam,A.,1996. *Biochemical Methods. New Age* International Publisher, Coimbature, 256 p.

Salaj, I. and Jasa. B. 1965. A contribution on the nutrition of spinach *Bull.Vyzk. USA. Zelin* (9):99-100

Sharma, A., Sharma, S., and Singh, Y. 2006. Stability analysis for marketable head yield and its component horticultural traits in cabbage under dry temperature condition of north- western Himalayas. *Indian J. Genet.* 66 (2): 163-164.

Sharma, P. C., Mishra, B., Singh, R. K., and Singh, V. P. 2001. Variability in the response of spinach, fenugreek and coriander to alkalinity and salinity stresses. *Indian Plant Physiol.* 6(3): 329-333.

Shinohara, Y. and Suzuki, Y. 1982. Effects of light and nutritional conditions on the ascorbic acid content of lettuce. *J. Japan. Soc. Hort. Sci.* 50(2): 239–246.

Shinohara, Y., Suzuki, Y., and Shibuya, M. 1987. Effects of cultivations method, growing season and cultivar on the ascorbic acid content of tomato fruits. *J. Japan. Soc. Hort. Sci.* 51(3): 338–343.

Shukla, S, Bhargava, A., Chatterjee, A., and Singh, S. P. 2006. Genotypic variability in vegetable amaranth (*Amaranthus tricolor* L.) for foliage yield and its contributing traits over successive cuttings and years. *Euphytica*, 15(1): 103-110.

Simpson . J. E., Adair, C.H., Kihler, G.O., Dawson, E.N., Debald, H. A., Kester,E.B., and Klick, J.T. 1965. Quality evaluation studies of foreign and domestic rices. *Tech. Bull. No.1331. Series*, U.S.D.A, 86p.

Singh, B., Kumar, B., Mahesh. K., and Sirohi, N. P.S. 2005. Growing parthenocarpic cucumber in greenhouse is ideal for peri-urban vegetable growers. *Indian Hortic.* 49(4): 22-23.

Singh, B., Kumar, M., and Sirohi, N. P. S. 2007. Protected cultivation of cucurbits under low cost protected structures: A sustainable technology for peri-urban areas of Northern India. *Acta Hortic.*, 731: 267-272.

Singh, G. P., Meena, M. L., and Prakash, J. 2015. Effect of different levels of nitrogen and cuttings on growth, leaf yield and quality of spinach beet (*Beta vulgaris* var. *bengalensis*) cv. All Green. *Eur. J. Biotechnol. Biosci.* 3(6): 38-42.

Singh, S., Agrawal, M., and Agrawal, S. B. 2014. Differential sensitivity of spinach and amaranthus to enhanced UV-B at varying soil nutrient levels: association with gas exchange, UV-B-absorbing compounds and membrane damage. *Photosynth. Res.* 115:123–138.

Singh,V.C., Sundarajan, S., and Eeraragavathatham,D.1986. Effect of spilt application of N on growth and yield of amaranthus (*Amaranthus trusties*). *South Indian Hort.*, 33(2) : 100-102.

Sirohi, P.S. and Behera, T.K. 2000. Protected cultivation and seed production vegetables. *Indian Hortic.*, 43 (1) : 23- 25.

Smitha, K. and Sunil, K. M. 2016. Influence of growing environment on growth characters of cucumber (*Cucumis sativus*). *J. Trop. Agric.* 54 (2): 201-203.

Snedecor, G.W. and Cochran, W.G.1975 *Statistical Methods*. Oxford and IBH Publishing Company, New Delhi, 593p

Soundy, P. and Smith, I.E. 1992. Response of lettuce (*Lactuca sativa* L.) to nitrogen and phosphorus fertilization. *J. S. Afr. Soc. Hort-Science* 2:82–85.

Subbiah, D. V. and Asija, G . L. 1956. Rapid procedure for estimation of available nitrogen in soil. *Curr. Sci.* 25: 259-260.

Suresh, K., Lakkineni, K.. C. and Nair, T.V.R. 1996. Relationship between leaf nitrogen and photosynthetic rate of *Brassica juncea* and *B. campestris*. *J. Agron. Crop Sci.* 177 : 107-113.

Tambe, N. L. 1989. Graded levels of N, P and K on growth and yield of amaranthus cv. Lai Rajgira. M.Sc. (Ag.) thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, 62 p.

Thangam, M. and Thamburaj, S. 2008. Comparative performance of tomato varieties and hybrids under shade and open conditions. *Indian J. Hortic.* 65(4): 429-433.

Tisdale, S. L., Nelson, W. L., Beaton, J. D., and Havlin, J. L. 1990. *Soil Fertility and Fertilizers* (5th Ed.). Prentice Hall of India Private Ltd., 301-342 p.

Uddin, H. and Chowhan, S. 2016. Performance of Indian spinach and papaya in litchi based agroforestry system. *Int. J. Agric. Res. Innov. Tech.* 6 (1): 34-40.

Varalakshmi, B. 2004. Characterization and preliminary evaluation of vegetable amaranth (*Amaranthus* spp.) germplasm. *Plant.Genet. Res. Newsletter* 137: 55-57.

Varalakshmi, B., Kesava Rao, V., and Naik, J. 2011. Antioxidant rich amaranthus varieties, Arka Samraksha and Arka Varma. *J. Hort. Sci.* 6(2): 163-165.

Vattakunnel, P. R. 2014. Production technology of chilli (*Capsicum annum*.L. *capitata*) under protected cultivation. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 68p.

Wang, Z. and Li, S. 2004. Effects of nitrogen and phosphorus fertilization on plant growth and nitrate accumulation in vegetables. *J. Plant Nutr.* 27(3): 539-556.

Wang, Z. H., Li, S., and Malhi, S. 2008. Effects of fertilization and other agronomic measures on nutritional quality of crops. *J. Sci. Food Agr.* 88: 7–23.

Wani, K. P., Singh, P. K., Amin, A., Mushtaq, F., and Dar, Z. A. 2011. Protected cultivation of tomato, capsicum and cucumber under Kashmir valley conditions. *Asian J. Sci. Tech.* 1(4): 56-61.

Watson, D. J. 1947. Comparative physiological studies in the growth of field crops.I. Variation in net assimilation rate and leaf area between species and varieties, and between years. *Ann. Bot.* 11:41-76.

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

Weerakkody, W. A. P. 2003. Nutritional value of fresh leafy vegetables as affected by pre-harvest factors. *Acta Hort*ic. 60 (4): 511–515.

Weston, L. A., and Barth, M. M. 1997. Preharvest factors affecting postharvest quality of vegetables. *Hortic Sci.* 30 (5): 812–816.

Xu, H.L., Wang, R., Xu, R.Y., Mridha, M.A.U., and Goyal, S. 2003.Yield and quality of leafy vegetables grown with organic fertilizations *Acta Hortic.* 627: 25- 33

Yadav, R. K., Kalia, P., Kumar, R., and Jain, V. 2013. Antioxidant and nutritional activity studies of green leafy vegetables. *Int. J. Agric. Food Sci. Technol.* 4(7): 707-712.

Yi-minn, Z. B., Feng, H., Zheng-xiang, W., and Jing-hua, Z. 2001. Effect of potash application on early ripening and yield of cabbage. *Better Crops Int.* 15(2): 10-11.

PRODUCTIVITY OF SPINACH BEET AS INFLUENCED BY VARIETIES AND NUTRIENT DOSES

by

VINOD ALUR

(2014-11-218)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695522

KERALA, INDIA

2017

ABSTRACT

The investigation entitled "Productivity of spinach beet as influenced by varieties and nutrient doses" was carried out at College of Agriculture, Vellayani, Thiruvananthapuram to assess the suitability of five varieties of spinach beet under protected and open conditions, to standardize the nutrient doses and to work out the economics. The experiment was laid out in split plot design in the Instructional Farm, College of Agriculture Vellayani at 8.5^0 N latitude, 76.9^0 E longitude, under protected and open conditions as two separate experiments during August- November 2015 and 2016 respectively. The treatments included five varieties (V_1: All Green; V_2: Pusa Bharathi; V_3: Punjab Green; V_4: Indam Kolkatta; V_5: Trendy) in main plots and three nutrient levels (N_1: 40:20:40 kg NPK ha^{-1}; N_2: 60:30:60 kg NPK ha^{-1}; N_3: 80:40:80 kg NPK ha^{-1}) in sub plots with four replications. The soil belonged to the order oxisol.

The results of the experiment under protected condition revealed that among the five varieties tested, Punjab Green was found superior in terms of the number of leaves, leaf area index (LAI) and yield. The maximum leaf yield recorded by Punjab Green was 4.78 kg m^{-2} followed by All Green (4.56 kg m^{-2}). Plant height, total number of leaves $plant^{-1}$ and LAI were significantly higher at N_3 (80:40:80 kg ha^{-1})compared to the lower doses. The same NPK level recorded the highest yield of 4.70 kg m^{-2} which was significantly superior to the other levels. The interaction effects were significant with v_1n_3 recording maximum leaf yield (5.06 kg m^{-2}) followed by v_3n_3 (5.01 kg m^{-2}).

Nutrient uptake (NPK), protein and Fe contents were the highest in Punjab Green which was significantly superior to the other varieties, while vitamin C was the highest in Pusa Bharathi. Spinach beet fertilized with 80:40:80 kg NPK ha^{-1} showed significantly higher values for NPK uptake, Ca content and vitamin C. Soil pH was

found to increase with higher levels of nutrients and organic carbon content decreased from the initial values. Available NPK status in soil were found to increase with the increased NPK application.

The var. Punjab Green showed maximum net returns (₹ 881.59from $10m^2$) and benefit-cost ratio (1.44) and among nutrient levels, nutrient dose of 80:40:80 kg NPK ha^{-1} was found to be the most economical (net returns from 10 m^2 - ₹835.54, B:C ratio- 1.42). Taking into account the interaction effects, the varieties All Green and Punjab Green at 80:40:80 kg NPK ha^{-1} could be recommended for cultivation under protected conditions.

In open field condition, the var.All Green recorded significantly taller plants with the highest number of leaves, LAI and leaf yield. Among the different nutrient levels, N_3 (80:40:80 kg NPK ha^{-1}) was found to be significantly superior in yield attributes and leaf yield in spinach beet. The interaction of Pusa Bharathi and 80: 40: 80 kg NPK ha^{-1} registered significantly higher yield (4.14 kg m^{-2}) followed by All Green at 80 :40 : 80 kg NPK ha^{-1} (4.02kg m^{-2}).

Nutrient uptake, vitamin A, C, protein and Ca contents were significantly high in the var. All Green and inthe nutrient dose of 80 :40:80 kg NPK ha^{-1}. Interaction effect of the above combination (v_1n_3) also recorded higher values for the plant nutrient contents. Available N, P and K contents in soil significantly increased with increase in NPK levels.

Economic analysis revealed that the interaction v_2n_3 (Pusa Bharathi and 80 :40 : 80 kg NPK ha^{-1}) was most profitable (net returns ₹ 495.39 from 10 m^{-2} and B:C ratio 1.25) followed by v_1n_3(net returns ₹ 418.36 from 10 m^{-2} and B:C ratio 1.21).

The variety Punjab Green and All Green were the most suitable varieties for cultivation in polyhouse while All Green and Pusa Bharathi could be recommended for cultivation in the open. The Ca, protein chlorophyll content and NPK uptake were the highest in Punjab Green and All Green in the polyhouse and open respectively. The NPK dose of 80:40:80 kg NPK $ha^{-1}$was found to be the suitable

nutrient dose under both conditions irrespective of the variety. Taking into account the economics of cultivation, the combinations, All Green + 80:40:80 kg NPK ha^{-1} was the most profitable in the polyhouse while Pusa Bharathi + 80:40:80 kg NPKha^{-1}, for cultivation in the open.

സംഗ്രഹം

ഇലവർഗ്ഗപച്ചക്കറിവിളകളിൽ ഉൾപ്പെടുന്ന പാലക്ക് ചീരയിൽ വിവിധയിനങ്ങളെയും വളപ്രയോഗത്തെയും ആസ്പദമാക്കി 2015-16 വർഷങ്ങളിലായി വെള്ളായണി കാർഷിക കോളേജ് വിളപരിപാലനവിഭാഗത്തിൽ ഗവേഷണപഠനം നടത്തുകയുണ്ടായി. തുറസ്സായ സ്ഥലങ്ങളിലും ഹരിതഗൃഹങ്ങളിലും (സംരക്ഷിതകൃഷി) അനുയോജ്യമായ ഇനം, പാക്യജനകം(N), ഭാവഹം(P) ,ക്ഷാരം(K) പോഷകമൂലകങ്ങളുടെ തോത്, പാലക്ക് കൃഷിയിൽ ഇവയുടെ വരവ്ചെലവ് നിർണ്ണയിക്കുക എന്ന ലക്ഷ്യങ്ങളോടെ പരീക്ഷണം വെള്ളായണി ഇൻസ്ട്രഷണൽ ഫാമിൽ സ്പ്ലിറ്റ്പ്ലോട്ട് ഡിസൈൻ രീതിയിൽ നടപ്പിലാക്കി .അഞ്ച് ഇനങ്ങൾ (ആൾഗ്രീൻ, പൂസഭാരതി, പഞ്ചാബ് ഗ്രീൻ, ഇൻഡാം കൽക്കട്ട, ട്രെൻഡി) മൂന്നു് NPK തോതുകൾ (80:40:80; 60:30:60; 40:20:40 കി.ഹെക്ടർ ഒന്നിന്) നാലു തവണ ആവർത്തിച്ച് ആഗസ്റ്റ് - നവംബർ 2015 ൽ ഹരിതഗൃഹത്തിലും 2016 ൽ തുറസ്സായസ്ഥലത്തും കൃഷിയിറക്കി.

സംരക്ഷിത കൃഷിയിൽ പഞ്ചാബ്ഗ്രീൻ ഏറ്റവും നല്ലയിനമായും ഒരു ഹെക്ടറിന് 80:40:80 കിലോ NPK ഹെക്ടർ വിളവിലും വരുമാനത്തിലും ഏറ്റവും മെച്ചപ്പെട്ടതായും തെളിഞ്ഞു. എന്നാൽ NPK ചേരുമ്പോൾ ആൾഗ്രീൻ/പഞ്ചാബ്ഗ്രീൻ,+80:40:80 കി. NPK ഹെക്ടറൊന്നിന് എന്ന കോംബിനേഷനാണ് നല്ലതായി കണ്ടത്.

തുറസ്സായ കൃഷിയിൽ ഏറ്റവും അനുയോജ്യമായി കണ്ടത് ആൾഗ്രീൻ എന്ന പാലക്കിനമാണ്. ഇവിടെയും ഹെക്ടറിനു് 80:40:80 കി. NPK അളവ് തന്നെയായിരുന്നു മികച്ചത്. ഇനം+വളം എന്ന കോംബിനേഷനിൽ പുസാഭാരതി +80:40:80കി. NPK മികച്ച വിളവും ലാഭവും നല്കുന്നതായി കണ്ടെത്തുവാൻ കഴിഞ്ഞു.

Appendices

Appendix- I

Weather data for the cropping period (August 2015 to September 2015)

Standard weeks	Temperature (^{0}C)		Rainfall (mm)	Relative humidity (%)		Bright sun shine (h)
	Maximum temperature	Minimum temperature		Maximum	Minimum	
31	31.3	24.5	2.3	87.6	78.1	9.9
32	31.8	24.7	1.1	90.0	76.1	9.5
33	32.4	24.7	57.6	87.9	73.4	8.9
34	31.8	24.7	15.9	91.3	76.7	9.6
35	31.9	24.7	0.0	89.9	81.1	10.2
36	31.5	24.2	101.2	91.7	84.3	6.7
37	31.2	24.0	67.3	93.4	86.4	8.6
38	31.0	24.6	66.0	93.1	81.9	8.3
39	31.8	24.5	55.3	88.9	83.0	8.2
40	31.2	23.9	34.8	91.9	79.0	8.6
41	31.3	23.8	149.1	92.6	80.6	8.3
42	31.4	24.4	20.7	91.3	78.9	7.8
43	31.2	24.2	50.9	93.3	82.4	7.8
44	31.1	23.5	204.1	92.7	81.0	9.3

Appendix- II

Weather data for the cropping period (August 2016 to November 2016)

Standard weeks	Temperature (^{0}c)		Rain fall (mm)	Relative humidity(%)		Bright sunshine (h)
	Maximum	Minimum		Maximum	Minimum	
31	31.2	24.9	6.0	91.9	76.7	9.3
32	32.3	25.2	1.0	88.7	75.3	9.7
33	31.8	24.5	9.6	92.1	77.4	9.6
34	31.8	25.0	20.8	91.0	76.0	9.7
35	31.7	24.5	2.0	91.0	77.4	9.2
36	31.5	34.4	0.2	92.3	76.6	9.4
37	31.9	24.5	91.3	91.3	74.9	9.6
38	32.0	24.7	2.6	92.2	76.8	9.2
39	31.9	24.7	0.0	91.1	74.3	9.1
40	31.7	24.3	0.0	90.9	74.1	9.7
41	31.6	24.3	0.0	90.3	76.3	9.7
42	32.1	24.3	12.0	88.0	74.0	9.0
43	31.5	24.1	0.0	91.4	75.7	8.5
44	31.9	24.4	30.6	92.4	80.4	7.7
45	32.0	24.2	0.0	91.7	76.7	7.6
46	31.7	24.0	2.0	92.1	77.6	6.7
47	32.2	24.2	10.2	94.9	82.6	6.9
48	32.0	23.4	24.0	92.1	79.3	8.0

Appendix- III

Weather data during the cropping period in polyhouse (August 2015 to November 2015)

Standard Weeks	Soil temperature (^{0}C)	Air temperature (^{0}C)	Relative humidity (%)	Light intensity (K lux)
33	29.7	33.4	90	54.4
34	30.0	32.0	93	43.1
35	30.3	33.1	92	42.1
36	30.3	33.5	94	44.1
37	29.6	33.0	95	45.0
38	30.4	33.4	90	44.1
39	31.0	33.3	91	41.9
40	29.1	32.3	94	31.1
41	30.0	33.0	95	44.6
42	29.3	32.7	93	49.3
43	29.0	31.7	95	47.3
44	29.4	32.5	95	47.4

APPEDINX – IV

Average input costs and marketing price of produce

Items	Cost (₹)
Inputs	
Seeds	
All Green	180 kg^{-1}
Pusa Bharathi	210 kg^{-1}
Punjab Green	180 kg^{-1}
Indam Kolkatta	1000 kg^{-1}
Trendy	2000 kg^{-1}
Labour wages	
Men	600 day^{-1}
Woman	600 day^{-1}
Manures and Fertilizer	
Farm Yard Manure	5 kg^{-1}
Urea	8 kg^{-1}
Rock phosphate	15 kg^{-1}
Muriate of potash (MOP)	18 kg^{-1}
Produce	
Market price of spinach beet	60 kg^{-1}