"YIELD AND QUALITY OF TOMATO (*Solanum lycopersicum* L.) WITH INDIVIDUAL AND INTEGRATED APPLICATION OF INORGANIC POTASSIUM, POTASSIUM HUMATE AND TRIACONTANOL"

PALAKSHI BORAH

B.Sc. (Ag.)

MASTER OF SCIENCE IN AGRICULTURE

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

2012

"YIELD AND QUALITY OF TOMATO (*Solanum lycopersicum* L.) WITH INDIVIDUAL AND INTEGRATED APPLICATION OF INORGANIC POTASSIUM, POTASSIUM HUMATE AND TRIACONTANOL"

BY

PALAKSHI BORAH
B.Sc. (Ag.)

THESIS SUBMITTED TO THE ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

CHAIRPERSON: Dr. V.SAILAJA

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY COLLEGE OF AGRICULTURE
RAJENDRANAGAR, HYDERABAD – 500 030
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY

2012

CERTIFICATE

Ms. PALAKSHI BORAH has satisfactorily prosecuted the course of research and that the thesis entitled **"YIELD AND QUALITY OF TOMATO (*Solanum Lycopersicum* L.) WITH INDIVIDUAL AND INTEGRATED APPLICATION OF INORGANIC POTASSIUM, POTASSIUM HUMATE AND TRIACONTANOL"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any University.

Place: Hyderabad
Date:

(Dr.V.SAILAJA)
Chairperson

DECLARATION

I, **PALAKSHI BORAH** , hereby declare that the thesis entitled **"YIELD AND QUALITY OF TOMATO (*Solanum Lycopersicum* L.) WITH INDIVIDUAL AND INTEGRATED APPLICATION OF INORGANIC POTASSIUM, POTASSIUM HUMATE AND TRIACONTANOL"** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is a result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Hyderabad **(PALAKSHI BORAH)**

Date: **I.D. No. RAM/10-69**

LIST OF CONTENTS

CERTIFICATE

This is to certify that the thesis entitled **"YIELD AND QUALITY OF TOMATO (*Solanum lycopersicum* L.*)* WITH INDIVIDUAL AND INTEGRATED APPLICATION OF INORGANIC POTASSIUM, POTASSIUM HUMATE AND TRIACONTANOL"** submitted in partial fulfillment of the requirements for the degree of 'Master of Science in Agriculture' of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Ms. PALAKSHI BORAH** under our guidance and supervision.

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

(Dr. V. SAILAJA)
Chairperson of the Advisory Committee

Thesis approved by the Student Advisory Committee

Chairperson	:	**Dr. V.SAILAJA** Assistant Professor Department of Soil Science and Agricultural Chemistry College of Agriculture, ANGRAU Rajendranagar, Hyderabad – 500 030	____________________
Member	:	**Dr. P. CHANDRA SEKHAR RAO** Professor and Univ. Head Department of Soil Science and Agricultural Chemistry College of Agriculture, ANGRAU Rajendranagar, Hyderabad – 500 030	____________________
Member	:	**Dr. A.PRATAP KUMAR REDDY** Associate Professor Department of Agronomy College of Agriculture, ANGRAU Rajendranagar, Hyderabad – 500 030	____________________

Date of final viva-voce:

ACKNOWLEDGEMENTS

It gives me great pleasure to humbly place on record my profound sense of gratitude, indebtedness and heartful thanks to the chairperson of my advisory committee, Dr.(Mrs) ***V. Sailaja****, Assistant Professor, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar, Hyderabad, ANGRAU, for her constant attention and meticulous guidance all through the course of this study. This space is inadequate to express the extent of appreciation and thankfulness not just for her help in this work but for her understanding and benevolent nature as a person, that I have experienced in every interaction with her.*

I deem it my privilege to express my gratitude with exaltation to Dr. ***P. Chandrasekhar Rao****, Professor and University Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, ANGRAU, Rajendranagar, Hyderabad and member of Advisory Committee for his insightful guidance, evoking nature on the work at every stage. My sincere thanks are due to him for his transcendent suggestions, valuable comments and efforts to embellish the study and for providing the facilities and constant encouragement during the research work.*

I extend my deep sense of reverence and gratitude to the member of my advisory committee, Dr. ***A. Pratap Kumar Reddy****, Associate Professor, Department of Agronomy, College of Agriculture, Rajendranagar, Hyderabad for his constant encouragement, ready help and valuable suggestions which led to the successful completion of my present investigation.*

*It gives me great pleasure to express my deep sense of gratitude to Dr.****V. Govardhan,*** *Professor, Dr.****K. Jeevan Rao,*** *Professor, Dr.* ***D. Balaguravaiah****,Professor, Dr.****G. Jayasree****, , Dr.* ***G. Padmaja****, , Dr.* ***M. Jeevaratna Raju****, , Dr.****CH. Sujani Rao****, and Dr.* ***Harish Kumar Sharma****, Associate Professors of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar, Hyderabad for their constant encouragement, valuable suggestions and kindness.*

I extend my heartfelt thanks to Ms. ***J. Aruna Kumari****, Assistant Professor, Dept. of Biochemistry, Dr.* ***Hussain*** *and Dr.* ***Susheela****, Farm Managers, College farm, College of Agriculture, Rajendranagar, Hyderabad for their support and help during my research work.*

I wish to express my genuflect love and affectionate gratitude to my father Sri. ***Phanidhar Borah*** *for his inspiration, moral support and blessings that kept me enthusiastic throughout my life and my mother Smt.* ***Reena Borah*** *for her blessings and affectionate love which brings out the best in every one of my endeavors.*

The instrument of acknowledgement would remain out of tune if I do not express my thanks to my beloved sisters ***Pallabi*** *and* ***Priyanka*** *whose unconditional love, unbounded affection and moral support were my strongest assets during the period of my study.*

I feel immense pleasure and joy in expressing my profound affection and gratitude to my friends **Alekhya, Doni, Shifa, Minakshi, Sonali, Richa, Chirag**; my roommate **Shilpa**; my colleagues **Kiran, Naveen, Uma** and **Sudharshana** and my juniors who shared my fears, tears and joys, turned hopeless moments to hopeful things which put forth new tender issues in my life.

I express with gratitude the unabated help received from my seniors **Kalyani, Chaitanya, Santhosi**, **Madhavi**, **Vijaya Laxmi**, **Chandra Shaker**, **Ram Prasad**, **Srinivasan** for their suggestions, motivation and help during my work.

I am also thankful to **Shobha**, **Anita, Samuel, Bikshpati, Kaja, Sriniva, Kailash** and other non-teaching staff of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar for helping me in several works.

I am greatly thankful to the ICAR and to Acharya N. G. Ranga Agricultural University for giving me this opportunity to pursue my post graduation study.

I convey my wholehearted thanks to all my well wishers requesting their forgiveness for not mentioning them here by name.

Above all, I am grateful to 'God' giving me enough strength and fortitude to meet various challenges.

Needless to say omissions and errors are mine.

Date: **(PALAKSHI BORAH)**

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF PLATES

LIST OF SYMBOLS AND ABBREVIATIONS

@	:	at the rate of
c mol (p^+) kg^{-1}	:	centimoles per kilogram
CD	:	critical difference
CEC	:	Cation exchange capacity
cm	:	centimeter
d Sm^{-1}	:	Deci Siemens per meter
DAS	:	Days after sowing
DAT	:	Days after transplanting
DAP	:	Diammonium Phosphate
EC	:	Electrical conductivity
EC	:	Emulsifiable concentrate
EDTA	:	Ethylene Di-amine Tetra Acetic Acid
et al.	:	and others
Fed	:	Feddan
Fig.	:	Figure
FYM	:	Farmyard manure
g ha^{-1}	:	grams per hectare
HPO_3	:	Metaphosphoric acid
HA	:	Humic acid
h^{-1}	:	per hour
i.e.,	:	that is
K	:	Potassium
KH	:	Potassium humate
K-humate	:	Potassium humate
kg ha^{-1}	:	kilogram per hectare
kg	:	kilogram
L	:	litre
M ha	:	million hectare
m^2	:	square meter
mg	:	milli gram (s)
mg g^{-1}	:	milligrams per gram
mg kg^{-1}	:	milligrams per kilogram
mL	:	milli litre
mins	:	minutes
M	:	Molar
MOP	:	Muriate of potash
NaOH	:	Sodium hydroxide
N	:	Normality
N	:	Nitrogen
NS	:	Not significant
nm	:	Nanometre
OC	:	Organic carbon
OD	:	Optical density
P	:	Phosphorus
pH	:	soil reaction
ppm	:	parts per million
q ha^{-1}	:	quintals per hectare
RBD	:	Randomized block design
RDF	:	Recommended dose of fertilizers
Rs.	:	Rupees

r	:	Correlation Co- efficient
rpm	:	Revolutions per minute
SEd±	:	Standard error of difference
sec	:	Second
TRIA	:	Triacontanol
t ha^{-1}	:	tonnes per hectare
viz.,	:	namely
%	:	Per cent
°C	:	Degree Celcius
µg	:	micro gram
µM	:	micro molar

Author	:	**PALAKSHI BORAH**
Title	:	**YIELD AND QUALITY OF TOMATO (*Solanum lycopersicum* L.) WITH INDIVIDUAL AND INTEGRATED APPLICATION OF INORGANIC POTASSIUM, POTASSIUM HUMATE AND TRIACONTANOL**
Degree	:	**MASTER OF SCIENCE IN AGRICULTURE**
Department	:	**SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**
Faculty	:	**AGRICULTURE**
Chairperson	:	**Dr. V. SAILAJA**
University	:	**ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY**
Year of submission	:	**2012**

ABSTRACT

A field experiment was conducted during *kharif*, 2011 on sandy clay soil to study the effect of individual and integrated use of inorganic potassium, potassium humate and triacontanol on yield and quality of tomato with the title "**Yield and quality of tomato (*Solanum lycopersicum* L.) with individual and integrated application of inorganic potassium, potassium humate and triacontanol**". The experiment was conducted in randomized block design with sixteen treatments replicated thrice. The treatments included the individual application of inorganic K at 30, 45, and 60 kg K_2O ha^{-1} level and their integration with either potassium humate or triacontanol or both (12 no') besides the individual application of potassium humate, triacontanol and inorganic K at 90 kg K_2O ha^{-1} (3 no') and a treatment comprising the combination of triacontanol and potassium humate (1 no'). The effect of different treatments was evaluated in terms of dry matter production, chlorophyll and carotenoid contents at flowering and yield at harvest. Plant samples were analyzed for their per cent nutrient composition with respect to N, P and K at flowering and at harvest. The uptake of nutrients was computed. The fresh fruit samples were analysed for quality parameters. Soil nutrient status with regard to available N, P and K were studied at flowering and at harvest of tomato crop.

The soil under study was sandy clay in texture, slightly alkaline and normal in salt content with a CEC of 35.8 c mol (p^+) kg^{-1}. The soil was medium in organic carbon (0.67%), low in available nitrogen (156.7 kg N ha^{-1}), high in available phosphorus (57.0 kg ha^{-1}) and potassium (449.0 kg ha^{-1}).

Among the treatments, T_4 receiving 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol showed significantly higher dry matter production of 30.79 q ha^{-1} which was 29 % more when compared to control receiving recommended dose of 60 kg K_2O ha^{-1}. However, this was on par with the dry matter produced by integrated application of potassium humate and triacontanol along with a lower dose of 45 kg K_2O ha^{-1}.

The yield of tomato varied from 102.7 to 135.0 q ha^{-1}. The treatment receiving 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol recorded the highest fruit yield of 135.0 q ha^{-1} which was 18 % more than recommended dose of K.

The quality parameters *viz.*, ascorbic acid, lycopene content and TSS were found significantly higher in T_4 with the corresponding values of 4.27 and 33.1 mg 100 g^{-1} and 3.33 Brix %. On the contrary the titratable acidity gradually decreased with increasing levels of inorganic K application having a significantly higher value of 0.68 per cent with 30 kg K_2O ha^{-1}. The N, P and K content and uptake by the crop were found to be significantly influenced by the treatment T_4 which was significantly superior to the recommended dose of K.

There was greater reduction in the available N and P content of the soil in T_4 at both the stages. Available K content of the soil got depleted from the initial value of 449 kg ha^{-1} in all the treatments. The depletion was higher i.e., 10 per cent with the application of triacontanol alone and got reduced to 2 per cent inT_4.

Thus by virtue of the above facts, the treatment T_4 is found to be the best in effective utilization of the nutrients resulting in improved fruit yield, quality and returns of the crop (high benefit – cost ratio) besides maintaining the available K status.

Chapter I

INTRODUCTION

In the past, the agricultural production was focused on maximizing the quantity of fruits and vegetables produced for commercial market. However, modern consumers are now interested in optimizing the nutritional composition of foods. Therefore, much attention has now been placed on the agricultural practices that will enhance the nutritional content of fruits and vegetables being produced today (Wang, 2006). Fertilizers play an important role in increasing the production and improving the quality of vegetables and among them potassium is considered to be the prime nutrient because of its role in various physiological processes.

Vegetables play a very important role in human diet. They are rich source of vitamins and minerals. These functional foods contain bioactive ingredients known as phytochemicals or nutraceuticals that may increase health and fitness. One such phytochemical is the carotenoid, lycopene found in tomato fruit and it is associated with the inhibition of heart disease (Rissanen *et al*., 2003).

Tomatoes are a great vegetable loaded with a variety of vital nutrition especially important for the human diet because of their content of vitamin C, carotenes, lycopene and phenolic compounds and vitamin B1. In addition, tomatoes are a good source of vitamin B6, folate, copper, niacin, vitamin B2, magnesium, iron, pantothenic acid, phosphorus, vitamin E and protein (Davey *et al.*, 2000).

According to Annual Report, National Horticultural Board (2010), in India, tomato is cultivated in 0.61 million hectares with a production of 11.97 million tonnes and productivity of 19.3 tonnes per hectare. In Andhra Pradesh, it is cultivated in 0.74 lakh hectares with production and productivity of 1.4 million tonnes and 19 tonnes per hectare respectively.

In plants, the physiological functions of K include enzyme activation, osmo-regulation, photosynthesis and translocation of products of photosynthesis (Bergmann, 1992). In tomato, and in almost all fruit and vegetable crops, K improves fruit quality (Dorais *et al*., 2001).

From the literature it is understood that besides K, organic products like Triacontanol (a neem based product with the formula $CH_3(CH_2)_{28}CH_2OH$) and K- humate also affect the quality of tomato (Ali and Elbordiny, 2009 ; Khan *et al*., 2009). Triacontanol plays an important role in manipulating the yield potential and augmenting the uptake of nutrients in many vegetable species including tomato. The major growth regulatory effects of triacontanol are photosynthesis stimulation and enhanced water uptake, which eventually result in an increase in the dry weight. Triacontanol application has also been reported to increase dry weight, CO_2 fixation, reducing sugars, soluble proteins and free amino acids in various crops (Ries and Houtz, 1983), indicating its role towards growth, yield and quality improvement of the crop.

The favorable effect of humic substances in stimulating growth, yield and yield attributes could be attributed to the presence of auxin like properties in HA (Schnitzer, 1978). The biological benefits are that it will stimulate plant growth through increasing root systems, accelerate cell division and increase the dry matter yield without any detrimental effect on the plants. The plants take more mineral elements due to better-developed root systems (Zientara, 1983). Though limited research was carried out earlier on individual use of the three components there was no information on the influence of the integrated use of inorganic potassium, potassium humate and triacontanol on growth, yield and quality of tomato.

Hence, keeping the above facts in view, the research work entitled **"Yield and quality of tomato (*Solanum lycopersicum* L.*)* with individual and integrated application of inorganic potassium, potassium humate and triacontanol"** was conducted to know whether any interaction exists between inorganic K, triacontanol and K- humate with the following objectives.

OBJECTIVES:

1. To study the response of tomato to the individual application of inorganic K, triacontanol and K -humate in terms of yield and quality.

2. To study the effect of individual application of inorganic K, triacontanol and K –humate on the K content and uptake by tomato.

3. To study the interaction effect of inorganic K, triacontanol and K –humate on the yield, quality, K content and uptake by tomato.

4. To compute the economics of the individual and integrated use of inorganic K, triacontanol and K -humate for tomato.

Chapter II

REVIEW OF LITERATURE

The literature pertinent to the present investigation *viz*.,"**Yield and quality of tomato (*Solanum lycopersicum* L.) with individual and integrated application of inorganic potassium, potassium humate and triacontanol**" has been reviewed and the effects of individual and integrated application of inorganic K, potassium humate and triacontanol are presented under the following heads

2.1 Effect on dry matter production at flowering and yield at harvest

2.2 Effect on quality of crops

2.3 Effect on nutrients (N, P and K) content and uptake by plant

2.4 Effect on soil available nutrients at flowering and harvest

2.5 Simple correlations of K nutrition with yield and quality of the crop

2.6 Economics of the individual and integrated use of inorganic K, triacontanol and K - humate in tomato

2.1 Effect on dry matter production at flowering and yield at harvest

Potassium plays a vital role in growth, plant productivity, metabolism, ionic balance, activation of several enzymes and plants' defense system (Marschner, 2002)

The total K was directly proportional to the dry matter content (Besford and Maw, 1975). The root yield of carrot increased when muriate of potash was applied at 100 kg ha^{-1} (Basavaraja, 1986).

The total fruit yield of tomato significantly increased to 35.4 t ha^{-1} with increasing levels of potassium up to 100 kg K_2O ha^{-1} as compared to control yield of 29.2 t ha^{-1} on a sandy loam soil with 65 ppm of available K (Rao, 1994). Lal *et al*. (1995) suggested that on a silty clay loam soil with medium K status the treatments receiving 60 and 90 kg K_2O ha^{-1}were at par.

Tomato crop needs moderate to high levels of K. Significantly higher yield of 525.33 q ha^{-1} was obtained with the application of 90 kg K_2O ha^{-1} as against 297.66 q ha^{-1} in the control on a loamy sand soil medium in available K content (Majumdar *et al*., 2000).

Increasing levels of potassium up to 60 kg ha^{-1} on a sandy loam soil with 136.45 kg K_2O ha^{-1} resulted in increased marketable yield per hectare to 304.83 kg ha^{-1} of tomato as compared to control yield of 267.30 kg ha^{-1} (Gupta and Sengar, 2000).

Bokhtiar *et al*. (2001) reported that four irrigation levels and K application at the level of 120 kg K_2O ha^{-1} proved to be the best combination for the sustainable radish cultivation in shallow red–brown terrace soil of Bangladesh.

On a loamy sand soil with an available K status of 190 kg K_2O ha^{-1}, the K levels progressively increased the yield of tomato from 14.9 t ha^{-1} at K_0 level to 15.5 and 16.3 t ha^{-1} at K_{40} and K_{80} levels respectively (Duraisami and Mani, 2002).

The highest yield of tomato was obtained at a K level of 360 kg K_2O ha^{-1} with a yield of 8.52 t ha^{-1} and the lowest yield of 5.90 t ha^{-1} was in the control. The effect of different rates of K on the yield is significant at 1 % level (Yagmur *et al*., 2004). Significantly higher fruit yield of tomato i.e., 24.9 t ha^{-1} was obtained with application of 100 kg K_2O ha^{-1} as against 12.6 t ha^{-1}in the control and the same level of K from SOP produced 15.4 t ha^{-1}. The yield increase was more pronounced with K applied as MOP compared to SOP (Akhtari *et al*., 2010).

Increasing K rates from 0 to 200 kg K ha^{-1} increased marketable fruit yield by 10% and total fruit yield by 9% as compared to control (Liu *et al*., 2011).

Foliar application of potassium humate @ 2000 and 1250 mg kg^{-1} on soybean increased the average yield by 14.06 per cent compared to the control (Dong Fang *et al*., 2002).

Soaking the seeds of wheat alone or combined with foliar spray of potassium humate significantly increased both grain and straw yield of wheat plants, as compared to control. The highest increase resulted from soaking seeds and as foliar spray enriched potassium humate, which showed 36.9 and 85.8% increase over the control for grain and straw yields respectively (Ali and Elbordiny, 2009). Similar findings were reported on tomato by Rady (2011) that significant positive effects of 100 kg potassium humate along with 50 t FYM ha^{-1} was obtained on shoot dry weight $plant^{-1}$, root DW $plant^{-1}$ and total fruit yield ha^{-1}.

Increase in wheat yield was from 2.5 to 3.6 t ha^{-1} by the use of applied humic fertilizer (Shahryari and Mollasadeghi, 2011).

Triacontanol is a straight chain alcohol of 30 carbon atoms and has been recognized as a plant growth regulator and plays an important role in manipulating the yield potential by augmenting the uptake of nutrients in many vegetable species including tomato (Ries and Houtz, 1983).The per cent increase in the dry matter of tomato with application of triacontanol was to the magnitude of 30 per cent (Eriksen *et al*., 1981).

Application of triacontanol increased the yield of lablab bean by 8 to 13 per cent and by 101 to 156 per cent in Indian mustard. Maximum seed yield of 19.33 q ha^{-1} of lablab bean and 11.60 q ha^{-1} of Indian mustard was obtained with foliar spray of 0.5 ppm triacontanol (Jadhav *et al*., 1987).

Application of triacontanol (Vipul 0.1 per cent EC) @ 300 ml ha^{-1} to tomato on a slightly alkaline soil with a high available K status of 295 kg K_2O ha^{-1} produced the highest fruit yield of 35.1 t ha^{-1} which was 16 per cent more over control (Muthuvel *et al*., 2001).

Namdeo *et al*. (2001) reported that foliar application of 250 mL triacontanol ha^{-1} to chickpea at 30, 40 and 50 days after sowing (DAS) produced the highest growth and yield components with 25.8 per cent increase in grain yield compared to the control.

Application of triacontanol (Vipul of 0.1 per cent EC) @ 300 mL ha^{-1} to chilli grown on a sandy loam soil with medium status of available K resulted in the highest dry pod yield of 36 t ha^{-1}(Muralidharan *et al*., 2002).

Application of triacontanol (Vipul 0.1%) @ 0.75 mL L^{-1} to tomato resulted in highest number of branches per plant (14.2), fruits per plant (94.67) and early and total yields per plant of 0.480 and 3.24 kg respectively (Dhall and Ahuja, 2004).

Application of triacontanol @ 1 ppm to tomato resulted in increased fruit yield, as compared to control (Khan *et al*., 2006). Foliar spray of 10^{-6} M TRIA to hyacinth bean

(*Lablab purpureus* L.) significantly increased seed yield by 56.3 per cent when compared to unsprayed plants (Naeem *et al*., 2009).

Foliar application of triacontanol along with the recommended dose of NPK on the growth and yield of lowland rice revealed that triacontanol sprayed at 0.1 per cent concentration realized the highest plant height of 81 cm, number of tillers/hill of 8.02, grain yield of 4.71 t ha^{-1} and straw yield of 7.25 t ha^{-1} (Vaiyapuri and Sriramachandrasekharan, 2003).

In a field experiment on a sandy loam soil high in available K status, the application of 100% NPK with humic acid applied to soil @ 10 kg ha^{-1} and as foliar spray @ 0.1% + rhizome dipping at 0.1% significantly enhanced the growth and yield attributes, fresh and cured rhizome yields of turmeric (Baskar and Sankaran, 2005).

Application of 100% or 75% STCR recommended levels of NPK along with potassium humate at 30 or 40 kg ha^{-1} or combination of soil application of potassium humate @ 20 kg ha^{-1} + 1% seed soaking + 0.1% foliar spraying with 100% STCR recommended fertilizers recorded significantly higher yield of cotton on a typic vertic Ustochrept (Kalaichelvi and Chinnusamy, 2008).

Sathiyabama and Selvakumari (2001) reported that application of 10 kg humic acid ha^{-1}, along with 75% recommended NPK to amaranthus influenced the production of green matter significantly, besides recording higher nutrient content.

The higher bulb yield of 18.7 t ha^{-1} in onion was obtained in the treatment receiving 100% NPK plus humic acid @ 20 kg ha^{-1} which was higher by 11.31 per cent over the yield with inorganic fertilizers alone (Sangeetha *et al*., 2008).

Application of 75% RDF along with humic acid @ 30 kg ha^{-1} to chilli was found to be superior in increasing yield of fresh and dry fruits to 12.86 and 3.35 t ha^{-1} respectively (Dileep and Sasikala, 2009).

The combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration proved to be the best to increase the fruit yield of tomato by 57.6 per cent over control on a sandy loam soil rating low in available K content of 108 kg ha^{-1} (Khan *et al*., 2009).

2.2 Effect on quality of crops

Curcumin content of mother and primary rhizomes of turmeric increased significantly when muriate of potash was applied 90 kg ha^{-1} (Mohanbabu and Muthuswami, 1984).

Increased values of TSS (in per cent), titratable acidity (in per cent) and ascorbic acid (in mg 100 g^{-1}) in the fruit of tomato to 4.2, 0.54 and 28 respectively were observed with K application @ 200 kg K_2O ha^{-1} with the corresponding values of 3.9, 0.45 and 24 in the control (Rao, 1994).

Tomato crop needs moderate to high levels of K. The total soluble solid and ascorbic acid contents were higher i.e., 4.77 per cent and 28.677 mg per 100 g with the application of 90 kg K_2O ha^{-1} (Majumdar *et al.*, 2000).

The K levels progressively increased the TSS of 3.91 at K_0 level to 4.01 and 4.30 at K_{40} and K_{80} levels respectively in tomato (Duraisami and Mani, 2002).

The TSS and Vitamin C contents of tomato fruit increased up to 240 kg K_2O ha^{-1}. Significant relationships existed between the enhanced fertilizer rates and TSS, acidity and Vitamin C (Yagmur *et al.*, 2004).

Maximum Lycopene content of 7.4 mg per 100 g was obtained with the application of 60 kg K_2O ha^{-1} along with N and P_2O_5 @ 60 : 60 kg ha^{-1} (Diana *et al.*, 2007) on a soil with available K content of 160 ppm.

Foliar application of enriched humic substances showed a significant influence on the quality of tomato by recording higher value of total soluble solids (5.3Brix %), reducing sugars (2.0%), total sugars (2.30%), acidity (0.52%) and ascorbic acid (30.0 mg/100g) as compared to control (Reddy *et al.*, 2004).

Rady (2011) reported that significant positive effects were found with the application of 100 kg potassium humate + 50 MT FYM ha^{-1} on leaf free proline content, fruit vitamin C and total soluble solids (TSS) contents of tomato when compared with the other three combinations of potassium humate and FYM i.e., 50 kg KH+25 metric tonnes FYM, 50 kg KH+50 MT FYM, 100 kg KH+25 MT FYM.

Application of triacontanol (Vipul of 0.1 per cent EC) @ 300 mL ha^{-1} to tomato resulted in maximum TSS of 4.68 °Brix, highest ascorbic acid content of 20.7 mg 100 g^{-1}, highest sugar content of 5.01 per cent and lowest titratable acidity of 0.45 per cent as compared to control (Muralidharan *et al.,* 2000). Foliar application of triacontanol (Vipul 0.1 per cent EC) @ 300 ml ha^{-1} to chilli resulted in the highest capsaicin content of 4.67 mg/100 g, total soluble solids content of 12.1 ^{o} brix, and ascorbic acid content of 126 mg 100 g^{-1} in ripe fruits (Muralidharan *et al*., 2002).

Application of triacontanol @ 1ppm to tomato resulted in increased lycopene content to 1235 µg 100 g^{-1} and β-carotene content to 1710 µg 100 g^{-1} in fruits as compared to control (Khan *et al*., 2006).

Foliar spray of 10^{-6} M triacontanol to hyacinth bean (*Lablab purpureus* L.) significantly increased the protein content by 14.5 per cent over unsprayed plants (Naeem *et al*., 2009). The treatments receiving K at rates of 200, 400, and 600 kg K_2O ha^{-1} increased the soluble solid content of tomato fruit by 3, 6, and 8 per cent respectively over control (Liu *et al*., 2011).

The treatment receiving 100% NPK plus humic acid @ 20 kg ha^{-1} significantly improved the quality parameters such as total soluble solids, ascorbic acid content, total sugars and pyruvic acid content of onion bulb as compared to other treatment combination (Sangeetha *et al*., 2008).

The combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration proved to be the best to increase the leaf chlorophyll, ß carotenoid contents, lycopene, ascorbic acid and fruit yield of tomato by 15.2, 8.3, 9.5, 6.7 and 57.6 per cent over control on a sandy loam soil rating low in available K content of 108 kg ha^{-1} (Khan *et al*., 2009).

Foliar application of K humate @ 40 L fed^{-1} (1 feddan = 4200 m^2) enriched with N, P and K showed 95.6 and 68.4 per cent increase over control for protein and carbohydrate content, respectively (Ali and Elbordiny, 2009)

Application of 75% RDF along with humic acid @ 30 kg ha^{-1} to chilli crop was found to be superior in producing the fruits with maximum quality having the ascorbic acid, oleoresin, capsanthin and capsaicin contents of 140.80 mg 100 g^{-1}, 14.12 per cent, 45.52 ASTA units and 0.79 per cent respectively (Dileep and Sasikala, 2009)

2.3 Effect on the nutrients (N, P and K) content and their uptake by the crops

Application of potassium to potato crop in graded levels in the form of muriate of potash and potassium schoenite showed a significantly higher K uptake at 100 kg K_2O ha^{-1} (Maity and Arora, 1980).

The K content of cabbage grown on an Alfisol with an available K status of 140 kg ha^{-1} was influenced significantly with the application of K. The K content of the plant at 30, 60 days of age and at harvest were 2.0, 1.30 and 1.68 per cent in the control, which increased significantly to 3.08, 1.85 and 2.27 per cent with the application of 200 kg K_2O ha^{-1}. The K content of the curd also showed a significant increase from 2.0 to 2.78 per cent in the treatment (Rao and Subramanian, 1991).

Lal *et al*. (1995) reported that application of 90 kg K_2O ha^{-1} to sesame resulted in increased K content to 0.68 per cent and K uptake to 35.1 kg ha^{-1} over control.

Application of different levels of potassium showed significant increase in K content and total K uptake by sweet potato. The per cent K content of shoot was lower (1.57%) than the K content in tubers (2.17%) at harvest. This was due to translocation of potassium from source to sink during tuber formation and development stage (Padmaja and Sreenivasa Raju, 1999).

Significant increase in K content of carrot with increase in level of K was observed in a field experiment on a sandy loam soil. The mean K content in per cent increased from 1.56 to 2.37, 2.2 to 5.37 and 1.97 to 3.74 per cent at 30, 60 and 90 DAS. The K uptake also increased with K level (Anjaiah *et al*., 2005).

The leaf K content of tomato increased from 2.44 to 3.85 g kg^{-1} with the application of 372 kg K_2O ha^{-1} on loamy soil with low available K content and it was found that the leaf K content and lycopene content correlated positively (Taber *et al*., 2008).

The highest K uptake of 106.77 kg ha^{-1} by chilli was noticed with the application of K at 150% RDK through sulfate of potash in 2 split doses in a field experiment conducted in Karnataka, India, on Typic Chromustert (Prabhavathi *et al*., 2009).

Application of 10 kg humic acid ha^{-1} along with 75% recommended NPK to amaranthus resulted in a higher nutrient content (Sathiyabama and Selvakumari (2001). Increased contents of both macronutrients (N, P and K) and micronutrients (Fe, Mn, Zn, and Cu) and their uptake by wheat and broad bean plants were recorded by increasing the rate of potassium humate from 50 to 100 micro g g^{-1} (Rizk and Mashhour, 2008).

The foliar application of potassium humate at a rate of 40 L Fed^{-1} individually or combined with soaking was more effective on N, P and K uptakes by straw and grain of wheat plants than other treatments. In addition, foliar application of K-humate enriched had a greater effect as compared to K-humate only (Ali and Elbordiny, 2009).

Significant positive effect was showed by of 100 kg KH + 50 MT FYM ha^{-1} on leaf mineral composition (N, P, K, Fe, Mn, and Zn), leaf and fruit nitrite (NO_2^-) and nitrate (NO_3^-) contents, when compared with the other three KH+FYM treatments i.e., 50 kg KH+25 metric tonnes (MT) FYM, 50 kg KH+50 MT FYM, 100 kg KH+25 MT FYM. (Rady, 2011).

Application of triacontanol (Vipul 0.1 per cent EC) @ 300 mL ha^{-1} to tomato resulted in maximum K content of 3.62 and 2.72 per cent respectively in the fruit and stover; with corresponding removal to the extent of 90.0 and 68.9 kg ha^{-1} by fruits and stover (Muthuvel *et al*., 2001).

Foliar application of 250 mL ha^{-1} triacontanol (Vipul) to chickpea recorded the highest K uptake of 72.38 kg ha^{-1} compared to the control (Namdeo *et al*., 2001). Similarly, foliar application of triacontanol @ 0.1% along with the recommended dose of NPK registered the highest removal of nutrients to the extent of 106.7, 29.0, 51.8 kg NPK ha^{-1}respectively (Vaiyapuri and Sriramachandrasekharan, 2003).

The combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration showed maximum increase in N, P and K contents exceeding control by 14.9, 32.6 and 26.3 per cent respectively (Khan *et al*., 2009).

2.4 Effect on soil available nutrients at flowering and at harvest

With increase in the dose of potassium there was a progressive increase in the status of available K in the soil with the highest value of 209.5 kg ha^{-1}at 80 kg K_2O ha^{-1} level as against 181.8 kg ha^{-1} in the control on a loamy sand with available K content of 190 kg ha^{-1}

with tomato as the test crop (Duraisamy and Mani, 2002). Similarly, the available P status of the soil increased with the application of potassium humate to the soil (Kalaichelvi and Chinnusamy, 2005).

2.5 Simple correlations of K nutrition with yield and quality of the crop

Bray's per cent yield correlated positively and significantly with plant K (r=0.64**), K uptake (r=0.87**) by mustard and available K content of soil with r = 0.56* (Ghosh and Mukhopadhyay, 1996).

The soil exchangeable K correlated positively and significantly with the leaf K (0.25^{**}), fruit K (0.54^{**}) and soluble solids (0.23^{**}). The plant K content also showed a positive and significant correlation with fruit K (0.19^{**}) and soluble solid (0.28^{**}) in tomato on a silty clay soil (Hartz *et al*., 1999).

The colour value of chillies has significant positive relationship with available K of soil (Bidari *et al*., 2004). Potassium concentration of whole red fruit/ pericarp component in chilli bear significant positive relationship with quality attributes particularly colour value (r = 0.86* and 0.96*).

Prabhavathi *et al*. (2008) reported that highest correlation coefficients (r) 0.855** and 0.909** were observed in case of colour value and per cent oleoresin respectively with K concentration of whole red chilli fruit.

In a field experiment on a loam soil with low available K content, it was found that the leaf K content and lycopene contents correlated positively with levels (Taber *et al*., 2008).

2.6 Economics of the individual and integrated use of inorganic K, triacontanol and K -humate

Increasing potassium dose from 0 to 60 kg K_2O ha^{-1} in sesame gave net returns of Rs.12, 514 /- ha^{-1} and Benefit - cost ratio of 2.51 (Lal *et al*. 1995). Application of 80 kg K_2O ha^{-1} to soybean resulted in increased net returns of Rs. 10,627.16/- ha^{-1} over the net returns of Rs. 8026.17/- ha^{-1} from the control (Singh and Singh, 1995).

Foliar application of Triacontanol @ 0.05% to mustard gave significantly highest net returns (Rs. 9026 ha^{-1}); the per cent increase over the growth regulators such as multiplex and mixtalor was to the tune of 84.99 and 18.45 of respectively (Sumeria, 2003).

Economic analysis showed that the application of 60 K_2O ha^{-1} to intercropping of french bean and potato earned Rs. 49819 ha^{-1} maximum profit which has Rs. 8406 ha^{-1} more over control (Sherawat and Singh, 2009).

Based on the literature available, it is understood that though there is some work on the individual use of inorganic K, potassium humate and triacontanol on crops like tomato for which the quality plays a role in producing marketable yield, the research on the integrated use of the three components is not documented which may further improve the growth, yield and quality of the crop thus giving good returns.

Chapter – III

MATERIALS AND METHODS

The present investigation entitled **"Yield and quality of tomato (*Solanum lycopersicum* L.) with individual and integrated application of inorganic potassium, potassium humate and triacontanol"** was carried out under field conditions during *kharif*, 2011. The details of the research work carried out, methodologies adopted and materials used in these investigations are as follows.

3.1 Location of the Experimental Site

The field experiment was conducted at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is geographically situated at $78^0$28' East longitude and $17^0$19' North latitude and at an altitude of 542.3 m above mean sea level. The climate of Hyderabad is tropical semi-arid.

3.1.1 Characteristics of the experimental site

The experiment was conducted in sandy clay soil. The initial soil sample was collected prior to the layout of the experiment from 0-15 cm depth and analyzed for physical, physico-chemical and chemical properties following standard analytical methods.

3.1.2 Methods of soil analysis

The initial soil sample and soil samples collected at different stages of the crop from the field were analyzed for physical, physico-chemical and chemical properties following standard procedures as given below.

	Soil characters	Method of analysis
I)	**Physical properties**	
a)	Mechanical composition	Piper (1966)
II)	**Physico-chemical properties**	
a)	Soil reaction (pH) (1:2.5 soil : water suspension)	Glass electrode pH meter, Model DI-707 (Jackson, 1973)

b)	Electrical conductivity (1:2.5 soil : water extract)	Conductivity bridge, DI-909 (Jackson, 1973)
III)	**Chemical properties**	
1)	Organic carbon (%)	Wet digestion method (Walkley and Black, 1934)
2)	Available nitrogen	Alkaline permanganate method (Subbiah and Asija, 1956)
3)	Available phosphorus	Olsen's method (Olsen *et al*, 1954)
4)	Available potassium	Ammonium acetate method Jackson (1973)

3.1.3 Weather during the crop growth period

The weather parameters were collected from the meteorological observatory located at Agricultural Research Institute, Rajendranagar, Hyderabad. The weather data during the crop season is presented in Table3.1.

3.2 Field Experiment

The field experiment was laid out in Randomized Block Design with sixteen treatments replicated thrice. The layout plan is depicted in Fig.3.1.

3.2.1 Crop details

Crop	:	Tomato
Variety	:	ArkaVikas
Season	:	*Kharif*, 2011
Duration	:	105-120 days
Seed rate	:	500 g ha^{-1}
Spacing	:	60 cm x 45 cm
Gross plot size	:	6 m x 4.05 m
Net plot size	:	5.4 m x 3.15 m
Planting pattern	:	Single row-line planting
Treatments	:	16

Replications	:	3
Design	:	RBD
Recommended dose of fertilizers	:	120– 60 – 60 N-P_2O_5-K_2O kg ha^{-1}

3.2.2 Treatment details

T_1: 60 kg K_2O ha^{-1} (Recommended K) as basal application (control)

T_2: T_1 + Foliar application of triacontanol

T_3: T_1 + Foliar application of K- humate

T_4: T_1 + Foliar application of triacontanol and K- humate

T_5: 45 kg K_2O ha^{-1} as basal application

T_6: T_5 + Foliar application of triacontanol

T_7: T_5 + Foliar application of K- humate

T_8: T_5 + Foliar application of triacontanol and K- humate

T_9: 30 kg K_2O ha^{-1} as basal application

T_{10}: T_9+ Foliar application of triacontanol

T_{11}: T_9 + Foliar application of K- humate

T_{12}: T_9+ Foliar application of triacontanol and K- humate

T_{13}: Foliar application of triacontanol

T_{14}: Foliar application of K- humate

T_{15}: Foliar application of triacontanol and K- humate

T_{16}: Inorganic K @ 90 kg K_2O ha^{-1} as basal application

Triacontanol was sprayed @ 1µ M concentration 4 times starting from 40DAT @ 10 days interval and K- humate was applied as foliar spray one time @ 0.5 L per acre at flowering. Potassium humate has 12 % K and about 0.2 kg of K was applied through foliar application of K – humate.

3.2.3 Calendar of operations

The details of the calendar of operations carried out from sowing to harvest of tomato crop are furnished below

S.No.	Name of the operation		Date of the operation
1.	Nursery bed preparation and sowing	-	16-6-2011 & 17-6-2011
2.	Irrigation and weeding	-	18-6-2011 to 27-6-2011
3.	Insecticide spraying in nursery	-	28-6-2011 & 11-7-2011

4.	Irrigation and weeding	-	12-7-2011
5.	Main field preparation		19-7-2011
5.	Layout	-	20-7-2011
6.	Transplanting & Irrigation		21-7-2011
7.	Application of fertilizers (treatment wise)	-	27-7-2011
8.	Gap filling	-	29-7-2011
9.	Weeding &Earthing up	-	8-8-2011 & 29-8-2011
10.	Irrigation	-	10& 17-8-2011
11.	Application of first split dose of urea	-	23-8-2011
12.	Application of potassium humate		29-8-2011
13.	First spraying of triacontanol	-	5-9-2011
14.	Application of second split dose of urea	-	8-9-2011
15.	Application of insecticide	-	10-9-2011
16.	Second spraying of triacontanol	-	16-9-2011
17.	Application of third split dose of urea	-	26-9-2011
18.	Third spraying of triacontanol	-	27-9-2011
19.	Fourth spraying of triacontanol	-	10-10-2011
20.	Irrigations	-	As per requirement
21.	Harvesting (14 pickings)	-	17-9-2011to23-11-2011

3.2.4 Cultivation details

3.2.4.1 Field preparation

The experimental field was ploughed with tractor drawn disc plough followed by two ploughings with cultivator and the clods were broken with rotavator. The field was uniformly leveled.

3.2.4.2 Nursery raising and transplanting

The seeds were sown on well prepared raised nursery bed. Necessary plant protection measures were followed while raising nursery for the control of common insect pests and diseases. Thirty days old seedlings were transplanted at the rate of one seedling per hill with a spacing of 60 x 45 cm. Gap filling was done wherever necessary, within a week after transplantation.

3.2.4.3 Fertilizer application

Inorganic potassium in the form of muriate of potash was applied after transplanting to the respective plots as per the treatment requirements and was incorporated into the soil. Nitrogen was applied in the form of urea. Nitrogen was applied in three split doses at 30, 45 & 60 DAT. Entire dose of phosphorus (60 kg P_2O_5 ha^{-1}) was applied as basal in the form of diammonium phosphate.

3.2.4.4 Irrigation

First irrigation was given immediately after transplanting while subsequent irrigations were given depending on moisture and weather conditions. A total of five irrigations were given to the tomato crop of 110 days duration, because of irregular rains during the crop growth period.

3.2.4.5 Cultural practices

Gap filling was done a week after planting. Hand weeding was done twice at 15 and 30 days after transplanting and earthing up was done to prevent lodging.

3.2.4.6 Plant Protection

Proper plant protection measures were taken up against tomato fruit borer and other diseases. Blitox-50 was sprayed @ 3g L^{-1} to nursery bed to control damping off disease. Insecticide chloropyriphos @ 2ml L^{-1} was sprayed at fruiting stage for the control of fruit borer.

3.2.4.7 Harvesting

Tomato fruits were harvested at five days interval and a total of 14 pickings were taken and yield was recorded, the dry matter yield at flowering and haulm yields at harvest were also recorded and expressed in q ha^{-1}.

3.3 Soil and Plant Analysis

3.3.1 Soil analysis

The soil samples collected at different growth stages of the crop *viz.*, flowering and final harvest were analysed for available N, P and K and organic carbon content.

3.3.2 Plant analysis

Plant samples collected at flowering and at final harvest were oven dried at 65^0 C. The dried samples were powdered and analyzed for per cent N, P and K contents by adopting the standard procedures (Piper, 1966).

The dry matter production (kg ha^{-1}) was also recorded to compute nutrient uptake at different growth stages.

$$\text{N uptake (kg ha}^{-1}\text{)} = \frac{\text{N content (\%) x Dry matter production (kg ha}^{-1}\text{)}}{100}$$

$$\text{P uptake (kg ha}^{-1}\text{)} = \frac{\text{P content (\%) x Dry matter production (kg ha}^{-1}\text{)}}{100}$$

$$\text{K uptake (kg ha}^{-1}\text{)} = \frac{\text{K content (\%) x Dry matter production (kg ha}^{-1}\text{)}}{100}$$

3.3.3 Fruit analysis for quality

Fresh tomato fruits were analyzed for quality parameters following standard procedures.

3.3.3.1 Lycopene content

Lycopene content of tomato fruit was assessed as per the procedure given below and expressed in mg 100 g^{-1} (Ranganna, 1986).

Reagents

1. Acetone
2. Petroleum ether
3. Sodium sulphate 5 %: This was prepared by dissolving 5 g Sodium sulphate in 100 mL of distilled water.

Procedure

Ten grams of the puree was taken and extracted repeatedly with acetone in a pestle and mortar until the residue is colorless. The acetone extract was transferred to a separating funnel containing 10 to 15 mL of petroleum ether and mixed gently. The carotenoid pigments were taken into the petroleum ether by diluting the acetone (lower phase) with water or water containing 5% sodium sulphate. The lower phase was transferred to another separating funnel and the petroleum ether extract containing carotenoid pigments to an amber coloured bottle. Extraction of the acetone phase was repeated similarly with petroleum ether until it is colourless. The acetone phase was discarded. To the petroleum ether extract, a small quantity of anhydrous sodium sulphate was added, transferred to a 50 mL volumetric flask and diluted to the mark with petroleum ether and the colour was measured in a 1cm cell at 473 nm in a spectrophotometer using petroleum ether as blank.

Calculation

Lycopene content of the sample was calculated as given below using the relationship that an optical density (OD) of 1.0 = 2.88 µg of lycopene per ml.

$$\text{mg of lycopene per 100 g} = \ = \frac{2.88 \times \text{OD of sample} \times \text{volume made up} \times 100}{\text{Wt of the sample} \times 1000}$$

3.3.3.2 Ascorbic acid

Ascorbic acid (vitamin C) content of tomato fruit was analyzed by dichlorophenol indophenol dye method as given below and expressed in mg 100 g^{-1} (Ranganna, 1986).

Reagents

1. Metaphosphoric acid 3%: Prepared by dissolving the sticks or pellets of metaphosphoric acid in glass distilled water.
2. Ascorbic acid standard: Accurately 100 mg of L-ascorbic acid was taken and made up to 100 ml with 3% metaphosphoric acid.

3. Dye solution: 50 mg of the sodium salt of 2, 6-dichlorophenol-indophenol was dissolved in approximately 150 mL of hot glass distilled water containing 42 mg of sodium bicarbonate. Cooled and diluted with glass distilled water to 200 ml.

Procedure

Standardization of Dye

An aliquot of 5ml of standard ascorbic acid solution was taken and 5 mL of HPO_3 was added. Microburette was filled with the dye and then titrated with the dye solution to a pink colour which should persist for 15 sec. Dye factor was determined, i.e. mg of ascorbic per mL of the dye, using the formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

Preparation of sample

A sample of 10g of the sample was taken, blended with 3% HPO_3 and made up to 100 mL with HPO_3. Filtered through filter paper.

Assay of the extract

An aliquot (2-10 mL) of the HPO_3 extract of the sample was taken and titrated with the standard dye to a pink end-point which should persist for at least 15 sec. In the next determination, most of the dye required was added and then titrated accurately. The aliquot of sample taken should be such that the titre should not exceed 3 to 5 mL.

Calculation

The ascorbic acid content of the sample was calculated from the following formula:

$$\text{mg of ascorbic acid per 100 g of the sample} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Wt of sample taken for estimation}}$$

3.3.3.3 Titratable Acidity

The titratable acidity of tomato fruit was assessed as per the procedure described below and expressed in g 100 mL^{-1} (Friedrich, 2001).

Reagents

1. NaOH 0.1 N
2. Phenolpthalein indicator

Procedure

The sample was taken and macerated by adding equal parts of distilled water and centrifuged at 2500 rpm for 5 mins. The supernatant was then transferred to a 100 mL volumetric flask and volume made upto 100 mL with distilled water. Then 10 mL of aliquot was taken in a conical flask and 2- 3 drops of phenolpthalein indicator was put in it. After that it was titrated against 0.1 N NaOH till light pink color appears. The end point was noted and titratable acidity was estimated.

Calculation

The titratable acidity of the sample was calculated from the following formula:

$$TA\ (g/100\ ml) = \frac{V \times N \times \text{meq. wt of citric acid} \times 100 \times 2}{1000 \times v}$$

Where *V* is volume of sodium hydroxide solution used for titration (mL), *N* is normality of sodium hydroxide solution, meq. wt. is milliequivalent weight of the standard i.e., citric acid which equals to 64, *v* is sample volume (mL) and 2 is the dilution factor.

3.3.3.4 Total Soluble Solids

The total soluble sugars of tomato fruit was analyzed using digital refractometer and expressed as % Brix value (Ranganna, 1986).

Procedure

The sample was taken and crushed and filtered. The digital refractometer was taken and zero setting was performed before using. Approximately 0.3 mL of distilled water was placed on the prism surface. After that the start key was pressed and the measured value got displayed on the screen after the arrow blinked 3 times. After ‘000’ got displayed the zero setting had been successfully completed. Then the water was dried off the prism surface by wiping with a tissue paper and approximately 0.3 mL of the sample was placed on the prism surface. The start key was pressed and the measured value got displayed on the screen after the arrow blinked 3 times. The measured value remains displayed for approximately 2 minutes.

Calculation

The percentage of TSS was expressed in Brix value (%).

3.3.3.5 Leaf Chlorophyll and Carotenoid

Carotenoid

Total carotenoid content of tomato leaves was estimated using the method of Ma Clachlan and Zalik (1963).

Reagents

1. Acetone 80 %

Procedure

One hundred mg fresh tissue from interveinal areas of leaves was ground using mortar and pestle in acetone 80 %. The suspension was filtered using filter paper (Whatman No. 1). The absorbance of the pigment solution was recorded at 480 and 510 nm using a spectrophotometer using acetone 80 % as blank.

Calculation

The contents were expressed as mg g^{-1}.

3.3.3.6 Chlorophyll content

Chlorophyll content of the intact leaves was recorded with a SPAD meter and the readings were expressed in SPAD units.

3.4 Benefit Cost Ratio

The benefit cost ratios were calculated using the following formula

$$\text{Benefit Cost Ratio} = \frac{\text{Net Returns (Rs ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs ha}^{-1}\text{)}}$$

3.5 Statistical Analysis

The data on various parameters were statistically analyzed following the method of analysis of variance for randomized block design (Snedecor and Cochron, 1967). Critical difference for examining treatment means and their significance was calculated at 5 per cent level of probability.

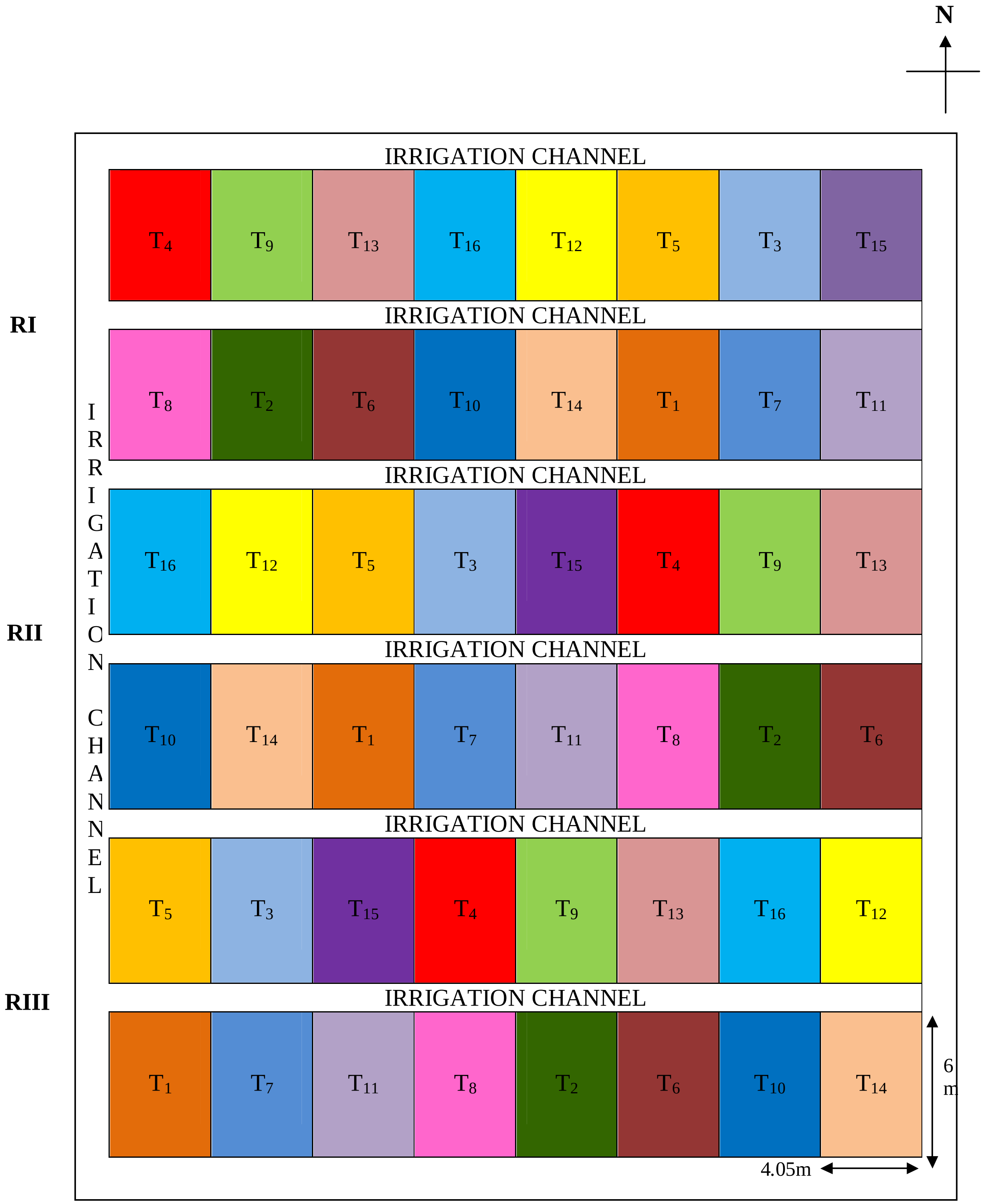

Figure 3.1. Layout of the field experiment

Design	**: Randomized block design**
Replications	**: 3**
Treatments	**: 16**
Gross Plot size	**: 6 m × 4.05 m**
Net Plot size	**: 5.4 m × 3.15 m**

Table 3.1 Weekly mean meteorological data recorded during the crop growth period (June to December, 2011).

Period	Temperature (^{o}C)		RH (%)		Rain fall (mm)	Sun shine (hrs)	Evapo-ration (mm)
	Max	Min	I	II			
28-03 JUN	38.1	25.8	67	41	0.0	7.0	6.5
04-10	34.0	24.7	75	52	26.8	5.7	6.3
11-17	34.9	24.0	76	43	4.3	5.7	5.8
18-24	35.3	24.4	72	38	0.0	7.4	6.1
25-01 JUL	35.0	24.2	75	44	9.6	1.5	5.9
02-08	31.3	22.4	91	64	89.0	2.5	4.5
09-15	30.7	22.6	84	64	38.8	5.6	5.2
16-22	31.6	23.3	82	59	15.0	5.2	5.0
23-29	30.6	21.9	93	65	48.2	5.2	4.3
30-05 AUG	29.5	22.6	87	65	10.4	3.2	4.6
06-12	31.4	23.3	90	63	1.8	4.9	5.0
13-19	31.7	23.2	89	76	11.0	6.2	5.2
20-26	30.2	22.2	95	73	106.6	3.5	3.5
27-02 SEP	27.7	22.1	89	80	61.5	1.5	3.4
03-09	29.7	22.2	90	79	30.6	5.2	2.7
10-16	31.3	22.5	89	74	0.0	6.2	2.9
17-23	30.5	22.4	83	69	12.0	5.0	2.8
24-30	31.7	20.7	88	74	3.5	6.5	2.9
01-07 OCT	32.4	20.5	89	74	8.2	6.8	2.7
08-14	32.0	21.1	91	64	28.5	5.5	2.7
15-21	32.9	19.9	90	67	1.0	8.2	2.8
22-28	31.7	19.9	91	76	10.2	7.1	2.8
29-04 NOV	29.5	19.7	91	61	27.5	4.4	2.4
05-11	30.7	14.4	77	38	0.0	9.2	2.4
12-18	30.7	14.5	85	42	0.0	8.6	2.4
19-25	29.8	12.5	81	42	0.0	9.1	2.4
26-02 DEC	30.2	17.2	78	42	0.0	8.0	2.5
03-09	30.5	12.9	84	33	0.0	8.6	2.4
10-16	30.2	14.2	83	50	0.0	8.1	2.2
17-23	29.0	11.8	82	49	0.0	8.4	2.2
24-31	29.8	11.6	84	32	0.0	8.7	2.2

Chapter IV

RESULTS AND DISCUSSION

The present experiment entitled **"Yield and Quality of Tomato (*Solanum lycopersicum* L.) with individual and integrated application of Inorganic Potassium, Potassium humate and Triacontanol"** was carried out during *kharif* season on sandy clay soil at College Farm, College of Agriculture, Rajendranagar, Hyderabad during 2011. The effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on dry matter production, yield, nutrient uptake, quality parameters and available nutrient status were studied under field conditions. The results of investigation are presented and discussed in this chapter.

4.1 Salient soil characteristics of the experimental site

The initial soil sample collected from experimental field was analyzed for physical, physico-chemical and chemical properties. The data pertaining to salient soil characteristics are presented in Table4.1.

The soil was sandy clay in texture, slightly alkaline in reaction with a pH of 7.64, normal in salt content (0.19 dS m^{-1}), with a CEC of 35.8 c mol (p^+) kg^{-1}, medium in organic carbon content (0.67%), low in available nitrogen (156.7 kg N ha^{-1}), high in available phosphorus (57.0 kg P ha^{-1}) and potassium (449.0 kg K ha^{-1}).

4.2 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on dry matter production (q ha^{-1}) of tomato at flowering

The dry matter put forth by tomato at flowering was significantly influenced by the combined application of inorganic K, potassium humate and triacontanol.

At flowering, the dry matter produced with the individual application of recommended dose inorganic K @ 60 kg K_2O ha^{-1}(T_1), foliar applications of triacontanol (T_{13}) and potassium humate (T_{14}) were 23.79, 21.57 and 20.30 q ha^{-1} respectively.

A higher dose of 90 kg K_2O ha^{-1} (T_{16}) also was found to be inferior with a dry matter production of 25.17 q ha^{-1}. Individual application of either triacontanol or potassium humate or their combined application without inorganic K produced significantly lower dry matter yields of tomato (Table4.2).

Among the treatments, T_4 receiving 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol showed significantly higher dry matter production of 30.79 q ha^{-1} which was 29 % more when compared to control receiving recommended dose of 60 kg K_2O ha^{-1}. However, this was on par with the dry matter produced by integrated application of potassium humate and triacontanol along with a lower dose of 45 kg K_2O ha^{-1}(Table4.2).

These findings are in agreement with the reports of Besford and Maw (1975). Potassium plays a vital role in growth and plant productivity, metabolism, ionic balance, activation of several enzymes and plant defense systems (Marschner, 2002). Plant growth regulator triacontanol plays an important role in manipulating the yield potential and augmenting the uptake of nutrients in many vegetable species including tomato (Muthuvel *et al.*, 2001). TRIA treated plants had a significantly higher rate of photosynthesis and hence increased the dry weight by 30 per cent as was documented by Eriksen *et al.* (1981). The positive influence of TRIA on tomato is stimulation of photosynthesis and enhanced water uptake, which eventually results in increase in the dry weight. It also hastens the cell elongation and division and results in the increased fruit size due to assimilation of more carbohydrates (Sharma, 1995; Ries and Houtz, 1983).

4.3 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on fruit yield

The total fruit yield of the tomato recorded at different pickings were presented in Table4.3 and illustrated in Fig.4.1. The yield of tomato varied from 102.7 q ha^{-1} in the treatment receiving individual application of 30 kg K_2O ha^{-1} (T_9) to a significantly higher yield of 135.0 q ha^{-1} when 60 kg K_2O ha^{-1} was integrated with triacontanol and potassium humate (T_4), which was 18 per cent more when compared to control (T_1) receiving recommended dose of K.

However, the fruit yields obtained from the treatments integrating the triacontanol and potassium humate with either 45 or 60 kg K_2O ha^{-1} were all at par. Individual applications of either inorganic K at any level or triacontanol or potassium humate were found to be significantly inferior to the best treatment (Table4.3).

Conjunctive use of chemical fertilizer with foliar application of potassium humate and triacontanol produced higher yields as compared to their individual applications due to increase in nutrient uptake from soil and effective utilization of foliar applied nutrients. This might be due to soil application of inorganic potassium resulting in increased uptake of nutrients and improved translocation of photosynthates and other metabolites to the reproductive parts and foliar application of potassium humate and triacontanol resulted in accumulation of increased assimilates in the sink and increase in chlorophyll content and photosynthetic area of the plant, which is responsible for the increased photosynthetic efficiency (Muthuvel *et al.*, 2001 and Marschner, 2002). The results are in agreement with the findings of Duraisamy and Mani (2002) in tomato.

Application of TRIA might also have reduced the flower drop and increased the partitioning of assimilates towards sink to increase the number and weight of the fruits per plant and harvest index (Jadhav *et al.*, 1987).

Earlier research also established that the crop responded best to the treatment combination of inorganic K at 90 kg K_2O ha^{-1} and TRIA @ 1 µM that enhanced fruit yield by 57.6 per cent over the control (Khan *et al.*, 2009). Similar results were observed by Baskar and Sankaran (2005) in turmeric. Schnitzer (1978) reported that the favorable effect of humic substances in stimulating growth, yield and yield attributes could be attributed to the presence of auxin like properties in humic acid.

4.4 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on haulm yield (q ha^{-1}) of tomato at harvest

The mean haulm yield at harvest showed a significant increase from 21.17 q ha^{-1} with 30 kg K_2O ha^{-1} alone (T_9) to 34.19 q ha^{-1} obtained from the treatment receiving 60 kg K_2O ha^{-1} along with the foliar applications of triacontanol and potassium humate (T_4)

which surpassed the haulm yield obtained with inorganic K alone at the same level of application by 35 per cent (Table4.4).

However, this was on par with the dry matter produced with the integrated application of inorganic K at 45 kg K_2O ha^{-1} and foliar application of potassium humate and triacontanol (T_8). The treatment was significantly superior over the individual application of even 90 kg K_2O ha^{-1} (T_{16}) or potassium humate (T_{14}) or triacontanol (T_{13}). The results are in agreement with the findings of Khan *et al*. (2009) that combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration increased the dry weights per plant by 52.1 per cent over control. This could be due to greater availability of K released from the applied source and stimulation of photosynthesis and enhanced water uptake due to application of triacontanol which eventually result in an increase in dry weight (Sharma, 1995).

4.5 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on leaf chlorophyll and carotenoid content

Fresh leaf samples at flowering stage were analysed for leaf chlorophyll and carotenoid contents. The data pertaining to leaf chlorophyll and carotenoid contents was furnished in Table4.5 and the trends were shown in Figures 4.6 and 4.7.

When compared to the chlorophyll content of 47.00 SPAD units formed with recommended K (T_1), the combination of 60 kg K_2O ha^{-1}, triacontanol and potassium humate (T_4) was only found to be significantly higher; the value being 52.41 SPAD units which accounts for 11.5 per cent more chlorophyll content. The lowest value of 38.55 was found in the treatment receiving only 30 kg K_2O ha^{-1}(T_9). Individual applications of inorganic K @ 60 and 90 kg K_2O ha^{-1} or triacontanol or potassium humate were all on par with each other in influencing the chlorophyll content of leaves at flowering.

The carotenoid content of the leaves did not show any significant increase with the application of inorganic K in graded levels. However lower carotenoid content of 0.25 mg g^{-1} was obtained with inorganic K alone @ 30 kg K_2O ha^{-1}. This could be due to that acetic thiokinase, the enzyme responsible for the formation of acetyl CoA has been shown to require K for activity (Hiatt and Evans, 1960). Since the condensation of two molecules of acetyl CoA is the first step in the classical pathway of carotenoid precursor formation (Porter and Anderson, 1967), a lowering of the carotenoid level could be expected under low K.

When compared to the recommended K alone, the individual application of triacontanol or potassium humate or their combination without inorganic K were significantly superior registering carotenoid contents of 0.50, 0.48 and 0.64 mg g^{-1} respectively. Phytoene desaturase that synthesise phytoene from geranyl diphosphate is the first committed step in the carotenoid bio synthetic pathway (Rodriquez-Amaya, 2001). These studies directly implicate electron transport in the desaturation of phytoene to form lycopene. K has a known role in ATP synthesis, proton uptake and electron flow in the thylakoid membranes of plastids, which are the site of carotenoid biosynthesis (Lebedeva *et al.*, 2002). Thus the effect of K on the biosynthesis may be indirectly mediated by the electron transport chain involved in phytoene desaturation.

The leaf carotenoid content was found to be significantly higher with the combined use of inorganic K @ 60 kg K_2O ha^{-1} the value being 0.74 mg g^{-1} which was significantly superior over all other treatments.

Khan *et al*. (2009) reported that combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration gave maximum values for leaf chlorophyll and β-carotenoids contents, surpassing the control by 15.2 and 8.3% respectively indicating towards the higher photosynthetic efficiency of the treated plants. Furthermore, the increased photosynthetic pigments can be attributed to the increase in number and size of chloroplasts, the amount of chlorophyll per chloroplast and increase in grana formation (Ivanov and Angelov, 1997).

4.6 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on quality parameters of fruit

Fresh ripened tomato fruits at harvest were analysed for their quality parameters *viz.*, ascorbic acid, lycopene content, titratable acidity and total soluble solids. The data pertaining to quality parameters of fruit was given in Table4.6 and 4.7 and the trends were shown in Figures 4.2 and 4.5.

4.6.1 Lycopene

The lycopene content of fruit varied from 3.08 to 4.27 mg 100 g^{-1}. The lycopene content was significantly higher in the fruits of the treatment receiving integrated application of inorganic K at 60 kg K_2O ha^{-1} along foliar application of potassium humate and triacontanol (T_4) recording a value of 4.27 mg 100g^{-1} of fruit when compared to the value of 3.74 analysed with recommended dose of 60 kg K_2O ha^{-1}. However, this was on par with the lycopene content (4.15 mg 100 g^{-1}) of fruit with same level of K along with potassium humate (T_3). Significantly lower lycopene content of 3.08 mg 100 g^{-1} was with the application of inorganic K alone at 30 kg K_2O ha^{-1}(T_9).

The result is supported by findings of Khan *et al*. (2009) in tomato who reported that combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration resulted in 9.5 per cent increase over control. According to Fanasca *et al*. (2006), K might play a special role in the process of carotenoid biosynthesis by activating several of the enzymes that regulate carbohydrate metabolism and on the precursors of isopentenyl diphosphate which are directly involved in overall regulation of lycopene formation in tomato fruit. Lycopene content rises sharply as the K level increases. The inhibition of lycopene synthesis under low K conditions is concomitant to the accumulation of β-carotene as a result of either the activation of its synthesis or the inhibition of its metabolic transformations (Trudel and Ozbun, 1971).

4.6.2 Ascorbic acid

The ascorbic acid content progressively increased from 20.00 mg 100 g^{-1} fruit with the application of inorganic K @ 30 kg K_2O ha^{-1} (T_9) to a significantly higher content of 31.66 mg 100g^{-1} of fruit when inorganic K @ 60 kg K_2O ha^{-1} was conjunctively used with triacontanol and potassium humate (T_4). The ascorbic acid contents in the fruits obtained from the treatments receiving the foliar application of potassium humate in combination with triacontanol along with inorganic K @ 60 kg K_2O ha^{-1} or 45 kg ha^{-1} (T_8) or with inorganic K alone @ 90 kg K_2O ha^{-1} (T_{16}) were at a par.

Dileep and Sasikala (2009) also observed similar results in chilli and Khan *et al*. (2009) in tomato. Increase in ascorbic acid with increasing K-supply was due to close relationship between carbohydrate metabolism and ascorbic acid formation (Winson, 1966) and increase in ascorbic acid of tomato fruit due to application of triacontanol is possible as a result of conversion of sucrose or hexose sugar into ascorbic acid (Muralidharan *et al.*, 2000). Rao (1994) observed an increase in ascorbic acid content of tomato from 24 to 28 mg 100 g^{-1} with increased level of K application from 0 to 200 kg K_2O ha^{-1}. According to Majumdar *et al*. (2000) significant increase in ascorbic acid content was obtained upto 60 kg K_2O ha^{-1}.

4.6.3 Titratable acidity

Increasing levels of inorganic K application gradually decreased the titratable acidity from a significantly higher value of 0.68 per cent with 30 kg K_2O ha^{-1} (T_9) to 0.65, 0.53 and 0.50 per cent respectively at 45, 60 and 90 kg K_2O ha^{-1}. The lowest value of 0.43 per cent was recorded in T_4 wherein the inorganic K @ 60 kg K_2O ha^{-1} was applied along with foliar application of potassium humate and triacontanol. The titratable acidity values of the treatments receiving inorganic K at 30 kg K_2O ha^{-1} either alone or with triacontanol or at a level of 45 kg K_2O ha^{-1} registered 0.68, 0.66 and 0.65 per cent respectively and was at a par. At any level of inorganic K the titratable acidity progressively decreased due to integration with triacontanol, potassium humate and their combination.

The result is conformity with the findings of Diana *et al*. (2007) reporting that the acidity content decreases with increase in fertilizer doses. The decreased acidity in triacontanol treated fruits indicated that the fruits were at higher stage of maturity due to increased stage of respiration (Muralidharan *et al*., 2000).

4.6.4 Total soluble solids

The total soluble solids (Brix %) was 2.60 when recommended level of K (T_1) was applied which significantly increased by 28 per cent to a value of 3.33 with 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol (T_4). The lowest TSS of 1.47 Brix % was recorded in T_9 receiving inorganic K alone at 30 kg K_2O ha^{-1}. The Brix value of fruits with foliar application of potassium humate, triacontanol or combination of both recorded higher TSS than any of the inorganic K levels. This may be attributed to the increased translocation of assimilates from leaves to the economic parts in response to hormonal stimulation. The increased TSS as observed in the present study is in line with the findings of Booth *et al*. (1962) and Gunasekharan (1982) in tomato.

The result is supported by the findings of Sangeetha *et al*. (2008) in onion and Majumder *et al*. (2000) in tomato. This increase might be due to the increased translocation of nutrients and balanced nutrition as influenced by K (Duraisami and Mani, 2002).

4.7 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on N, P and K Contents of tomato

The nutrient contents (%) of tomato are furnished in Tables4.8 to 4.10 and illustrated in Figures 4.8 to 4.10.

4.7.1 Total nutrient (N, P and K) contents at flowering

4.7.1.1 Total nitrogen (%)

The nitrogen content at flowering was more when compared to the haulm at harvest as it got translocated to tomato fruit. Increasing levels of inorganic K from 30 to 60 kg K_2O ha^{-1} increased the N content at flowering significantly from 1.70 to 1.98 per cent. However, it was on par with the N content at 90 kg K_2O ha^{-1}. The N content in per cent at flowering was significantly higher among all the treatments with a value of 2.23 per cent due to the integrated application of inorganic K at 60 kg K_2O ha^{-1} and foliar application of triacontanol and potassium humate. Foliar applications of either triacontanol or potassium humate or their combination without inorganic K resulted in significantly higher N content of 2.05, 2.04 and 2.05 respectively than the recommended K application. This could be due to the low level of dry matter production in these treatments than with inorganic K at the recommended level that has resulted in more concentration of N (Table4.8).

4.7.1.2 Total phosphorus (%)

The increasing level of K application from 30 to 90 kg K_2O ha^{-1} increased the P content of the plant gradually and significantly from 0.33 to 0.40 per cent. The phosphorus content at flowering showed the lowest value of 0.32 per cent with the individual application of potassium humate which significantly increased to 0.42 per cent due to the integrated application of inorganic K at recommended level along with triacontanol and potassium humate. At each level of K application the P content increased progressively when applied in combination with either triacontanol or potassium humate or both than alone. The P content resulted due to the individual applications of triacontanol; potassium humate and inorganic K at 45 kg K_2O ha^{-1} were at a par.

4.7.1.3 Total potassium (%)

Among the inorganic K levels, the individual application at 45 kg K_2O ha^{-1} showed a significantly higher total K content of 1.06 per cent as against 1.01 per cent with 30 kg K_2O ha^{-1}. However, it decreased to 1.02 and 1.02 per cent with further increase in the dose of inorganic K to 60 and 90 kg K_2O ha^{-1}. Taber (2008) also opined that the leaf K content increased to 3.85 from 2.42 g kg^{-1} due to the application of 372 kg K_2O ha^{-1}. Reduced K content at higher dose of K could be due to the dilution effect because of more dry matter production at higher levels of K.

The individual application of triacontanol resulted in the lowest content of total K of 1.01 per cent and that of potassium humate was 1.01 per cent which was on par with the total K content with inorganic K application at 60 and 90 kg K_2O ha^{-1}.

Among all the treatments, integrated application of inorganic K at 60 kg K_2O ha^{-1} along with the foliar applications of triacontanol and potassium humate was found to be significantly superior over the other treatments the value being 1.13 per cent.

4.7.2 N, P and K contents of fruit

4.7.2.1 Total N content (%)

The graded levels of inorganic K application increased the total N content of the fruit (%) progressively and significantly from 1.76 at 30 kg K_2O ha^{-1} level to 2.04 due to the application of 45 kg K_2O ha^{-1}. However, it was on par with the total K contents of the fruits at 60 and 90 kg K_2O ha^{-1} levels.

Individual application of triacontanol and potassium humate resulted in significantly higher total N contents than the recommended dose of K application with the corresponding contents of 2.19 and 2.18 per cent. Their combination without inorganic K also proved even better with the value of 2.22 per cent.

The total N content (%) of tomato fruit ranged between 1.76 in the treatment receiving individual application 30 kg K_2O ha^{-1} to 2.40 when the crop received combined application of inorganic K at 60 kg K_2O ha^{-1} with foliar application of triacontanol and potassium humate.

4.7.2.2 Total P content (%)

Individual application of inorganic K in graded levels of 30, 45, 60 and 90 kg K_2O ha^{-1} showed a significant increase in total P content of the fruit from 0.41 to 0.45 per cent. Individual application of triacontanol and also the potassium humate recorded the same P content of 0.41 per cent. However, their combination without inorganic K resulted in a total P content of 0.42 per cent.

At any level of K application tested, the P content was significantly higher with the integrated application than the individual application of any of the components. The conjunctive use of inorganic K at 60 kg K_2O ha^{-1} along with the foliar application of triacontanol and potassium humate registered a significantly higher total P content of 0.51 per cent which was superior over all other treatments.

4.7.3.3 Total K content (%)

Application of inorganic K resulted in a significant increase in total K content from 1.15 to 1.19 per cent due to increase in the K level from 30 to 60 kg K_2O ha^{-1}. While, 60 and 90 kg K_2O ha^{-1} levels were at a par with regard to total K content of the fruit.

Foliar application of either triacontanol or potassium humate or combination of both were found to be inferior than inorganic K even at the lowest level with corresponding K contents of 1.12, 1.14 and 1.15 per cent.

Integrating the foliar applications of either triacontanol or potassium humate with inorganic K have resulted in a progressive increase in the total K content of the fruit at any level of inorganic K application. Significantly higher K content of 1.30 per cent was obtained with the combined use of inorganic K at recommended level along with foliar applications of triacontanol and potassium humate. Trudel and Ozbun (1971) also opined that the K content of both fruit and petiole increased with increasing concentration of K. This suggests that the fruit is quite efficient in monopolizing K under conditions of low K.

Khan *et al*. (2009) also obtained an increase in the NPK contents by 14.9, 32.6 and 26.3 per cent respectively with the combined application of inorganic K @ 90 kg K_2O ha^{-1} with TRIA @ 1µM. Maximum K content of 121.5 mg 100 g^{-1} in tomato under 90 kg K_2O ha^{-1} was observed by Majumdar *et al*. (2000).

4.7.3 Nutrient (N, P and K) contents of haulm

4.7.3.1 Total N content (%)

The total N content of the haulms was lower than that of the fruits. The individual application of triacontanol or potassium humate recorded a total N content of 1.67 and 1.67 respectively and were found to be significantly superior than the individual applications of 30 and 45 kg K_2O ha^{-1} with corresponding values of 1.57 and 1.61 per cent but were on par with 60 kg K_2O ha^{-1}. Application of inorganic K alone at 90 K_2O ha^{-1} resulted in a significant increase of haulm K content to 1.79 per cent.

At any level of K application, there was significant increase in haulm K content when integrated with both potassium humate and triacontanol. When the combination was tested at 60 kg K_2O ha^{-1} level, the haulm K content was significantly superior i.e., 1.83 per cent. However, the K content obtained with the above combination and inorganic K alone at 90 kg K_2O ha^{-1} was at a par.

4.7.3.2 Total P content (%)

The haulm P content of tomato showed a significant increase from 0.30 to 0.38 per cent when the individual application of inorganic K increased from 30 to 90 kg K_2O ha^{-1}. The individual application of either triacontanol or potassium humate were found to be on par with the inorganic K levels of 30 and 45 kg ha^{-1} but significantly differed from the P contents recorded with 60 and 90 kg K_2O ha^{-1}.

Integrated application of inorganic K at 60 kg K_2O ha^{-1} with triacontanol and potassium humate was significantly superior with a total P content of 0.39 per cent. However, this was on par with the P content recorded in the treatments comprising the integration of triacontanol and potassium humate at the remaining levels of K application.

It was also on par with the combined applications of either triacontanol (0.37 %) or potassium humate (0.37 %) or both with inorganic K at 60 kg K_2O ha^{-1}(0.39 %).

4.7.3.3 Total K content (%)

Application of inorganic K in graded levels of 30, 45, 60 and 90 kg ha^{-1} did not show any significant difference in total K content of haulms. However, a progressive increase was observed from 1.00 to 1.01 per cent.

Individual application of triacontanol resulted in a significantly lower total K content of 0.99 per cent which was on par with the individual application of potassium humate.

The conjunctive use of inorganic K at the recommended level of 60 kg K_2O ha^{-1} with the foliar applications of triacontanol and potassium humate was significantly superior over all other treatments with the K content of 1.12 per cent. This treatment showed 10 per cent more K content when compared with the recommended level of K application.

The total nutrient contents at harvest were higher due to partitioning of nutrients both to fruit and haulm indicating the requirement of more nutrients at fruit development stage. Results are in conformity with the findings of Khan *et al*. (2009) who reported that the combined application of 90 kg K_2O ha^{-1} with triacontanol @ 1 µM concentration showed maximum increase in N, P and K contents exceeding control by 14.9, 32.6 and 26.3 per cent respectively. Rao and Subramanian (1991) attributed the increase in the contents of nutrients in the plant to the applied potassium which is known for its role in plant nutrition by influencing nutrient use efficiency, water use efficiency; disease and pest resistance. Further potassium plays a role in the activation of more than 60 enzymes in the plant system which increases the metabolism and thus results in increased nutrient uptake.

4.8 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on N, P and K Uptake by tomato

The per cent N, P and K contents and dry matter production values were used to compute nutrient uptake by plants at different growth stages. The nutrient uptakes (kg ha^{-1}) by tomato are furnished in Tables4.11 to 4.13 and illustrated in Figures 4.11 to 4.13.

4.8.1 N uptake by the crop at flowering

The N uptake by the crop at flowering showed a significant increase from 36.07 due to the application of 30 kg K_2O ha^{-1} to 47.29 with the recommended dose of K. However, the N uptakes by the crop with 60 and 90 kg K_2O ha^{-1} were at a par. Among all the treatments, the one receiving recommended dose of K along with the foliar applications of triacontanol and potassium humate was significantly superior with the N uptake of 68.53 kg ha^{-1}. The individual application either inorganic K at any level or triacontanol or potassium humate were found to be inferior to their integrated application at all levels of K with corresponding uptake values of 53.37, 63.8 and 68.53 kg ha^{-1} when conjunctively applied with inorganic K at 30, 45 and 60 kg ha^{-1}.

4.8.2 P uptake by the crop at flowering

The P uptake by the crop at flowering showed similar pattern of response recording the lowest uptake of 6.45 kg ha^{-1} with the individual application of potassium humate. The removal of P by the crop increased from 6.89 to 10.15 kg ha^{-1} when the inorganic K application increased from 30 to 90 kg K_2O ha^{-1}. The crop fed with recommended dose of K removed 8.65 kg ha^{-1} of P, which increased significantly to 11.27, 10.75 and 12.91 kg ha^{-1} respectively when applied in combination with triacontanol, potassium humate and both.

At any level of K application, the crop removed more P when the three components were integrated, the significantly higher uptake of 12.91 kg ha^{-1} being recorded when the integration was with the recommended level of K which proved to be significantly superior over the highest level of K application.

4.8.3 K uptake by the crop at flowering

Increase in the level of K application did not show any significant increase in the K uptake by the crop. The lowest uptake of 20.56 kg ha^{-1} was obtained with the individual application of potassium humate (T_{14}). There was no significant difference among the three components when used individually.

Integrated application of inorganics and organics proved to be superior at all levels of K application; significantly higher uptake of 34.68 kg ha^{-1} was obtained with the integration at 60 kg ha^{-1} level.

Muthuvel *et al*. (2001) stated that plant growth regulator triacontanol plays an important role in augmenting the uptake of nutrients in many vegetable species including tomato. Martin and Liebhardt (1994) got a quadratic response in leaf K concentration to increasing K rate.

The enhancement in nutrient contents and uptake in the treatment combinations comprising of triacontanol may be attributed to the increased ability of the plants to absorb nutrients from the soil since the foraging ability of the plants could have been increased through the production of active roots and consequent improvement in the root growth (Muthuvel *et al*., 2001).

4.8.4 N, P and K uptake at harvest

4.8.4.1 N uptake at harvest

Increasing level of K application at 30, 45, 60 and 90 kg ha^{-1} increased the N uptake by the fruit significantly from 60.38 to 79.84 kg ha^{-1}. Foliar application of either triacontanol or potassium humate resulted in an N uptake of 84.17 and 82.77 kg ha^{-1} respectively those have surpassed the N uptake with the highest level of K application.

Integrated application of inorganic K at 60 kg ha^{-1} along with either triacontanol or potassium humate or both observed a significantly higher uptake of N by the fruit with the corresponding removals of 89.25, 96.31 and 107.97 kg ha^{-1}.

The nitrogen removed by haulm was lower than the fruit. Application of inorganic K alone at 30 kg K_2O ha^{-1} registered an N uptake of 33.27 kg ha^{-1} which increased significantly to 48.71 kg ha^{-1} with the application of 90 kg K_2O ha^{-1}. However, the treatments receiving 30 and 45 kg K_2O ha^{-1} in respect of N uptake were at a par. The individual application of either triacontanol or potassium humate were on par with the inorganic K application at 30 and 45 kg K_2O ha^{-1} levels with corresponding uptake values of 40.67 and 38.84 kg ha^{-1}.

Combining the use of organics and inorganic K at 60 kg K_2O ha^{-1} for tomato resulted in a significant increase in the N uptake by haulms to 62.47 kg ha^{-1} which was on par with the combination of either of them with the same level of K, the uptake being 57.47 and 54.34 kg ha^{-1} respectively.

4.8.4.2 P uptake at harvest

The P uptake by the fruit increased from the lowest value of 13.94 kg ha^{-1} to a significantly higher value of 16.53 kg ha^{-1} with the recommended dose of inorganic K alone. However, the recommended K and further higher dose of 90 kg K_2O ha^{-1} were at a par.

The foliar application of either triacontanol or potassium humate alone resulted in a P uptake of 15.94 and 15.77 kg ha^{-1} which were on par with the individual application of recommended K.

Conjunctive use of the inorganic K with the triacontanol and potassium humate at any level of K application showed a significant increase in the P uptake by the fruit; significantly higher uptake of 22.94 kg ha^{-1} was observed in the combination with 60 kg K_2O ha^{-1}.

Mean phosphorus uptake by haulm (9.26 kg ha^{-1}) was lower than the fruit (17.8 kg ha^{-1}). Inorganic K at the recommended dose of 60 kg K_2O ha^{-1} brought about a significant increase in the P uptake to 8.61 from 6.34 kg ha^{-1} due to 30 kg K_2O ha^{-1}which was on par with the uptake of recorded with 90 kg K_2O ha^{-1}.

The P uptake values by the haulms with the foliar applications of either triacontanol or potassium humate were 7.69 and 6.98 kg ha^{-1} respectively and were on par with the P removed by the treatment receiving 60 kg K_2O ha^{-1}.

Significantly higher P uptake of 13.27 kg ha^{-1} was obtained with the integrated use of inorganic K at 60 kg K_2O ha^{-1} with triacontanol and potassium humate. While the other combinations with the same level of K with either triacontanol or potassium humate with corresponding P uptake values of 11.93 and 11.41 kg ha^{-1} were also at a par.

4.8.4.3 K uptake at harvest

Potassium uptake was also greater by the fruit when compared to the haulms. Significant increase in K uptake by the fruit was observed between 30 and 60 kg K_2O ha^{-1} levels; the corresponding values being 39.5 and 45.27 kg ha^{-1}. Further increase in K level did not show any significant increase in the K uptake by the fruit. Foliar applications of triacontanol and potassium humate were on par with each other with respect to K uptake; the values being 42.87 and 43.37 respectively. The two treatments were also on par with the K uptake obtained with individual K application at any level.

Integrated application of inorganic K at 60 kg K_2O ha^{-1} along with potassium humate and triacontanol lead to significantly increased removal of K to an extent of 58.61 kg ha^{-1}.While, at the same level of inorganic K application, the conjunctive use of only potassium humate also was found to be at a par with the K uptake of 54.47 kg ha^{-1}.

Potassium uptake by haulms was lower than the fruit uptake due to the efficient partitioning of K to the fruits. Individual application of increasing level of inorganic K from 30 to 90 kg K_2O ha^{-1}, showed a significant increase in the K uptake from 21.26 to 27.51 kg ha^{-1}. However, there was no significant difference among uptake values of 45 and 60 kg K_2O ha^{-1} levels. Individual application of either triacontanol or potassium humate were not found to be significant.

Combined application of inorganic K at 60 kg ha^{-1} with the other two components resulted in a significant increase in the K uptake by the haulms of 38.20 kg ha^{-1}.

The results are supported by the findings of Vaiyapuri and Sriramachandrasekharan (2003) who reported that in low land rice the foliar application of triacontanol at 0.1% along with the recommended dose of NPK registered the highest uptake of nutrients (106.7, 29.0, 51.8 kg NPK/ha). The enhancement in nutrient uptake could be attributed to the increased ability of the plants to absorb nutrients from the soil since the foraging ability of the plants could have been increased through the production of active roots and consequent improvement in root growth. Chen and Aviad (1990), Fagbenro and Agboda (1993), David *et al*. (1994) also have reported promoted nutrient uptake of plants due to the addition of humic substances. The plants take more mineral elements due to better developed root systems. In addition, the stimulation of ions uptake in the applications of humic materials led many investigators to proposing that these materials affect membrane permeability (Zientara 1983). This is related to the surface activity of humic substances resulting from the presence of both hydrophilic and hydrophobic sites (Chen & Schnitzer 1978). Therefore, the humic substances may interact with the phospholipid structures of the cell membranes and react as carriers of nutrients through them.

Plant growth regulator triacontanol had a perceptible influence on the nutrient uptake and plays an important role in manipulating the yield potential and augmenting the uptake of nutrients in many vegetable species including tomato (Muthuvel *et al*., 2001).

4.9 Effect of individual and integrated application of inorganic potassium, triacontanol and potassium humate on soil properties at Flowering and at harvest

4.9.1 Organic carbon (%)

The data pertaining to organic carbon content in soil at both flowering and harvest stage was given in Table4.14.

Significant difference was not observed among the individual treatments or their combinations on organic carbon content of the soil either at flowering or at harvest. However, a marginal reduction was observed in the organic carbon content of the soil from the flowering stage to harvest with the corresponding values of 0.69 and 0.68 per cent.

4.9.2 Available nitrogen

The results pertaining to available nitrogen at flowering and harvest stage was given in Table4.15. Available N content of soil decreased from flowering to harvest. There was greater reduction in the available N of the soil in the treatment receiving 60 kg K_2O ha^{-1} along with foliar application of triacontanol and potassium humate (T_4) at both the stages with the corresponding values of 150.4 and 144.4 kg ha^{-1} respectively. Significantly higher available N in soil was left in the treatment receiving inorganic K alone @ 30 kg K_2O ha^{-1} with the values of 168.4 and 165.2 kg ha^{-1} respectively at both the stages. The per cent reduction from the initial status of 156.7 kg ha^{-1} was 12 and 14 respectively in the treatment T_4. This depletion in available N status could be due to exhaustive removal of N from the soil for putting forth more yields.

4.9.3 Available Phosphorus

There was depletion in the available P of the soil to an extent of 7.5 per cent from the initial value of 57.2 kg ha^{-1} by the end of the crop growth season (Table4.16). The mean available phosphorus in the soil depleted from 57.4 kg ha^{-1}at flowering to 52.9 kg ha^{-1} at the harvest of the crop. Inorganic K at the lowest dose (30 kg K_2O ha^{-1}) left significantly higher amount of available P in the soil which got significantly decreased to 56.09 kg ha^{-1}due to the application of 90 kg K_2O ha^{-1}. This exhaustion in available P of the soil could be due to the greater removal of available nutrients for putting forth higher dry matter and fruit yield. However, individual application of either triacontanol or potassium humate have marginally and non significantly increased the available P status of the soil in kg ha^{-1} than the initial with corresponding values of 59.24 and 57.6 at flowering and decreased non significantly at the harvest with the available P status of 55.81 and 56.16.

The treatment which was significantly superior with regard to the yield and quality of the crop i.e., the conjunctive use of inorganic K at 60 kg K_2O ha^{-1} and the foliar applications of triacontanol and potassium humate left significantly lower available P in the soil with the values of 50.58 and 44.6 kg ha^{-1} respectively at flowering and at harvest, which is 11 and 12 per cent lower respectively at both the stages than that recorded in the control (recommended dose of K). When compared with the initial available P status, there was a reduction of 12 and 22 per cent respectively at flowering and at harvest with the best treatment.

4.9.4 Available Potassium

There was an appreciable decrease in the mean available potassium in the soil from the flowering to harvesting stage in all the treatments (Table4.17).

At flowering, the available K was significantly lower due to the individual application of triacontanol; the value being 407.3 kg ha^{-1}, which however was on par with the individual application of inorganic K at 30 kg K_2O ha^{-1} or potassium humate with corresponding available K of 409.8 and 419.6 kg ha^{-1}. With increase in the level of K application to 60 kg K_2O ha^{-1}, the available K remained in the soil significantly increased to 441.7 kg ha^{-1}. With further increase in the dose of K there was no significant increase in the available K status.

The treatment receiving the combined application of recommended dose of 60 kg K_2O ha^{-1} with the foliar application of triacontanol and potassium humate showed a significantly higher available K at flowering of 452.5 kg ha^{-1}. The available K values in the treatments receiving inorganic K alone at 60 or 90 kg K_2O ha^{-1}, or combination of inorganic K at 60 kg K_2O ha^{-1} with either triacontanol or potassium humate or both or combination of inorganic K at 45 kg K_2O ha^{-1} with the two other components were found to be at a par.

Similar result was obtained at the harvest of the crop. There was depletion in the available K of the soil from the initial value of 449 kg ha^{-1} in all the treatments. The depletion was higher i.e., 10 per cent with the application of triacontanol alone and got reduced to 2 per cent in the treatment receiving the combination of recommended K with triacontanol and potassium humate. The results corroborate the findings of Duraisami and Mani (2002) who reported progressive increase in available K with increase in dose of K and the highest availability of 209.5 kg ha^{-1} was recorded by K_{80} level as against only 181.8 kg ha^{-1} at K_0 level.

The decrease in values of available N, P_2O_5 and K_2O from flowering to the harvest stage may be attributed to the greater removal of applied nutrients by the crop for the growth and yield of the crop.

The crop put forth more dry matter and fruit yield with good quality when treated with combination of 60 kg K_2O ha^{-1} along with triacontanol and potassium humate and hence exhausted more amounts of the nutrients from the soil leaving a smaller pool of available N and P.

4.10 Simple correlations among the fruit yield, quality parameters, K content of the plant and its uptake

The simple correlations were worked out between various parameters and the data was presented in Table4.18.

There existed a significant positive correlation between the fruit yield and lycopene content (0.601*), K content of the haulms (0.506*), available K at harvest (0.561*) at 5% level and with K content of the fruit (0.736**) and K uptake by fruit (0.957**) at 1% level. However, titratable acidity showed a significant negative correlation of -0.587* with fruit yield.

Titratable acidity had a significant negative correlation with all the parameters tested for correlation.

Lycopene content of the fruits correlated significantly at 1% level with K content of the plant and its uptake besides the available K status of the soil both at flowering and at harvest and at 5% level with total sugars.

The K content of the fruit had a significant and positive correlation at 1% level with K uptake at haulm and fruit, available K status both at flowering and harvest with the correlation (r) values of 0.883^{**}, 0.900^{**}, 0.757^{**} and 0.827^{**} respectively. Hartz *et al*. (1999) also found a significant correlation between plant K and fruit K (0.19**) and soluble solid (0.28**), fruit K and soil K (0.54**).

4.11 Effect of INM on Benefit cost ratio of tomato

Application of inorganic K in graded levels from 30 to 90 kg K_2O ha^{-1} progressively increased the benefit – cost ratio from 0.90 to 1.14. The gross returns, net returns and benefit – cost ratio were minimum when inorganic K alone was applied at 30 kg K_2O ha^{-1} with corresponding values of Rs. 102700=00, Rs. 48506=00 and 0.90 (Table4.19).

Among the different treatments, the treatment T_4 receiving the combined application of inorganic K at 60 kg K_2O ha^{-1} and foliar applications of triacontanol and potassium humate fared well economically giving gross returns of Rs. 1,35,000=00 followed by T_3, the combination of recommended K and foliar applied K with corresponding benefit – cost ratio of 1.40 and 1.35. The benefit – cost ratio was minimum i.e., 0.90 when inorganic K alone was applied at 30 kg K_2O ha^{-1}. The higher net returns in the integrated treatment could be due to efficient utilization of the inputs and realizing higher yield. Singh and Singh (1995) also obtained an enhanced net returns of Rs. 10033/- due to application of 40 kg K_2O/ha over the returns of Rs. 8026/- from control (no K).

The potassium nutrition of the crop through integrated use inorganic K at recommended level of 60 kg K_2O ha^{-1} with the foliar application of organics like triacontanol and potassium humate lead to effective utilization of the nutrients and resulted in improved fruit yield and also quality besides maintaining the available K status after the crop giving high net returns and benefit – cost ratio.

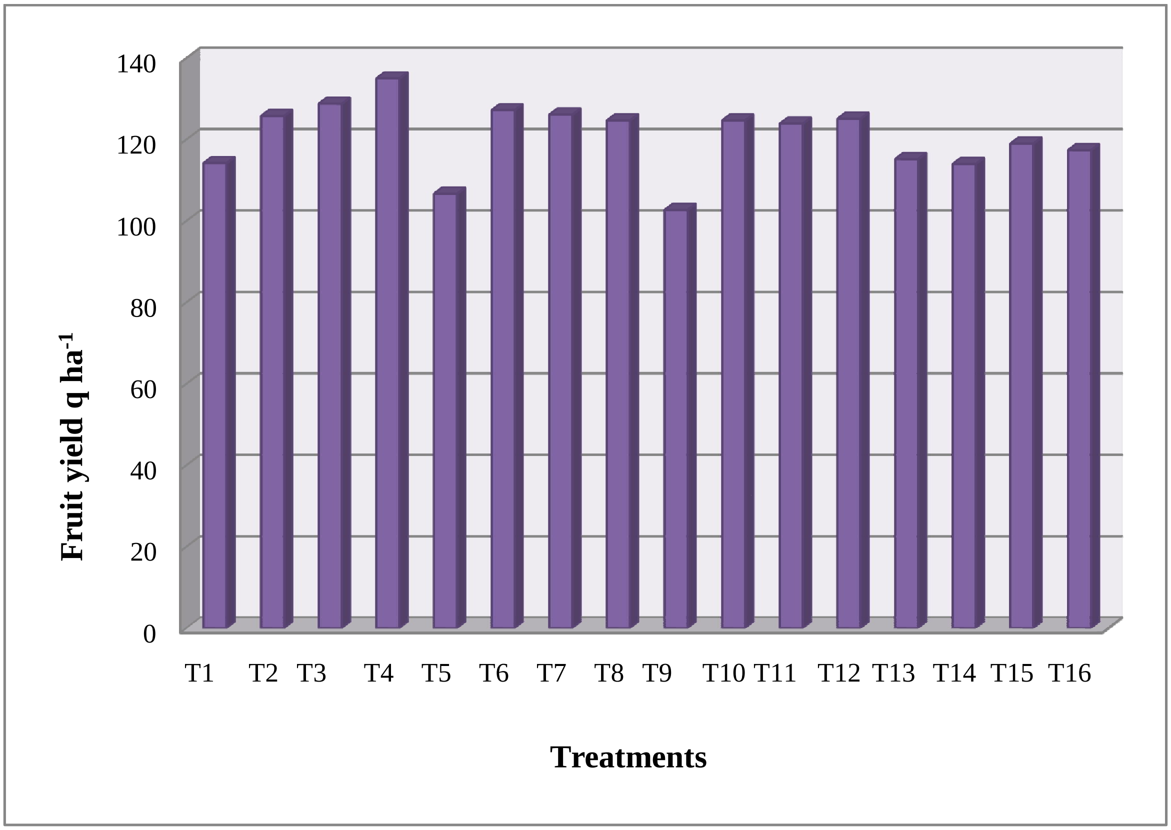

Figure 4.1. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on fruit yield (q ha^{-1}) of tomato

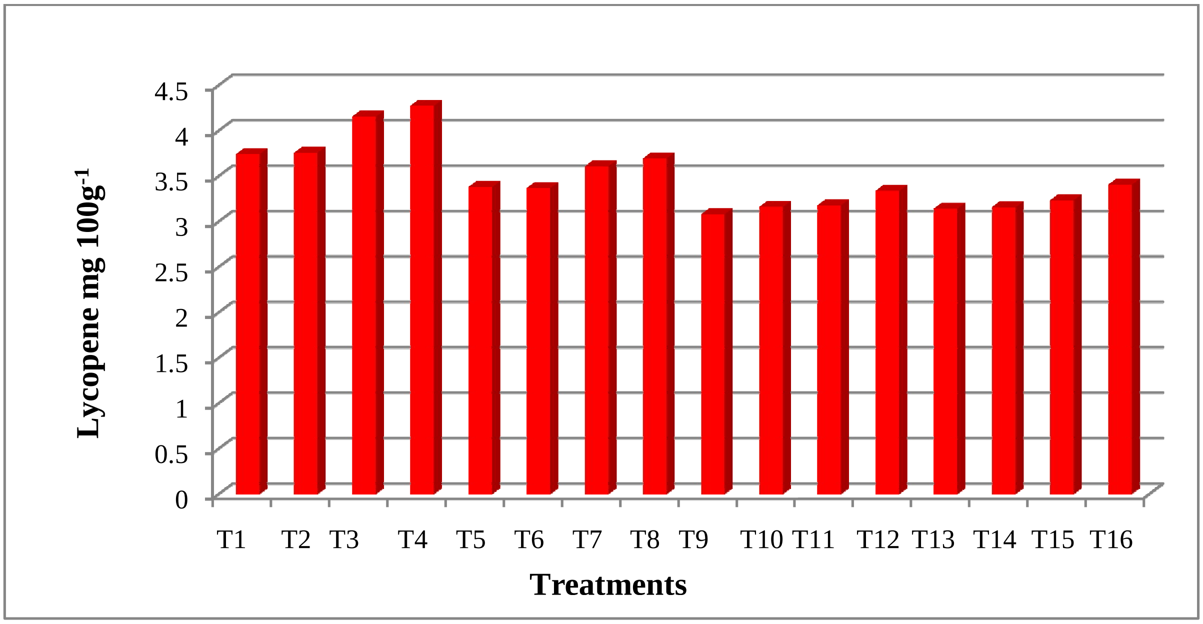

Figure 4.2. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on lycopene content (mg 100 g^{-1}) of tomato

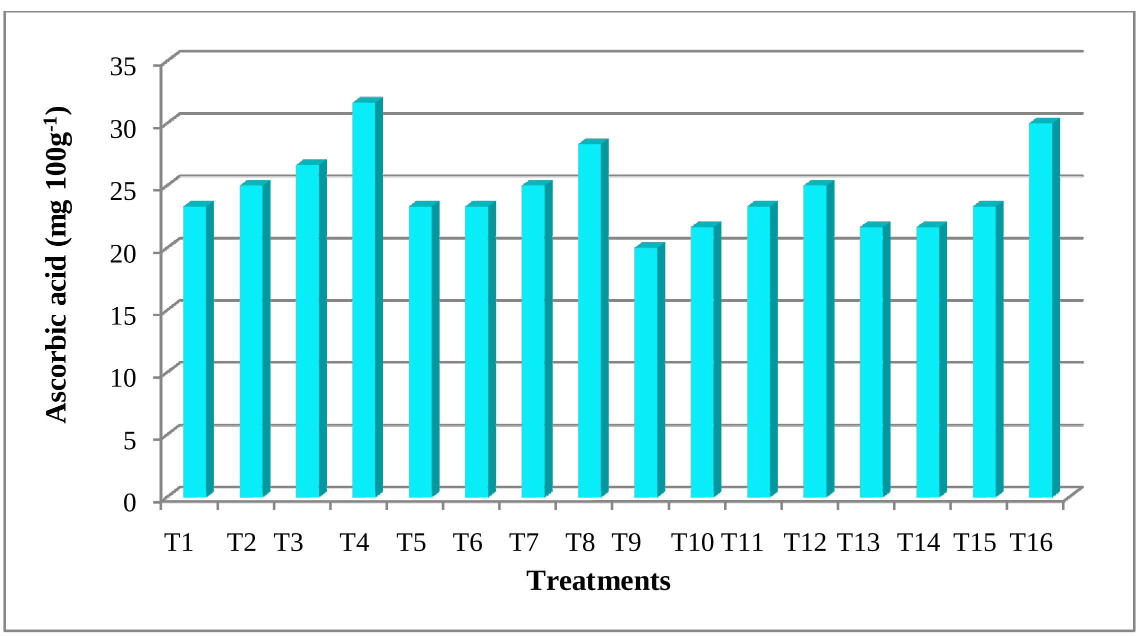

Figure 4.3. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on ascorbic acid content (mg 100 g^{-1}) of tomato

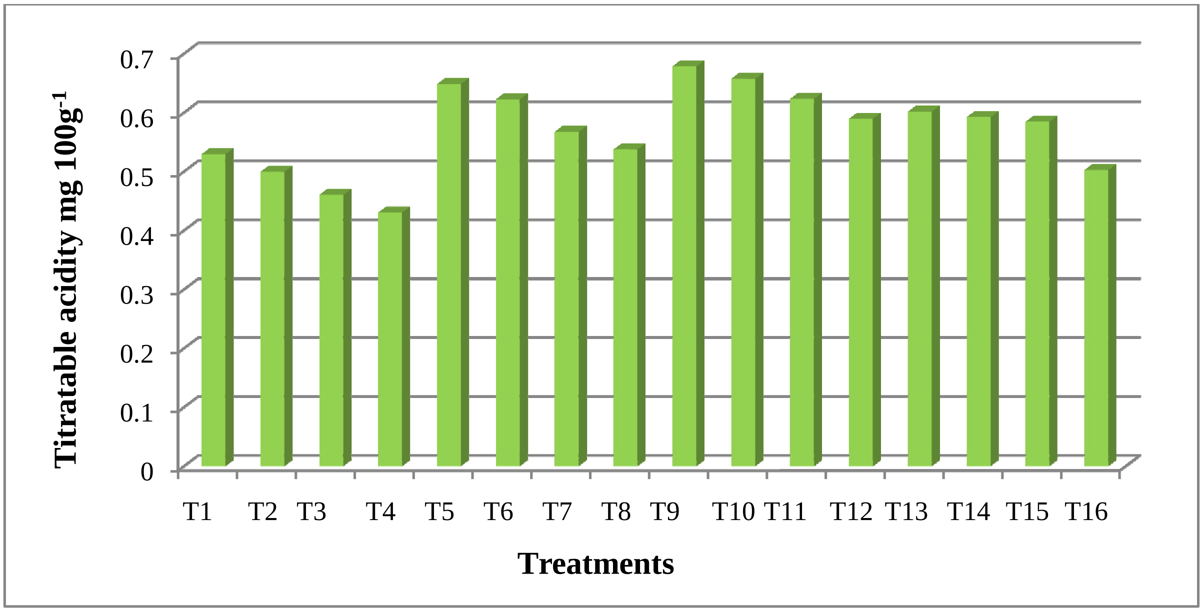

Figure 4.4. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on titratable acidity (mg 100 g^{-1}) of tomato

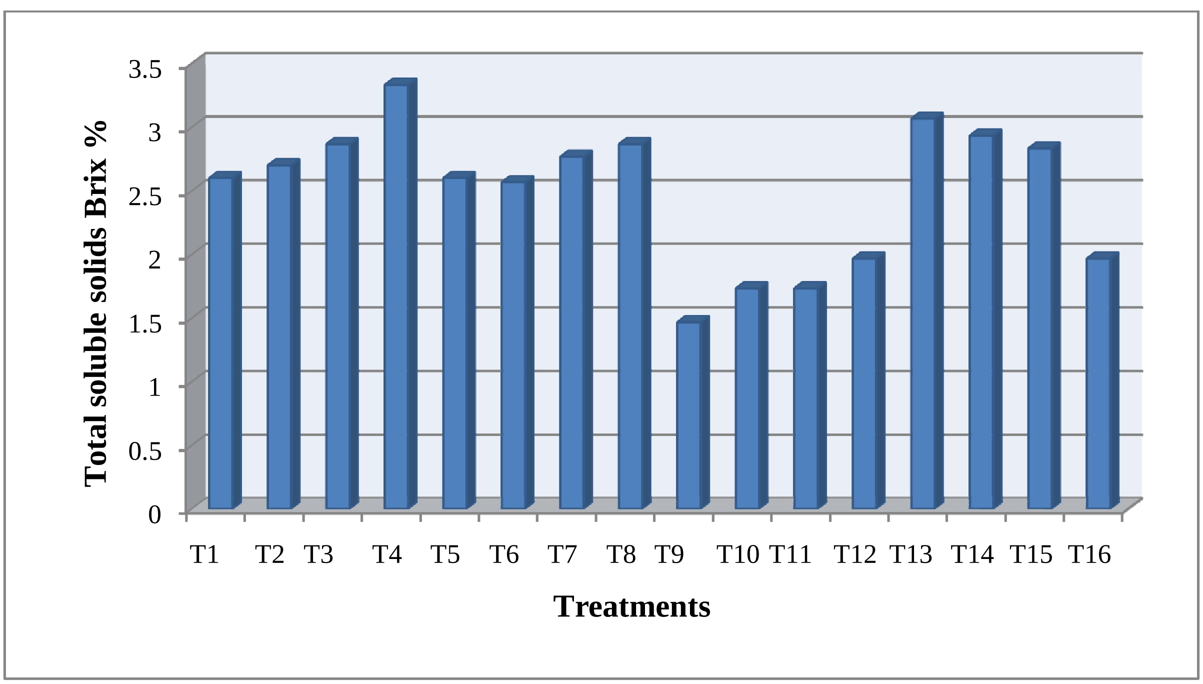

Figure 4.5. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on total soluble solids (Brix %) of tomato

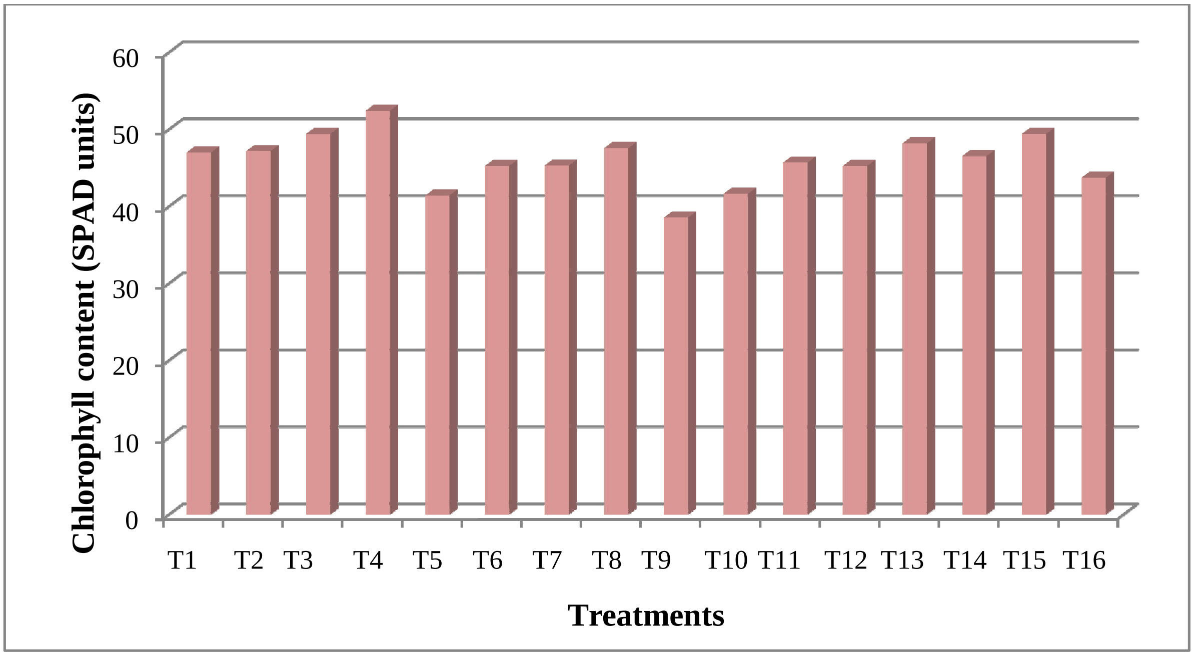

Figure 4.6. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on chlorophyll content (SPAD units) of tomato

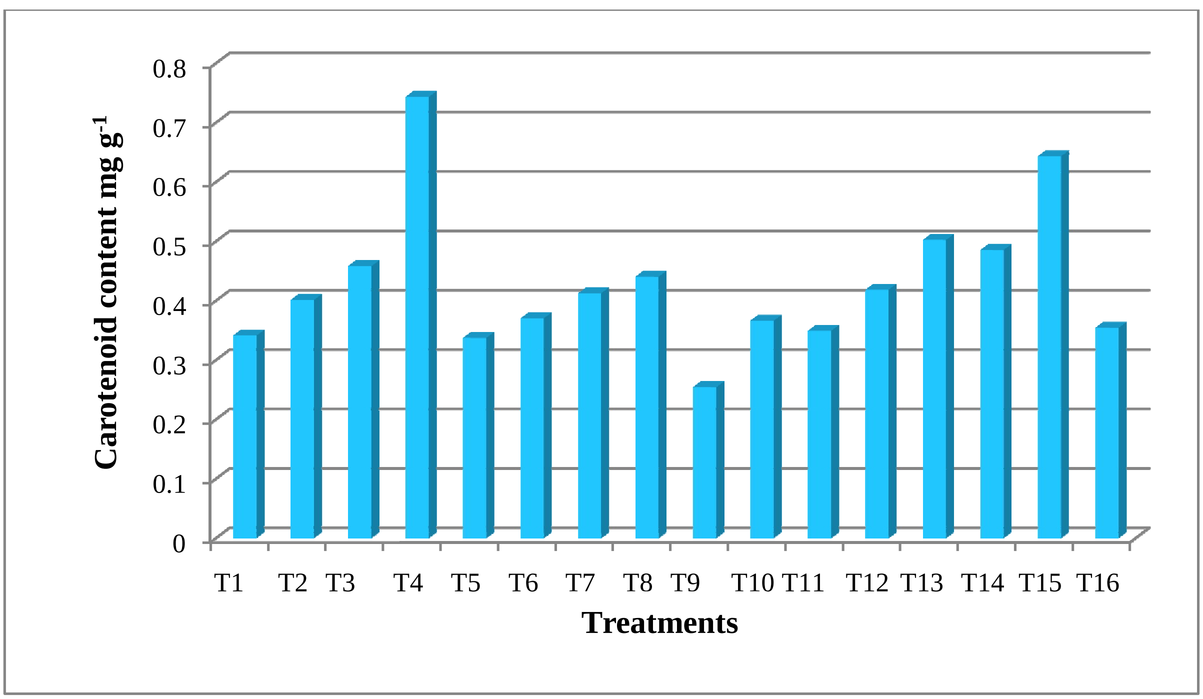

Figure 4.7. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on carotenoid content (mg g^{-1}) of tomato

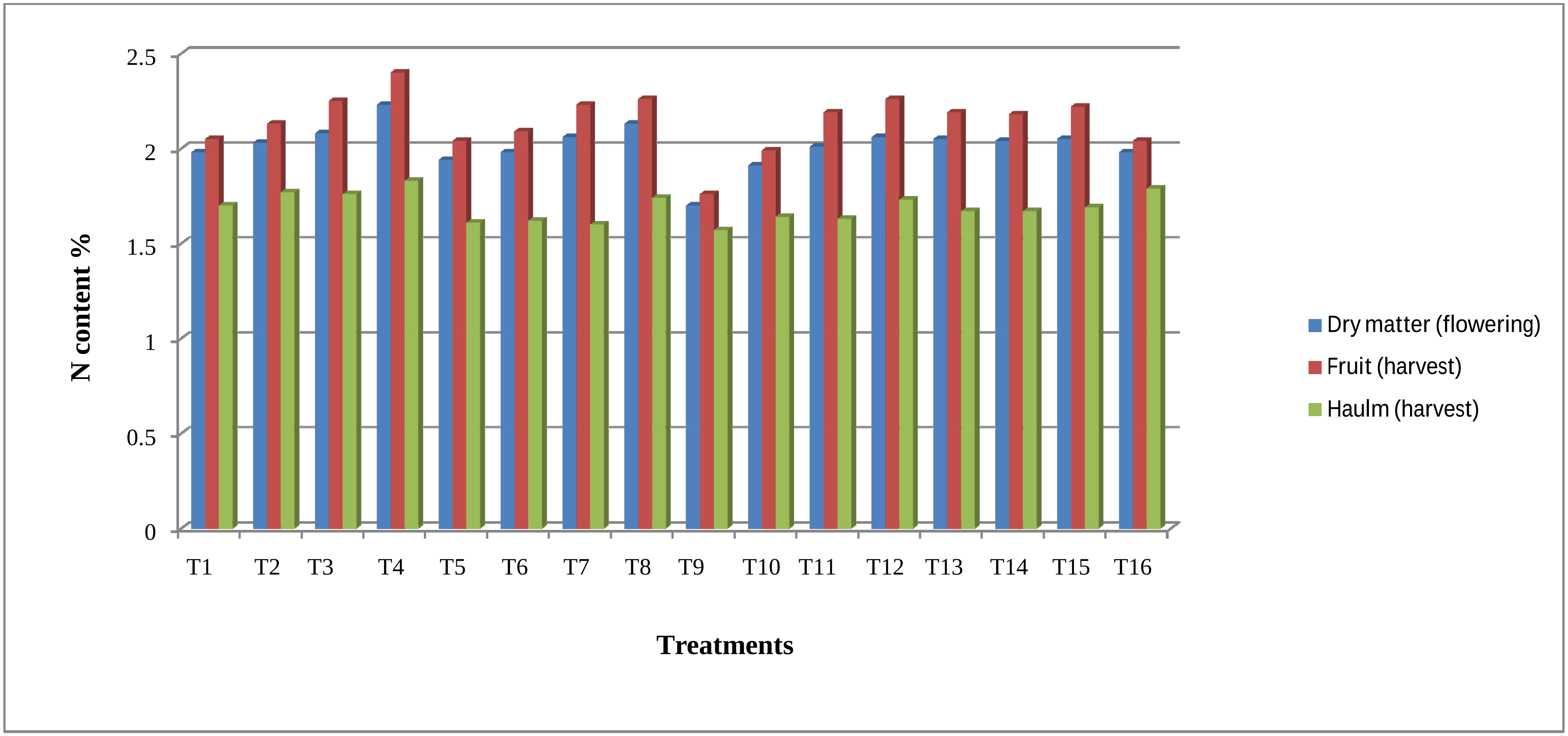

Figure 4.8. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen content (%) of tomato

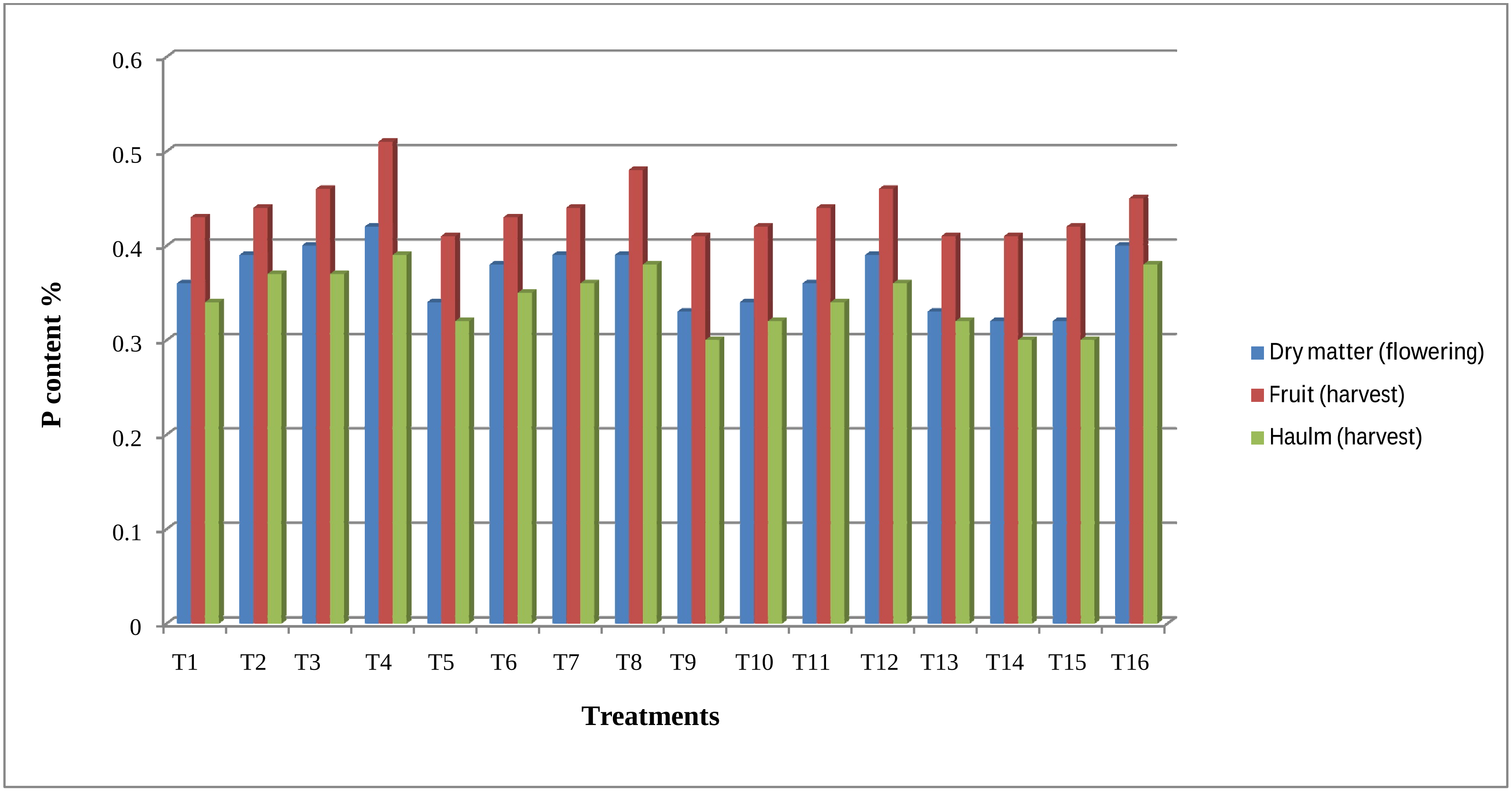

Figure 4.9. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on phosphorus content (%) of tomato

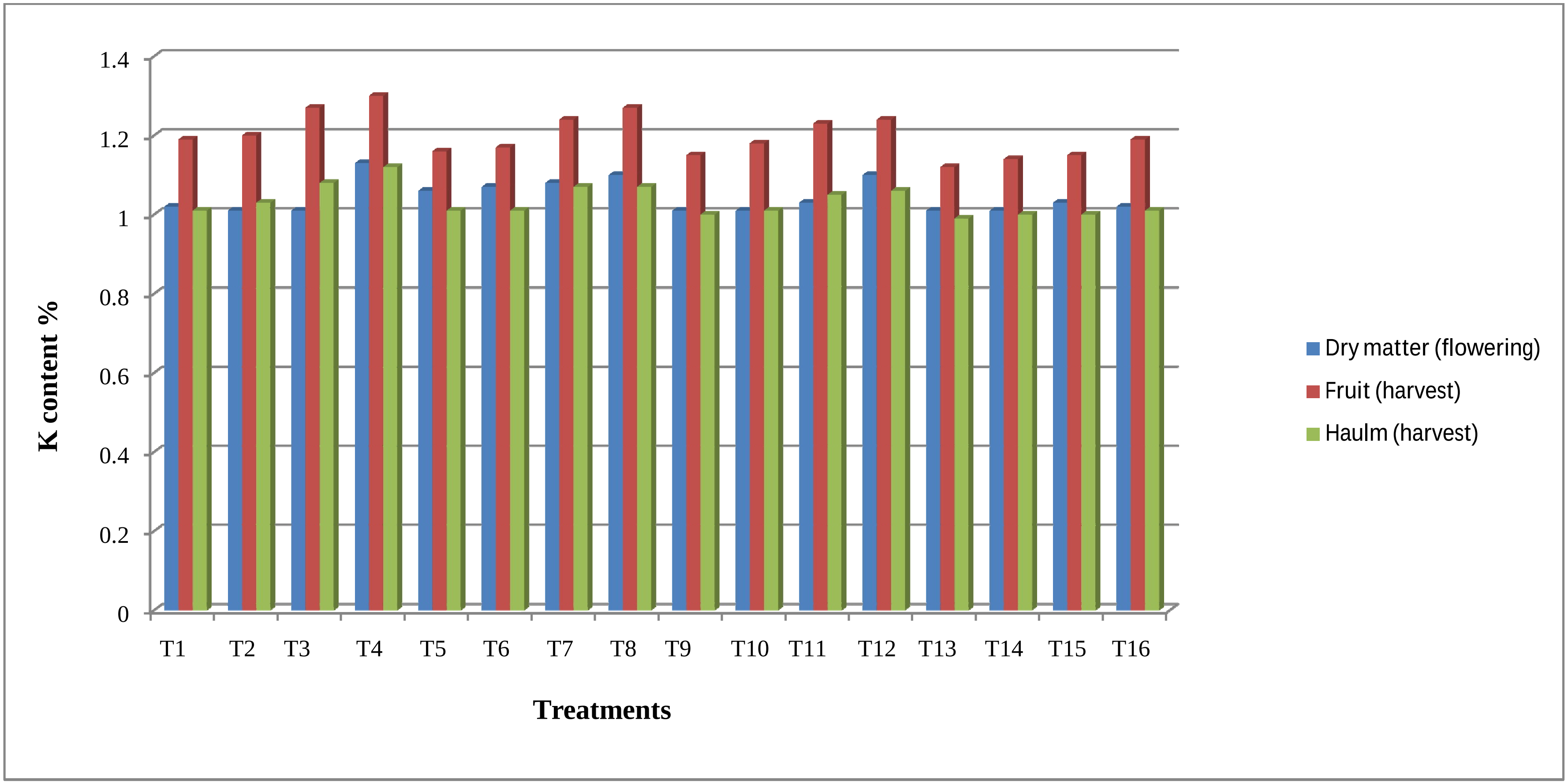

Figure 4.10. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on potassium content (%) of tomato

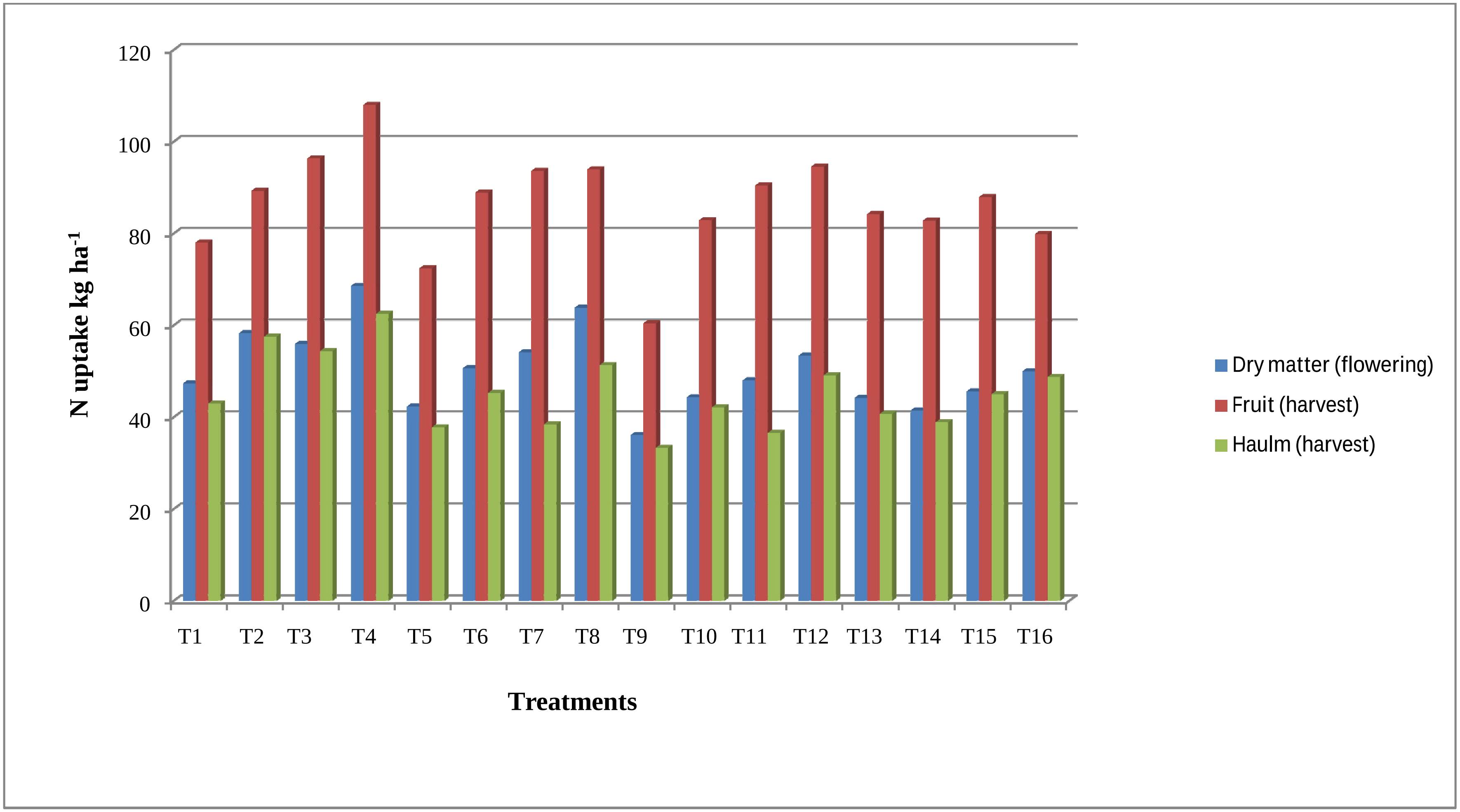

Figure 4.11. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen uptake (kg ha^{-1}) of tomato

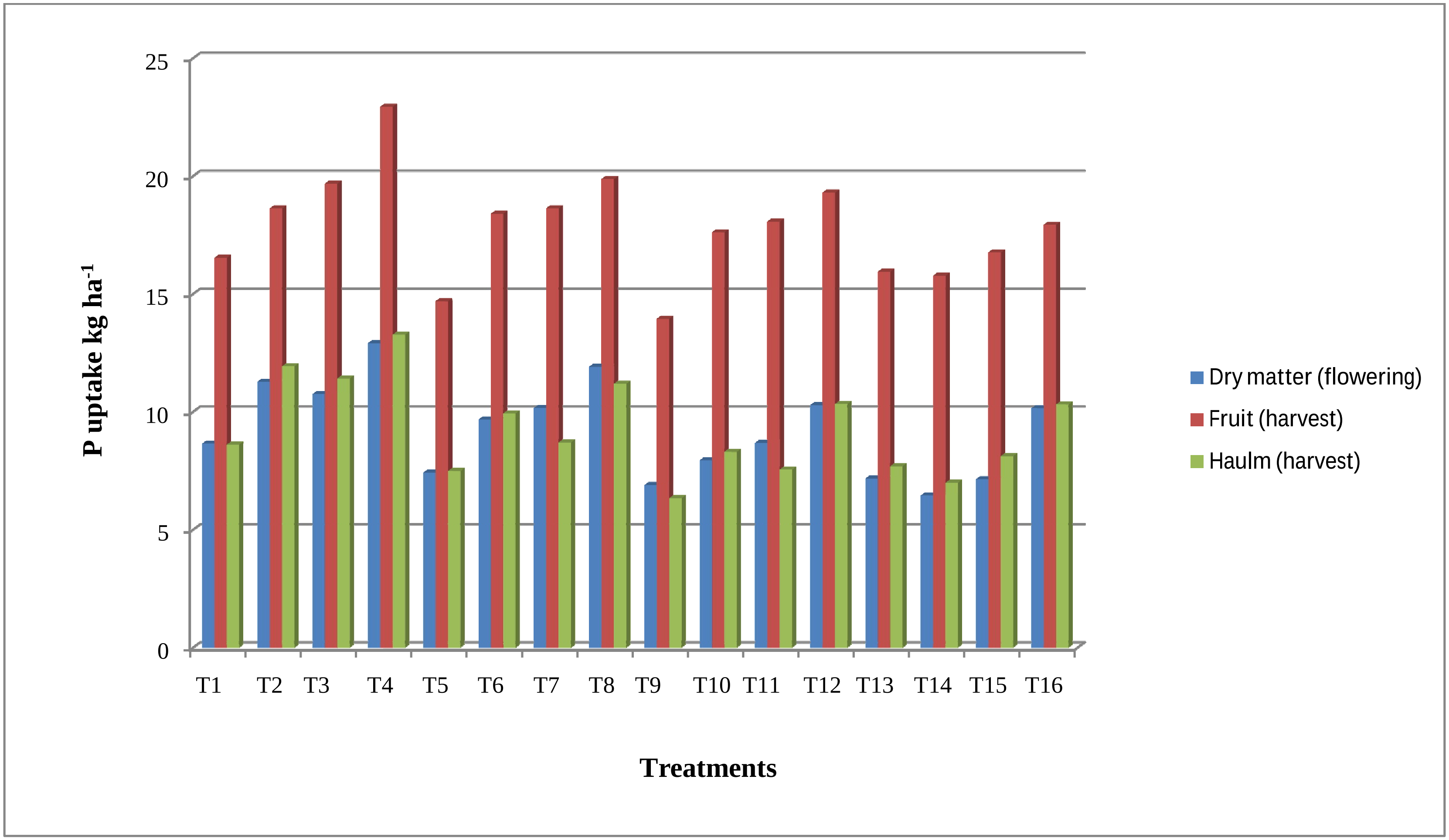

Figure 4.12. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on phosphorus uptake (kg ha^{-1}) of tomato

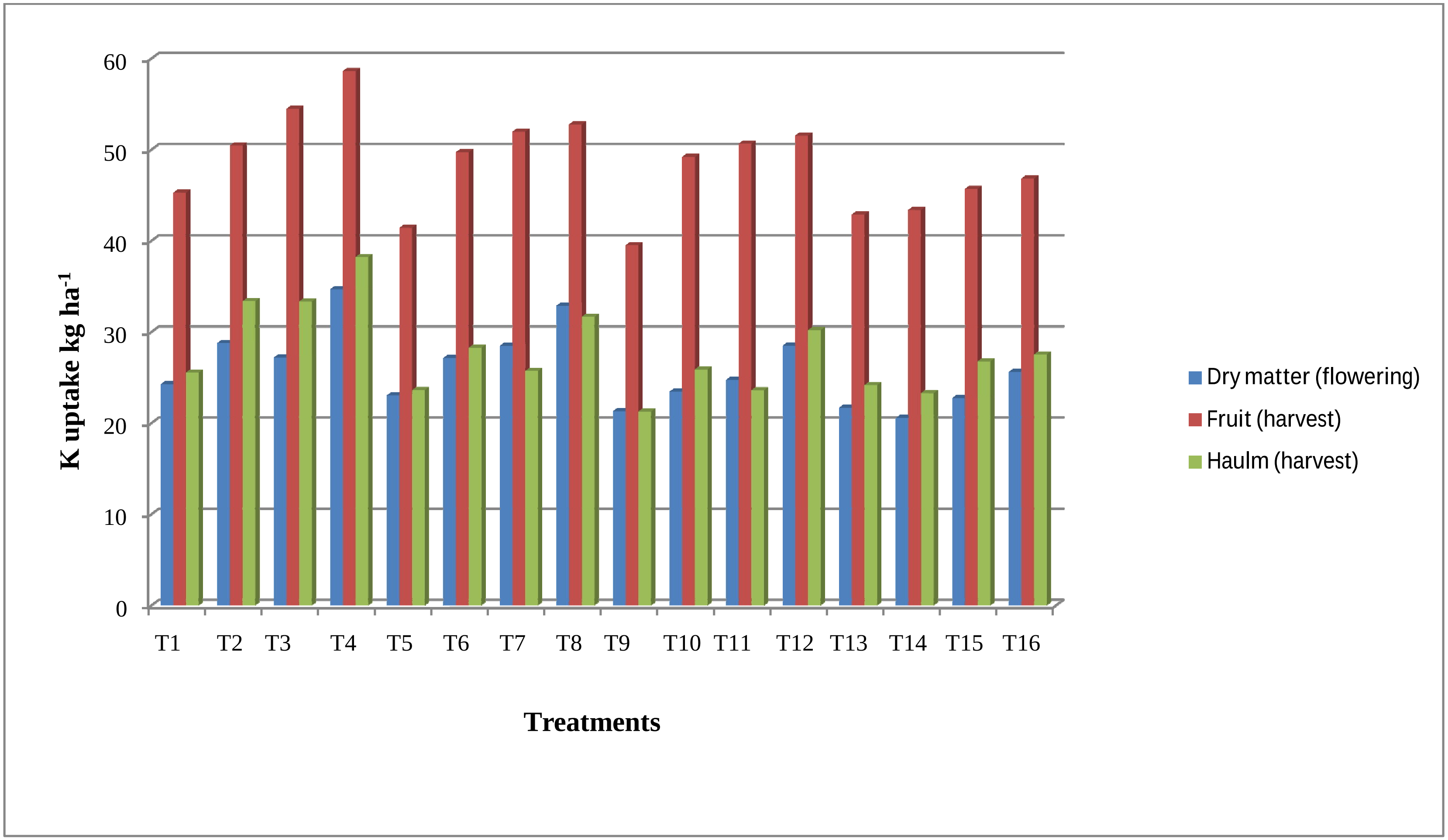

Figure 4.13. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on potassium uptake (kg ha^{-1}) of tomato

Plate 4: Effect of individual and integrated application of inorganic K, K- humate and triacontanol on tomato at harvest

Plate 1: View of tomato nursery with raised beds

Plate 2: Overall view of the experimental field of tomato during *kharif*, 2011

Plate 3: Effect of individual and integrated use of inorganic K, K-humate and triacontanol on tomato during flowering stage

Table4.19. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on Economics

Treatments	yield (q ha^{-1})	Total cost of cultivation	Gross returns Rs ha^{-1}	Net returns Rs ha^{-1}	Benefit cost ratio
T_1 : 60 kg K_2O per ha (Recommended)	114.2	54509.00	114200.0	59691.00	1.10
T_2 : T_1 + Foliar application of triacontanol	125.8	55819.00	125800.0	69981.00	1.25
T_3 : T_1 + Foliar application of K- humate	128.8	54846.00	128800.0	73954.00	1.35
T_4 : T_1 + Foliar application of triacontanol and K- humate	135.0	56156.00	135000.0	78844.00	1.40
T_5 : 45 kg K_2O per ha as basal application	106.7	54353.00	106700.0	52347.00	0.96
T_6 : T_5 + Foliar application of triacontanol	127.2	55663.00	127200.0	71537.00	1.29
T_7 : T_5 + Foliar application of K- humate	126.1	54691.00	126100.0	71409.00	1.31
T_8 : T_5 + Foliar application of triacontanol and K- humate	124.7	56000.00	124700.0	68700.00	1.23
T_9 : 30 kg K_2O per ha as basal application	102.7	54194.00	102700.0	48506.00	0.90
T_{10} : T_9+ Foliar application of triacontanol	124.7	55504.00	124700.0	69196.00	1.25
T_{11} : T_9 + Foliar application of K- humate	123.9	54532.00	123900.0	69368.00	1.27
T_{12} : T_9+ Foliar application of triacontanol and K- humate	125.1	55841.00	125100.0	69259.00	1.24
T_{13} : Foliar application of triacontanol	115.2	55189.00	115200.0	60011.00	1.09
T_{14} : Foliar application of K- humate	114.0	54217.00	114000.0	59783.00	1.10
T_{15} : Foliar application of triacontanol and K- humate	119.0	55526.00	119000.0	63474.00	1.14
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal	117.4	54825.00	117400.0	62575.00	1.14

Cost of tomatoes per kg = Rs.10.00; Cost of DAP per 50 kg = Rs.798 ; Cost of urea per 50 kg = Rs. 281
Cost of MOP per 50 kg = Rs 315 ; Cost of triacontanol per litre = Rs. 320 ; Cost of K-humate per litre = Rs. 25

Table4.18. Correlations among various plant parameters and soil characteristics

Parameters	Fruit yield	Lycopene	Ascorbic acid	Titratable Acidity	Total Sugar	K-content (haulm, flowering)	K-content (fruit, harvest)	K-uptake (haulm, flowering)	K-uptake (fruit, harvest)	Available K_2O (flowering)	Available K_2O (harvest)
Fruit yield	1.000	0.601*	0.383	-0.587*	0.330	0.506*	0.736**	0.770**	0.957**	0.475	0.561*
Lycopene		1.000	0.476	-0.878**	0.560*	0.415	0.785**	0.759**	0.726**	0.806**	0.762**
Ascorbic acid			1.000	-0.635**	0.612*	0.242	0.206	0.301	0.338	0.381	0.192
Titratable Acidity				1.000	-0.572*	-0.248	-0.663**	-0.666**	-0.664**	-0.724**	-0.598*
Total Sugar					1.000	0.285	0.174	0.353	0.297	0.157	0.041
K- content (haulm, flowering)						1.000	0.659**	0.775**	0.611*	0.417	0.486
K-content (fruit, harvest)							1.000	0.883**	0.900**	0.757**	0.827**
K-uptake (haulm, flowering)								1.000	0.874**	0.759**	0.797**
K-uptake (fruit, harvest)									1.000	0.625**	0.709**
Available K_2O (haulm, flowering)										1.000	0.952**
Available K_2O (harvest)											1.000

* Significant at P = 0.05

** Significant at P = 0.01

Table4.2. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on dry matter production of tomato at flowering stage

Treatments	Dry matter production (q ha^{-1})
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	23.79
T_2 : T_1 + Foliar application of Triacontanol	28.61
T_3 : T_1 + Foliar application of K- humate	26.84
T_4 : T_1 + Foliar application of Triacontanol and K- humate	30.79
T_5 : 45 kg K_2O per ha as basal application	21.80
T_6 : T_5 + Foliar application of Triacontanol	25.45
T_7 : T_5 + Foliar application of K- humate	26.29
T_8 : T_5 + Foliar application of Triacontanol and K- humate	29.91
T_9 : 30 kg K_2O per ha as basal application	21.15
T_{10} : T_9+ Foliar application of Triacontanol	23.13
T_{11} : T_9 + Foliar application of K- humate	23.91
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	25.91
T_{13} : Foliar application of Triacontanol	21.57
T_{14} : Foliar application of K- humate	20.30
T_{15} : Foliar application of Triacontanol and K- humate	22.19
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	25.17
CD (0.05)	4.93
SE(d) ±	2.40
CV (%)	11.85

Table4.4. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on haulm yield of tomato at harvest

Treatments	Haulm yield (q ha^{-1})
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	25.24
T_2 : T_1 + Foliar application of Triacontanol	32.47
T_3 : T_1 + Foliar application of K- humate	30.79
T_4 : T_1 + Foliar application of Triacontanol and K- humate	34.19
T_5 : 45 kg K_2O per ha as basal application	23.44
T_6 : T_5 + Foliar application of Triacontanol	27.89
T_7 : T_5 + Foliar application of K- humate	24.05
T_8 : T_5 + Foliar application of Triacontanol and K- humate	29.47
T_9 : 30 kg K_2O per ha as basal application	21.17
T_{10} : T_9+ Foliar application of Triacontanol	25.68
T_{11} : T_9 + Foliar application of K- humate	22.40
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	28.41
T_{13} : Foliar application of Triacontanol	24.23
T_{14} : Foliar application of K- humate	23.22
T_{15} : Foliar application of Triacontanol and K- humate	26.66
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	27.13
CD (0.05)	5.37
SE(d) ±	2.62
CV (%)	12.03

Table4.3. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on fresh fruit yield of tomato

Treatments	Fruit yield ($q\ ha^{-1}$)
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	114.2
T_2 : T_1 + Foliar application of Triacontanol	125.8
T_3 : T_1 + Foliar application of K- humate	128.8
T_4 : T_1 + Foliar application of Triacontanol and K- humate	135.0
T_5 : 45 kg K_2O per ha as basal application	106.7
T_6 : T_5 + Foliar application of Triacontanol	127.2
T_7 : T_5 + Foliar application of K- humate	126.1
T_8 : T_5 + Foliar application of Triacontanol and K- humate	124.7
T_9 : 30 kg K_2O per ha as basal application	102.7
T_{10} : T_9+ Foliar application of Triacontanol	124.7
T_{11} : T_9 + Foliar application of K- humate	123.9
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	125.1
T_{13} : Foliar application of Triacontanol	115.2
T_{14} : Foliar application of K- humate	114.0
T_{15} : Foliar application of Triacontanol and K- humate	119.0
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	117.4
CD (0.05)	11.25
SE(d) ±	5.48
CV (%)	5.57

Table4.5. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on leaf chlorophyll and carotenoid content of tomato at flowering stage

Treatments	Chlorophyll content (SPAD units)	Carotenoid content (mg g^{-1})
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	47.00	0.34
T_2 : T_1 + Foliar application of Triacontanol	47.18	0.40
T_3 : T_1 + Foliar application of K- humate	49.40	0.46
T_4 : T_1 + Foliar application of Triacontanol and K- humate	52.41	0.74
T_5 : 45 kg K_2O per ha as basal application	41.42	0.34
T_6 : T_5 + Foliar application of Triacontanol	45.25	0.37
T_7 : T_5 + Foliar application of K- humate	45.30	0.41
T_8 : T_5 + Foliar application of Triacontanol and K- humate	47.57	0.44
T_9 : 30 kg K_2O per ha as basal application	38.55	0.25
T_{10} : T_9+ Foliar application of Triacontanol	41.64	0.36
T_{11} : T_9 + Foliar application of K- humate	45.69	0.35
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	45.25	0.42
T_{13} : Foliar application of Triacontanol	48.19	0.50
T_{14} : Foliar application of K- humate	46.53	0.48
T_{15} : Foliar application of Triacontanol and K- humate	49.41	0.64
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	43.72	0.35
CD (0.05)	3.56	0.12
SE(d) ±	1.73	0.06
CV (%)	4.63	16.27

Table4.6. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on lycopene and ascorbic acid content of tomato

Treatments	**Lycopene (mg $100g^{-1}$)**	**Ascorbic Acid (mg $100g^{-1}$)**
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	3.74	23.33
T_2 : T_1 + Foliar application of Triacontanol	3.76	25.00
T_3 : T_1 + Foliar application of K- humate	4.15	26.66
T_4 : T_1 + Foliar application of Triacontanol and K- humate	4.27	31.66
T_5 : 45 kg K_2O per ha as basal application	3.38	23.33
T_6 : T_5 + Foliar application of Triacontanol	3.37	23.33
T_7 : T_5 + Foliar application of K- humate	3.61	25.00
T_8 : T_5 + Foliar application of Triacontanol and K- humate	3.69	28.33
T_9 : 30 kg K_2O per ha as basal application	3.08	20.00
T_{10} : T_9+ Foliar application of Triacontanol	3.16	21.66
T_{11} : T_9 + Foliar application of K- humate	3.17	23.33
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	3.34	25.00
T_{13} : Foliar application of Triacontanol	3.14	21.66
T_{14} : Foliar application of K- humate	3.16	21.66
T_{15} : Foliar application of Triacontanol and K- humate	3.23	23.33
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	3.41	30.00
CD (0.05)	0.12	5.78
SE(d) ±	0.06	2.82
CV (%)	2.06	14.04

Table4.7. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on titratable acidity and total soluble solids of tomato

Treatments	Titratable Acidity (mg $100g^{-1}$)	TSS (Brix %)
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	0.53	2.60
T_2 : T_1 + Foliar application of Triacontanol	0.49	2.70
T_3 : T_1 + Foliar application of K- humate	0.46	2.87
T_4 : T_1 + Foliar application of Triacontanol and K- humate	0.43	3.33
T_5 : 45 kg K_2O per ha as basal application	0.65	2.60
T_6 : T_5 + Foliar application of Triacontanol	0.62	2.57
T_7 : T_5 + Foliar application of K- humate	0.57	2.77
T_8 : T_5 + Foliar application of Triacontanol and K- humate	0.54	2.87
T_9 : 30 kg K_2O per ha as basal application	0.68	1.47
T_{10} : T_9+ Foliar application of Triacontanol	0.66	1.73
T_{11} : T_9 + Foliar application of K- humate	0.62	1.73
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	0.59	1.97
T_{13} : Foliar application of Triacontanol	0.60	3.07
T_{14} : Foliar application of K- humate	0.59	2.93
T_{15} : Foliar application of Triacontanol and K- humate	0.58	2.83
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	0.50	1.97
CD (0.05)	0.05	0.17
SE(d) ±	0.02	0.09
CV (%)	4.84	4.21

Table4.8. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen, phosphorus and potassium content by tomato at flowering stage

Treatments	Nutrient content (%)		
	N	P	K
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	1.98	0.36	1.02
T_2 : T_1 + Foliar application of Triacontanol	2.03	0.39	1.01
T_3 : T_1 + Foliar application of K- humate	2.08	0.40	1.01
T_4 : T_1 + Foliar application of Triacontanol and K- humate	2.23	0.42	1.13
T_5 : 45 kg K_2O per ha as basal application	1.94	0.34	1.06
T_6 : T_5 + Foliar application of Triacontanol	1.98	0.38	1.07
T_7 : T_5 + Foliar application of K- humate	2.06	0.39	1.08
T_8 : T_5 + Foliar application of Triacontanol and K- humate	2.13	0.39	1.10
T_9 : 30 kg K_2O per ha as basal application	1.70	0.33	1.01
T_{10} : T_9+ Foliar application of Triacontanol	1.91	0.34	1.01
T_{11} : T_9 + Foliar application of K- humate	2.01	0.36	1.03
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	2.06	0.39	1.10
T_{13} : Foliar application of Triacontanol	2.05	0.33	1.01
T_{14} : Foliar application of K- humate	2.04	0.32	1.01
T_{15} : Foliar application of Triacontanol and K- humate	2.05	0.32	1.03
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	1.98	0.40	1.02
CD (0.05)	0.03	0.03	0.01
SE(d) ±	0.02	0.01	0.01
CV (%)	0.97	4.80	0.76

Table4.9. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen, phosphorus and potassium content of tomato fruit

Treatments	Nutrient content (%)		
	N	P	K
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	2.05	0.43	1.19
T_2 : T_1 + Foliar application of Triacontanol	2.13	0.44	1.20
T_3 : T_1 + Foliar application of K- humate	2.25	0.46	1.27
T_4 : T_1 + Foliar application of Triacontanol and K- humate	2.40	0.51	1.30
T_5 : 45 kg K_2O per ha as basal application	2.04	0.41	1.16
T_6 : T_5 + Foliar application of Triacontanol	2.09	0.43	1.17
T_7 : T_5 + Foliar application of K- humate	2.23	0.44	1.24
T_8 : T_5 + Foliar application of Triacontanol and K- humate	2.26	0.48	1.27
T_9 : 30 kg K_2O per ha as basal application	1.76	0.41	1.15
T_{10} : T_9+ Foliar application of Triacontanol	1.99	0.42	1.18
T_{11} : T_9 + Foliar application of K- humate	2.19	0.44	1.23
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	2.26	0.46	1.24
T_{13} : Foliar application of Triacontanol	2.19	0.41	1.12
T_{14} : Foliar application of K- humate	2.18	0.41	1.14
T_{15} : Foliar application of Triacontanol and K- humate	2.22	0.42	1.15
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	2.04	0.45	1.19
CD (0.05)	0.06	0.02	0.02
SE(d) ±	0.03	0.01	0.01
CV (%)	1.66	3.10	1.10

Table4.10. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen, phosphorus and potassium content of tomato haulms at harvest

Treatments	Nutrient content (%)		
	N	P	K
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	1.70	0.34	1.01
T_2 : T_1 + Foliar application of Triacontanol	1.77	0.37	1.03
T_3 : T_1 + Foliar application of K- humate	1.76	0.37	1.08
T_4 : T_1 + Foliar application of Triacontanol and K- humate	1.83	0.39	1.12
T_5 : 45 kg K_2O per ha as basal application	1.61	0.32	1.01
T_6 : T_5 + Foliar application of Triacontanol	1.62	0.35	1.01
T_7 : T_5 + Foliar application of K- humate	1.60	0.36	1.07
T_8 : T_5 + Foliar application of Triacontanol and K- humate	1.74	0.38	1.07
T_9 : 30 kg K_2O per ha as basal application	1.57	0.30	1.00
T_{10} : T_9+ Foliar application of Triacontanol	1.64	0.32	1.01
T_{11} : T_9 + Foliar application of K- humate	1.63	0.34	1.05
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	1.73	0.36	1.06
T_{13} : Foliar application of Triacontanol	1.67	0.32	0.99
T_{14} : Foliar application of K- humate	1.67	0.30	1.00
T_{15} : Foliar application of Triacontanol and K- humate	1.69	0.30	1.00
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	1.79	0.38	1.01
CD (0.05)	0.06	0.03	0.01
SE(d) ±	0.03	0.01	0.01
CV (%)	2.03	4.44	0.81

Table4.11. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen, phosphorus and potassium uptake by tomato at flowering stage

Treatments	Nutrient uptake (kg ha^{-1})		
	N	P	K
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	47.29	8.65	24.25
T_2 : T_1 + Foliar application of Triacontanol	58.24	11.27	28.76
T_3 : T_1 + Foliar application of K- humate	55.89	10.75	27.18
T_4 : T_1 + Foliar application of Triacontanol and K- humate	68.53	12.91	34.68
T_5 : 45 kg K_2O per ha as basal application	42.27	7.42	23.03
T_6 : T_5 + Foliar application of Triacontanol	50.62	9.67	27.14
T_7 : T_5 + Foliar application of K- humate	54.09	10.16	28.47
T_8 : T_5 + Foliar application of Triacontanol and K- humate	63.80	11.91	32.87
T_9 : 30 kg K_2O per ha as basal application	36.07	6.89	21.30
T_{10} : T_9+ Foliar application of Triacontanol	44.28	7.94	23.44
T_{11} : T_9 + Foliar application of K- humate	47.97	8.68	24.73
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	53.37	10.28	28.48
T_{13} : Foliar application of Triacontanol	44.16	7.17	21.67
T_{14} : Foliar application of K- humate	41.39	6.45	20.56
T_{15} : Foliar application of Triacontanol and K- humate	45.56	7.14	22.73
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	49.94	10.15	25.60
CD (0.05)	9.99	2.00	5.21
SE(d) ±	4.87	0.97	2.54
CV (%)	11.87	12.95	11.99

Table4.12. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen, phosphorus and potassium uptake by tomato fruit

Treatments	Nutrient uptake (kg ha^{-1})		
	N	P	K
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	77.98	16.53	45.27
T_2 : T_1 + Foliar application of Triacontanol	89.25	18.63	50.44
T_3 : T_1 + Foliar application of K- humate	96.31	19.68	54.47
T_4 : T_1 + Foliar application of Triacontanol and K- humate	107.97	22.94	58.61
T_5 : 45 kg K_2O per ha as basal application	72.37	14.69	41.41
T_6 : T_5 + Foliar application of Triacontanol	88.87	18.40	49.72
T_7 : T_5 + Foliar application of K- humate	93.59	18.63	51.96
T_8 : T_5 + Foliar application of Triacontanol and K- humate	93.91	19.87	52.76
T_9 : 30 kg K_2O per ha as basal application	60.38	13.94	39.50
T_{10} : T_9+ Foliar application of Triacontanol	82.85	17.61	49.19
T_{11} : T_9 + Foliar application of K- humate	90.41	18.07	50.64
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	94.50	19.30	51.53
T_{13} : Foliar application of Triacontanol	84.17	15.94	42.87
T_{14} : Foliar application of K- humate	82.77	15.77	43.37
T_{15} : Foliar application of Triacontanol and K- humate	87.89	16.76	45.67
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	79.84	17.93	46.82
CD (0.05)	8.40	1.98	4.62
SE(d) ±	4.09	0.97	2.25
CV (%)	5.79	6.67	5.69

Table4.13. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on nitrogen, phosphorus and potassium uptake by tomato haulms at harvest stage

Treatments	Nutrient uptake (kg ha^{-1})		
	N	P	K
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	42.92	8.61	25.53
T_2 : T_1 + Foliar application of Triacontanol	57.47	11.93	33.37
T_3 : T_1 + Foliar application of K- humate	54.34	11.41	33.33
T_4 : T_1 + Foliar application of Triacontanol and K- humate	62.47	13.27	38.20
T_5 : 45 kg K_2O per ha as basal application	37.72	7.49	23.61
T_6 : T_5 + Foliar application of Triacontanol	45.22	9.93	28.26
T_7 : T_5 + Foliar application of K- humate	38.38	8.70	25.71
T_8 : T_5 + Foliar application of Triacontanol and K- humate	51.29	11.19	31.66
T_9 : 30 kg K_2O per ha as basal application	33.27	6.34	21.26
T_{10} : T_9+ Foliar application of Triacontanol	42.10	8.30	25.87
T_{11} : T_9 + Foliar application of K- humate	36.53	7.55	23.59
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	49.07	10.33	30.19
T_{13} : Foliar application of Triacontanol	40.67	7.69	24.15
T_{14} : Foliar application of K- humate	38.84	6.98	23.27
T_{15} : Foliar application of Triacontanol and K- humate	44.97	8.12	26.76
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	48.71	10.31	27.51
CD (0.05)	9.08	1.95	5.54
SE(d) ±	4.43	0.95	2.70
CV (%)	11.98	12.56	11.97

Table4.14. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on organic carbon content in soil

Treatments	Organic carbon (%)	
	Flowering	Harvest
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	0.69	0.68
T_2 : T_1 + Foliar application of Triacontanol	0.70	0.69
T_3 : T_1 + Foliar application of K- humate	0.71	0.70
T_4 : T_1 + Foliar application of Triacontanol and K- humate	0.72	0.71
T_5 : 45 kg K_2O per ha as basal application	0.68	0.67
T_6 : T_5 + Foliar application of Triacontanol	0.72	0.68
T_7 : T_5 + Foliar application of K- humate	0.70	0.69
T_8 : T_5 + Foliar application of Triacontanol and K- humate	0.70	0.70
T_9 : 30 kg K_2O per ha as basal application	0.68	0.67
T_{10} : T_9+ Foliar application of Triacontanol	0.68	0.68
T_{11} : T_9 + Foliar application of K- humate	0.69	0.69
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	0.70	0.70
T_{13} : Foliar application of Triacontanol	0.68	0.68
T_{14} : Foliar application of K- humate	0.68	0.68
T_{15} : Foliar application of Triacontanol and K- humate	0.68	0.68
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	0.69	0.68
CD (0.05)	NS	NS
SE(d) ±	0.04	0.02
CV (%)	6.35	2.60

Table4.15. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on available nitrogen in soil

Treatments	Available N (kg ha^{-1})	
	Flowering	Harvest
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	160.7	157.7
T_2 : T_1 + Foliar application of Triacontanol	153.9	152.6
T_3 : T_1 + Foliar application of K- humate	157.2	153.4
T_4 : T_1 + Foliar application of Triacontanol and K- humate	150.4	144.4
T_5 : 45 kg K_2O per ha as basal application	161.8	158.5
T_6 : T_5 + Foliar application of Triacontanol	159.1	156.4
T_7 : T_5 + Foliar application of K- humate	160.1	155.5
T_8 : T_5 + Foliar application of Triacontanol and K- humate	158.2	154.8
T_9 : 30 kg K_2O per ha as basal application	168.4	165.2
T_{10} : T_9+ Foliar application of Triacontanol	161.2	162.1
T_{11} : T_9 + Foliar application of K- humate	162.8	163.8
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	163.6	154.4
T_{13} : Foliar application of Triacontanol	166.7	164.4
T_{14} : Foliar application of K- humate	168.1	165.1
T_{15} : Foliar application of Triacontanol and K- humate	167.6	162.6
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	163.7	160.0
CD (0.05)	6.67	7.06
SE(d) ±	3.25	3.44
CV (%)	2.31	2.48

Table4.16. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on available P in soil

Treatments	Available P (kg ha^{-1})	
	Flowering	Harvest
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	56.74	50.43
T_2 : T_1 + Foliar application of Triacontanol	56.21	49.56
T_3 : T_1 + Foliar application of K- humate	53.19	49.00
T_4 : T_1 + Foliar application of Triacontanol and K- humate	50.58	44.60
T_5 : 45 kg K_2O per ha as basal application	58.91	54.55
T_6 : T_5 + Foliar application of Triacontanol	59.34	53.30
T_7 : T_5 + Foliar application of K- humate	56.52	53.60
T_8 : T_5 + Foliar application of Triacontanol and K- humate	56.05	52.14
T_9 : 30 kg K_2O per ha as basal application	63.50	56.99
T_{10} : T_9+ Foliar application of Triacontanol	59.82	55.14
T_{11} : T_9 + Foliar application of K- humate	58.91	55.00
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	59.74	54.24
T_{13} : Foliar application of Triacontanol	59.24	55.81
T_{14} : Foliar application of K- humate	57.60	56.16
T_{15} : Foliar application of Triacontanol and K- humate	58.38	55.41
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	56.09	50.61
CD (0.05)	6.61	5.91
SE(d) ±	3.22	2.88
CV (%)	2.88	2.63

Table4.17. Effect of individual and integrated application of inorganic potassium, potassium humate and triacontanol on available K in soil

Treatments	Available K (kg ha^{-1})	
	Flowering	Harvest
T_1 : 60 kg K_2O per ha (Recommended K) as basal application	441.7	428.1
T_2 : T_1 + Foliar application of Triacontanol	444.5	430.7
T_3 : T_1 + Foliar application of K- humate	447.1	433.8
T_4 : T_1 + Foliar application of Triacontanol and K- humate	452.5	436.7
T_5 : 45 kg K_2O per ha as basal application	432.6	422.3
T_6 : T_5 + Foliar application of Triacontanol	435.8	425.6
T_7 : T_5 + Foliar application of K- humate	437.2	429.0
T_8 : T_5 + Foliar application of Triacontanol and K- humate	443.5	433.1
T_9 : 30 kg K_2O per ha as basal application	419.6	413.5
T_{10} : T_9+ Foliar application of Triacontanol	418.2	421.3
T_{11} : T_9 + Foliar application of K- humate	427.0	420.9
T_{12} : T_9+ Foliar application of Triacontanol and K- humate	429.7	424.6
T_{13} : Foliar application of Triacontanol	407.3	402.3
T_{14} : Foliar application of K- humate	409.8	404.0
T_{15} : Foliar application of Triacontanol and K- humate	410.6	402.2
T_{16} : Inorganic K @ 90 kg K_2O ha^{-1} as basal application	451.0	430.5
CD (0.05)	14.12	14.23
SE(d) ±	6.88	6.94
CV (%)	1.62	1.67

Table 4.1. Salient soil characteristics of the experimental site

S No.	Soil characters	Value
I)	**Physical properties**	
a)	Mechanical composition	
	i) Sand (%)	49.4
	ii) Silt (%)	12.3
	iii) Clay (%)	38.3
	iv) Textural class	Sandy clay
II)	**Physico-chemical properties**	
a)	Soil reaction (pH) (1:2.5 soil : water suspension)	7.64
b)	Electrical conductivity (1:2.5 soil : water extract) (dS m^{-1})	0.19
c)	CEC (c mol (p+) kg^{-1})	35.8
III)	**Chemical properties**	
1)	**Organic carbon (%)**	0.67
2)	**Available nutrients (kg ha^{-1})**	
a)	Nitrogen (kg ha^{-1})	156.7
b)	Phosphorus (kg ha^{-1})	57.0
c)	Potassium (kg ha^{-1})	449.0

Chapter – V

SUMMARY AND CONCLUSIONS

The importance of potassium needs no emphasis in crop production. Inspite of its definite role in influencing the yield and quality of crops, very few studies have been conducted on K nutrition of vegetable crops. Besides potassium, K-humate and triacontanol also have been reported to play an important role in improving the yield and quality of vegetables. Research on the integration of the above three components was scanty. Hence a study was carried out to evaluate whether any interaction exists between inorganic potassium, potassium humate and triacontanol in influencing the yield, quality and economics of tomato.

The field experiment was carried out during *kharif*, 2011 on a sandy clay soil at College Farm, College of Agriculture, Rajendranagar, Hyderabad to study the **"Yield and quality of tomato (*Solanum lycopersicum* L.*)* with individual and integrated application of inorganic potassium, potassium humate and triacontanol''.** Initial soil was slightly alkaline in reaction, normal in salt content and medium in organic carbon per cent. The soil under study was low in available nitrogen, high in available phosphorus and potassium. The experiment was laid out in randomized block design with 16 treatments, replicated thrice with tomato as the test crop. The treatments included the individual application of inorganic K at 30, 45, and 60 kg K_2O ha^{-1} level and their integration with either potassium humate or triacontanol or both (12 no') besides the individual application of potassium humate, triacontanol and inorganic K at 90 kg K_2O ha^{-1} (3 no') and a treatment comprising the combination of triacontanol and potassium humate (1 no').

The observations on dry matter production, yield, quality parameters, nutrient content, nutrient uptake, and available nutrient status in soil were studied under field conditions. Economics of tomato cultivation with respect to treatments were also computed.

The treatment T_4 receiving 60 kg K_2O ha^{-1} with foliar application of triacontanol and K- humate put forth significantly higher dry matter yield (30.79 q ha^{-1}) at flowering, fresh fruit and haulm yields of 135 and 34.19 q ha^{-1} respectively at harvest of tomato, which was 29, 18 and 35 per cent more when compared to control (T_1) receiving recommended dose of K. However this was on par with the dry matter produced with the integrated application of inorganic K at 45 kg K_2O ha^{-1} and foliar application of potassium humate and triacontanol (T_8) at flowering and harvesting stages of tomato.

The quality parameters of tomato were also influenced significantly by the combined application of inorganic K and organics indicating that the T_4 treatment receiving 60 kg K_2O ha^{-1} with foliar application of triacontanol and K- humate recorded significantly higher ascorbic acid, lycopene contents and total sugars. However, the titratable acidity increased with decrease in the dose of potassium and was found to be significantly higher in T_9 receiving 30 kg K_2O ha^{-1}. The treatment T_4 receiving 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol showed significantly lower titratable acidity of the fruit.

The chlorophyll content of tomato was significantly higher at T_4 (52.41SPAD units) which was 11.5 per cent more over control (T_1) receiving recommended dose of K and was significantly superior over the individual application of even a higher dose of 90 kg K_2O ha^{-1} . The treatment was also found to influence significantly the leaf carotenoid content the value being 0.743 mg g^{-1}.

The percent N, P and K contents and their uptakes by the plant increased from flowering to harvesting stage of tomato. The highest total N, P and K contents were found to be highest in T_4 receiving 60 kg K_2O/ha along with foliar application of potassium humate and triacontanol at both flowering and harvest stage.

Availability of nutrients decreased from flowering to harvesting stage due to removal by crop. There was greater reduction in the available N content of the soil in the treatment receiving 60 kg K_2O ha^{-1} along with foliar application of triacontanol and potassium humate at both the stages with the corresponding values of 150.4 and 144.4 kg ha^{-1} respectively. Significantly higher available N in soil was left in the treatment receiving inorganic K alone @ 30 kg K_2O ha^{-1} with the values of 168.4 and 165.2 kg ha^{-1} respectively at both the stages. The per cent reduction from the initial status of 156.7 kg ha^{-1} was 12 and 14 respectively in the treatment T_4. With regard to available P, there was depletion in the available P of the soil to an extent of 7.5 per cent from the initial value of 57.2 kg ha^{-1} by the end of the crop growth season. The mean available phosphorus in the soil depleted from 57.4 kg ha^{-1}at flowering to 52.9 kg ha^{-1} at the harvest of the crop. Inorganic K at the lowest dose (30 kg K_2O ha^{-1}) left significantly higher amount of available P in the soil which got significantly decreased to 56.09 kg ha^{-1}due to the application of 90 kg K_2O ha^{-1}.

There was a spectacular decrease in the mean available potassium content of the soil from the flowering to harvesting stage in all the treatments.

At flowering, the available K was significantly lower due to the individual application of triacontanol; the value being 407.3 kg ha^{-1}, which however was on par with the individual application of inorganic K at 30 kg K_2O ha^{-1} or potassium humate with corresponding available K of 409.8 and 419.6 kg ha^{-1}. With increase in the level of K application to 60 kg K_2O ha^{-1}, the available K remained in the soil significantly increased to 441.7 kg ha^{-1}. With further increase in the dose of K there was no significant increase in the available K status. Similar results were obtained at the harvest of the crop. There was depletion in the available K of the soil from the initial value of 449 kg ha^{-1} in all the treatments. The depletion was higher i.e., 10 per cent with the application of triacontanol alone and got reduced to 2 per cent in the treatment receiving the combination of recommended K with triacontanol and potassium humate.

Conclusions

- Integrated use of 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol is the best for achieving higher yields.

- Foliar application of potassium humate and triacontanol resulted in accumulation of increased assimilates in the sink and increase in chlorophyll content of the plant. Thus, nutrient management in tomato with a combination of 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol is effective in terms of higher yield and quality.

- The quality of tomato fruits was improved by integrated use of inorganic potassium and foliar application of potassium humate and triacontanol.

- The changes in available nutrients *viz.*, N, P and K revealed that there was a decrease in these nutrients from vegetative to harvest stage due to nutrient removal by crop.

- Gross returns, net returns and B: C ratio was higher in treatment receiving 60 kg K_2O ha^{-1} along with foliar application of potassium humate and triacontanol.

LITERATURE CITED

Akhtari, M. E., Khan,M. Z., Rashid, M. T., Ahsan, Z and Ahmad, S. 2010. Effect of Potash Application on Yield and Quality of Tomato (*Lycopersicon Esculentum* Mill.). *Pakistan Journal of Botany*. 42(3): 1695-1702.

Ali, L.K.M and Elbordiny, M.M. 2009. Response of wheat plants to Potassium humate application. *Journal of Applied Sciences Research.*30: 1202-1209.

Anjaiah, T., Padmaja, G and Sreenivasa Raju, A. 2005. Influence of levels of K and FYM on yield and K uptake by carrot (*Daucus carota L.*) grown on an Alfisol. *Journal of Research*, ANGRAU. 33 (3): 82-86.

Annual Report, National Horticultural Board, Horticultural Statistics at a glance. 2010.

Basavaraja, P.K.1986. Effect of fertilizer potassium, sulphur and zinc on the root yield of Carrot. *South Indian Horticulture*. 34: 428-429.

Baskar, K and Sankaran, K. 2005. Effect of humic acid (potassium humate) on growth and yield of turmeric (*Curcuma longa* L.) in an *alfisol*. *Journal of spices and Aromatic crops*. 14(1): 34-38.

Bergmann, W. 1992. Causes, development and diagnosis of symptoms resulting from mineral, Macronutrients: Potassium. In: *Nutritional Disorders of Plants: Development, Visual and Analytical Diagnosis*. (Bergmann, W and Fischer, G., Eds.). Gustav Fischer Verlag, Jena, Germany. 117-132.

Besford, R. T and Maw, G. A. 1975. Effect of potassium nutrition on tomato plant growth and fruit development. *Plant and soil*. 42: 395-412.

Bidari, B.I., Martur, M.D and Math, K.K. 2004. Influence of soil properties on yield and quality of chillies (*Capsicum annuum* L.) and partitioning of nutrients in fruit components. Paper presented in "National Symposium on Input Use Efficiency in Agriculture – Issues and Strategies", 25-27th Nov. 2004, Kerala Agricultural University, Thrissur, Kerala.

Bokhtiar, S.M., Sirajul Karim, A.J.M., Hossain, K.M., Hossain, T and Egashira, K. 2001. Response of radish to varying levels of irrigation water and fertilizer potassium on clay terrace soil of Bangladesh. *Communications in Soil Science Plant Analysis*. 32 (17&18): 2979-2991.

Booth, A., Moorby, J., Devis, C R., Jones, H and Wareing, P. F. 1962. Effect of Indole-3 acetic acid on movement of nutrients within plants. *Nature*. 194: 204-205.

Chen, Y. and T. Avaid. 1990. Effect of humic substances on plant growth. pp. 161-186. In: American Society of Agronomy and Soil Science Society of America (eds.), Humic substances in soil and crop science; selected Readings. American Society of Agronomy, Madison, WI.

Chen, Y and Schnitzer, M. 1978. Water surface tension of aqueous solutions of soil humic substances. *Soil Science*. 125: 7–15.

Davey, M. W and Van Montagu, M. 2000. Plant L-ascorbic acid: chemistry, function, metabolism, bioavailability and effects of processing. *Journal of the Science of Food and Agriculture*. 825-860.

David, P. P., Nelson, P.V and Sanders D.C.1994. A humic acid improves growth of tomato seedling in solution culture. *Journal of Plant Nutrition*. 17: 173–184.

Dhall, R. K and Sanjeev Ahuja. 2004. Effect of triacontanol (vipul) on yield and yield attributing characters of tomato (*Lycopersicon esculentum* Mill.). *Environment and Ecology*. 22(1): 64-66.

Diana, Moigradean., Lazureanu, A., Gogoasa, I., Mariana-Atena Poiana., Monica Harmanescu and Gergen, I. 2007. Influence of NPK Fertilization on Nutritional Quality of Tomatoes. Buletinul USAMV-CN, nr. 64/2007 (1-2).

Dileep, S. N and Sasikala, S. 2009. Studies on the effect of different organic and inorganic fertilizers on growth, fruit characteristics, yield and quality of chilli. *International Journal of Agricultural Sciences.* 5(1): 229-232.

DongFang, Wang., BingChun, Ding., HongMei, Du., AiZhu, An and YongGui, Lu. 2002. Study on effects of applying potassium humate to soybean leaf for increased yield. *Soybean Science.* 21(4): 305-307.

Dorais, M., Ppadopoulas, A. P and Gosselin, A. 2001. Greenhouse tomato fruit quality. *Horticultural Reviews*. 26: 239-319.

Duraisami, V. P and Mani, A. K. 2002. Effect of major nutrients on yield and fruit quality of tomato under rainfed condition in Entisol. *South Indian Horticulture*. 50(1-3): 56-64.

Eriksen, A. B., Sellden, G., Skogen, D and Nilsen, S. 1981. Comparative analyses of the effect of triacontanol on photosynthesis, photorespirstion and growth of tomato (C_3-plant) and maize (C_4-plant). *Planta*. 152: 44-49.

Fagbenro, J. A and Agboda, A. A.1993. Effect of different levels of humic acid on the growth and nutrient uptake of teak seedlings. *Journal of Plant Nutrition*. 16: 1465–1483.

Fanasca, S., Colla, G., Maiani, G., Venneria, E., Rouphael, Y., Azzini, E and Saccardo, F. 2006. Changes in antioxidant content of tomato fruits in response to cultivar and nutrient solution composition. *Journal of Agriculture and Food Chemistry*. 54: 4319-4325.

Friedrich, J. E. 2001. *Current Protocols in Food Analytical Chemistry.* John Wiley & Sons, Inc. G2.1.1-G2.1.7

Ghosh, B.N and Mukhopadhyay, A.K. 1996. Potassium Status and Critical limit in Jagannathpur and Barakonda Soil Series of West Bengal. *Journal of the Indian Society of Soil Science*. 44: 281-285.

Gupta, C. R and Sengar, S. S. 2000. Response of tomato (*Lycopersicon esculentum* Mill.) to nitrogen and potassium fertilization in acidic soil of Bastar. *Vegetable Science*. 27(1): 94-95.

Gunasekaran, N. 1982. Studies on the effect of triacontanol on tomato. *Proceedings of National Seminar on the production technology of tomato and chillies*. Tamil Nadu Agricultural University. 72-74.

Hartz, T. K., Miyao, G., Mullen, R. J., Cahn, M. D., Valencia, J and Brittan, K. L. 1999. Potassium requirements for maximum yield and fruit quality of processing tomato. *Journal of American Society of Horticultural Science*. 1224: 199-204.

Hiatt, A. T and Evans, H. J. 1960. Influence of certain cations on activity of acetic thiokinase from spinach leaves. *Plant Physiology*. 35: 673-677.

Ivanov, A. G and Angelov, M. N. 1997. Photosynthesis response to triacontanol correlates with increased dynamics of mesophyll protoplast and chloroplast membranes. *Plant Growth Regulation*. 21: 145-152.

Jackson, M.L. 1973. *Soil chemical analysis*. Prentice hall of India Private Limited, New Delhi. India.

Jadhav, B. B., Patil, B. A and Patil, V. H. 1987. Effects of triacontanol on lablab-bean and Indian mustard. *Indian Journal of Agricultural Sciences*. 57(1): 56-58.

Kalaichelvi, K and Chinnusamy, C. 2005.Productivity of cotton – blackgram cropping system as influenced by STCR based fertilizer nutrients and potassium humate. *Annals of Agricultural Research. New Series*. 26(1): 75-79.

Kalaichelvi, K and Chinnusamy, C. 2008. Influence of STCR recommended NPK fertilizers levels and potassium humate in cotton. *Journal of Research, Birsa Agricultural University*. 20(6): 11-18.

Khan, M. M. A., Bharadwaj, G., Naeem, M., Mohammad, F., Singh, M., Nasir, S., Idrees, M and Moinuddin. 2009. Response of Tomato (*Solanum lycopersicum* L.) to application of Potassium and Triacontanol. *Acta Horticulturae*. 199-204.

Khan, M. M. A., Mujibur-Rahman, M., Naeem, M., Mohammad, F., Siddiqui, M. H and Nasir Khan, M. 2006. Triacontanol – Induced Changes In Growth, Yield And Quality Of Tomato (*Lycopersicon Esculentum* Mill.). *Electronic Journal of Environmental, Agricultural and Food Chemistry*. 5(4): 1492-1499.

Lal, N., Sarawgi, S. K., Tripathi, R. S and Bhambri, M. C. 1995. Effect of nitrogen, potassium and sulphur on seed yield, nutrient uptake, quality and economics of summer sesame (*Sesamum indicum*). *Indian Journal of Agronomy*. 40(2): 333-335.

Lebedeva, G. V., Belyaeva, N. E., Demin, O. V., Riznichenko, G. Y and Rubin, A. B. 2002. A kinetic model of primary photosynthetic processes. Description of the fast phase of chlorophyll fluorescence induction at different light intensities. *Biofizika*. 47: 1044-1058.

Liu, K., Zhang, T. Q., Tan, C. S. and Astatkie, T. 2011. Responses of Fruit Yield and Quality of Processing Tomato to Drip-Irrigation and Fertilizers Phosphorus and Potassium. *Agronomy Journal*. 103(5): 1339-1345.

Ma Clachlan, S and Zalik, S. 1963. Plastid structure, chlorophyll concentration and free amino acid composition of chlorophyll mutant of barley. *Canadian Journal of Botany*. 41: 1053-1062.

Maity, K and Arora, P.N. 1980. Effect of varieties levels and sources of potassium on the yield, dry matter and grade of potato tuber. *Indian Journal of Agronomy*. 25: 390-397.

Majumdar, S. P., Meena, R. L and Baghel, G. D. S. 2000. Effect of Levels of Compaction and Potassium on Yield and Quality of Tomato and Chilli Crops Grown on Highly Permeable Soils. *Journal of the Indian Society of Soil Science.* 48(2): 215-220.

Marschner, H. 2002. Mineral nutrition of higher plants. Academic Press, London.

Martin, H. W and Liebhardt, W. C. 1994. Tomato response to long-term potassium and lime application on a sandy ultisol high in non-exchangeable potassium. *Journal of Plant Nutrition*. 17(10): 1751-1768.

Mohanbabu, N and Muthuswami, S. 1984. Influence of potassium on the quality of turmeric. *South Indian Horticulture*. 32: 343-346.

Muralidharan, R., Saravanan, A and Muthuvel, P. 2002. Effect of plant growth regulators on yield and quality of chilli (*Capsicum annuum* Linn.). *South Indian Horticulture*. 50(1/3): 254-257.

Muralidharan, R., Saravanan, A and Muthuvel, P. 2000. Influence of biostimulants on yield and quality of tomato (*Lycopersicon esculentum* Mill.). *Madras agricultural Journal*. 87(10-12): 625-628.

Muthuvel, P., Muralidharan, R and Saravanan, A. 2001. Effect of bio-regulators on soil available nutrients, yield and uptake of nutrients by Tomato (*Lycopersicon esculentum*, Mill.). *Madras Agricultural Journal*. 115-117.

Namdeo, K. N., Kumar, M. M., Dwivedi, R. K and Tiwari, R. K. 2001. Effect of plant growth regulators on growth, yield and nutrient uptake by chickpea (*Cicer arietinum* L.). *Crop Research (Hisar)*. 21(3): 301-307.

Naeem, M., Khan, M. M. A and Moinuddin Siddiqui, M. H. 2009. Triacontanol stimulates nitrogen-fixation, enzyme activities, photosynthesis, crop productivity and quality of hyacinth bean (*Lablab purpureus* L.). *Scientia Horticulturae*. 121(4): 389-396.

Olsen, S.R., Cole, C.V., Watanabe, F.S and Dean, L.A. 1954. Estimation of available phosphorus in soil by extracting with sodium bicarbonate. USDA Circ. 939, Washington. In *Soil Chemical Analysis* (ed. M. L. Jackson) Prentice Hall of Indian Private Limited, New Delhi.

Padmaja, G and Sreenivasa Raju, A. 1999. Status of potassium found in Alfisols of Southern Telangana Zone of Andhra Pradesh. *Journal of Potassium Research.* 15 (1-4): 25-32.

Piper, C.S. 1966. *Soil and Plant Analysis*. Hans Publishers, Bombay.

Porter, J. W and Anderson, D. G. 1967. Biosynthesis of carotenoids. *Annual Review of Plant Physiology*. 18: 197-228.

Prabhavathi, K., Bidari, B. I., Shashidhara, G. B and Math, K. K. 2009. Effect of levels and sources of potassium on yield and nutrient uptake by chilli (*Capsicum annuum* L.) in a vertisol. *Asian Journal of Soil Science*. 4(1): 49-51.

Prabhavathi, K., Bidari, B. I., Shashidhara, G. B and Mathad, J. C. 2008. Influence of sources and levels of potassium on quality attributes and nutrient composition of red chillies. *Karnataka Journal of Agricultural Science*. 21(3): 379-381.

Rady, M. M. 2011. Effects On Growth, Yield And Fruit Quality In Tomato Using A Mixture Of Potassium Humate And Farm Yard Manure As An Alternative To Mineral-N Fertilizer. *Journal of Horticultural Science and Biotechnology*. 86(3): 249-254.

Ranganna, S. 1986. *Hand book of Analysis and Quality Control for Fruit and Vegetable Products*, second edition. Tata Mc Graw-Hill publishing company limited, New Delhi.

Rao, M. H and Subramanian, T.R . 1991. Effect of Potassium Application on the Yield and Content of Potassium, Calcium and Magnesium in Cabbage, Okra, Tomato and Beet-Root. *Journal of Potassium Research*. 7(3): 190-197.

Rao, M. H. 1994. Growth, Yield and Quality of Tomato, Carrot and Cauliflower as Influenced by Levels and Sources of Potassium. *Journal of Potassium Research*. 10 (4): 402-406.

Reddy, M. P., Dhanasekaran, K., Saravanan, K. P and Venkatakrishnan, D. 2004. Effect of foliar application of enriched humic substances on the performance of tomato (*Lycopersicon esculentum* Mill.). *Mysore Journal of Agricultural Science*. 38(4): 468-473.

Rizk, A. H and Mashhour, A. M. A. 2008. Effect of foliar application with potassium humate on growth and uptake of some nutrients by wheat and broad bean plants. *Egyptian Journal of Soil Science*. 48(4): 457-465.

Ries, S. K and Houtz, R. 1983. Triacontanol as a plant growth regulator. *Horticultural Science*. 18(5): 654-662.

Rissanen., Voutilainen, S., Nyyssonen, K., Salonen, R., Kaplan, G. A and Salonen, J. T. 2003. Serum lycopene concentrations and carotid atherosclerosis: The Kuopio Ischaemic Heart Disease Risk Factor Study. *American Journal of Clinical Nutrition*. 77; 133-138.

Rodriguez-Amaya, D. B. 2001. Carotenoids. *Archivos Latinoamericanos de Nutrition*. 49: 748-848.

Sherawat, S and Singh, O. P. 2009. Economic analysis of frenchbean+potato inter cropping and uptake of nutrient by different crops as influenced by nitrogen and potassium application. *International Journal of Agricultural Sciences*. 5(1): 82-84.

Sangeetha, M., Singaram, P., Gandhi, M. S and Paramasivam, P. 2008. Quality characteristics of onion as influenced by lignite humic acid and inorganic fertilizers. *Research on Crops*. 9(1): 106-109.

Sathiyabama, K and Selvakumari, G. 2001. Effect of humic acid on growth, yield and nutrition of amaranthus. *South Indian Horticulture.* 49(Special): 155-156.

Schnitzer, M. 1978. Humic substances- Chemistry and reactions. In: Schnitzer, M and Khan, S. V (Eds.) Soil Organic Matter (pp. 1-64). Elsevier Scientific Publishing Company, Amsterdam.

Shahryari, R and Mollasadeghi, V. 2011. Increasing wheat yield by use of humic fertilizer. *Advances in Environmental Biology*. 5(3): 516-518.

Sharma, S. K. 1995. Response of triacontanol application on certain morphological characters , fruit and seed yield and quality of tomato seed. *Annals of Agricultural Research*. 16(1): 128-130.

Singh, D and Singh, V. 1995. Effect of potassium zinc and sulphur on growth characters, yield attributes and yield of soybean (*Glycine max*). *Indian Journal of Agronomy*. 40(2): 223-227.

Snedecor, G.W and Cochron, W.G. 1967. *Statistical methods*. Oxford and IBH Publishing Company, New Delhi.331-334.

Subbiah, B.V and Asija, G. L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science*. 25: 259-260.

Sumeria, H.K. 2003. Response of mustard to phosphorus, triacontanol granule and growth promoters. *Agriculture Science Digest*. 23(2): 134-136.

Taber Henry., Penelope Perkins-Veazie., Shanshan Li., Wendy White., Steven Rodermel and Yang Xu. 2008. Enhancement of Tomato Fruit Lycopene by Potassium Is Cultivar Dependent. *HortScience*. 43(1): 159-165.

Trudel, M. J and Ozbun, J. L. 1971. Influnce of potassium on carotenoid content of tomato fruit. *Journal of American Society of Horticultural Science*. 96: 763-765.

Vaiyapuri, V and Sriramachandrasekharan, M. V. 2003. Foliar spray of growth hormones and nutrients on growth, yield and nutrient uptake of lowland rice. *Journal of Ecobiology*. 15(3): 197-201.

Walkley, A and Black, C.A. 1934. Estimation of organic carbon by chromic acid titration method. Soil Science. 37: 29-38.

Wang, S. Y. 2006. Effect of Pre-harvest Conditions on Antioxidant Capacity in Fruits. *Acta Horticulturae.* 299-306.

Winson, G. W. 1966. *Proceedings of 8th Congress of the International Potash Institute*. Brussel. pp. 303-312.

Yagmur, B., Okur, B and Ongun A. R. 2004. Effects on Enhanced Potassium Doses on Yield, Quality and Nutrient Uptake of Tomato. *IPI regional workshop on Potassium and Fertigation development in West Asia and North Africa; Rabat, Morocco.*

Zientara, M. 1983. Effect of sodium humate on membrane potential in internodal cells of Nitellopsis obtuse. *Acta Societatis Botanicorum Poloniae*. 52: 271–277.