

**STUDIES ON SULPHUR NUTRITION OF ONION AND GARLIC
IN SULPHUR DEFICIENT SOIL OF GHATAPRABHA LEFT
BANK COMMAND AREA**

SRINIDHI N.

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005**

OCTOBER, 2000

**STUDIES ON SULPHUR NUTRITION OF ONION AND GARLIC
IN SULPHUR DEFICIENT SOIL OF GHATAPRABHA LEFT
BANK COMMAND AREA**

**Thesis submitted to the
University of Agricultural Sciences, Dharwad
In partial fulfilment of the requirements for the
Degree of**

Master of Science (Agriculture)

In

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

By

SRINIDHI N.

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005**

OCTOBER, 2000

U. A. S.
University Library
BHARWAD.


Acc. No. Th-6532

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON SULPHUR NUTRITION OF ONION AND GARLIC IN SULPHUR DEFICIENT SOIL OF GHATAPRABHA LEFT BANK COMMAND AREA**” submitted by **Mr.SRINIDHI N.**, for degree of **MASTER OF SCIENCE (Agriculture) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**, to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university under my guidance and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

DHARWAD
OCTOBER, 2000


(P.L. PATIL)

Major Advisor

Approved by:

Chairman :



(P.L. PATIL)

Members :

1. 

(P.A. SARANGAMATH)

2. 

(S.S. MELI) 20/11

3. 

(B. BASAVARAJ)

4. 

(K. RAMACHANDRA NAIK)

ACKNOWLEDGEMENT

At the very outset, I find no suitable words to express my deepest sense of gratitude and profound indebtedness to Dr. P. L. Patil, Associate Professor, Department of Soil Science and Agricultural Chemistry, Kittur Rani Channamma College of Horticulture, Arabhavi, UAS, Dharwad, the esteemed Chairman of my advisory committee for his valuable guidance, sustained encouragement, constructive suggestions, critical comments, affectionate dealings and a lot more without which the research work could not have been accomplished. I feel privileged to have been associated with him during my master degree programme.

I extend my heartfelt thanks and gratitude to the members of my advisory committee, Dr. P. A. Parangamath, Professor and Head, Department of Soil Science and Agricultural Chemistry, Dr. S. S. Meti, Professor and Head, Department of Agronomy, Dr. B. Basavaraj, Assistant Professor, Department of Soil Science and Agricultural Chemistry and Dr. K. Ramachandra Naik, Assistant Professor of Horticulture, College of Agriculture, UAS, Dharwad, for their kind co-operation, constant encouragement and critical processing of the manuscript.

I gratefully acknowledge the co-operation and help extended by all members of the staff of Department of Soil Science and Agricultural Chemistry, UAS, Dharwad.

I avail this opportunity to express my immense thanks to Mr. K. M. Chidanandappa, Assistant Professor of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, Bangalore for his encouragement and advise in all my endeavours.

I feel the inadequacy of words to express my feelings for the intangible encouragement and affection of my father Sri Nanjappa, mother Smt. Narayanamma, doddamma Sri Chikkamuniyappa, brother Murthy, sisters Nagaveni, Shoba, Pushpa and Padma.

I owe my special thanks to Mr. Renukprasanna, for his timely help rendered during my venture of this study. I would like to extend my sincere thanks to Mr. Harikrishna, Miss. Reshmi Parhar, Mr. Ashok, Mr. P. A. Angadi, Dr. P. T. Goreji, Mr. Sunil, Smt. Subhadra, Miss. Indira, Mr. Jagadeesh, Mr. Nagaraj, Smt. Mangala, Mr. Anand, Mr. Madhasudan and other friends who have helped me directly or indirectly during the tenure of my study.

I am grateful to Mr. Ammana Kallolihar for neat drawing of the maps, Mr. Krishnanand V. Naik, Durga Computers for neat and timely typing of this manuscript and Mr. Ithyunjaya Binders for neat binding of this thesis.

Above all I gratefully acknowledge the Indian Council of Agricultural Research, New Delhi for awarding me the Junior Research Fellowship to pursue my studies.

DHARWAD

OCTOBER, 2000



SRIVIDYA N.

CONTENTS

CHAPTER	TITLE	PAGE NO.
I	INTRODUCTION	1-6
II	REVIEW OF LITERATURE	7-30
III	MATERIAL AND METHODS	31-47
IV	EXPERIMENTAL RESULTS	48-104
V	DISCUSSION	105-123
VI	SUMMARY	124-127
VII	REFERENCES	128-142
	APPENDICES	143-146

LIST OF TABLES

Table No.	Title	Page No.
1	Details of the experiment	36
2	Mean monthly meteorological data (1998-99) recorded at the meteorological observatory of the Agricultural Research Station, Arabhavi	37
3	Physical and chemical properties of the experimental site	40
4	Soil colour and particle size analysis of soils of KRCCH, Arabhavi	49
5	Some chemical properties of soils of KRCCH, Arabhavi.	53
6	Available nutrient status of soils of KRCCH, Arabhavi.	56
7	Correlation coefficients between some soil properties and available sulphur of soils of KRCCH, Arabhavi.	58
8	Drymatter accumulation in leaf and bulb of onion as influenced by sulphur levels	59
9	Bulb characteristics and yield of onion as influenced by sulphur levels	61
10	Biomass production of onion as influenced by sulphur levels	64
11	Nitrogen content in leaf and bulb of onion as influenced by sulphur levels	66
12	Phosphorus content in leaf and bulb of onion as influenced by sulphur levels	68
13	Potassium content in leaf and bulb of onion as influenced by sulphur levels	70
14	Sulphur content in leaf and bulb of onion as influenced by sulphur levels	71
15	Nutrient uptake by leaf and bulb of onion as influenced by sulphur levels	74
16	Total uptake of nutrients by onion as influenced by sulphur levels	76
17	Residual nutrient status after the harvest onion crop as influenced by sulphur levels	78
18	Economics of onion cultivation as influenced by sulphur levels	80
19	Drymatter accumulation in leaf and bulb of garlic as influenced by sulphur levels	83

20	Bulb characteristics and yield of garlic as influenced by sulphur levels	85
21	Biomass production of garlic as influenced by sulphur levels	88
22	Nitrogen content in leaf and bulb of garlic as influenced by sulphur levels	90
23	Phosphorus content in leaf and bulb of garlic as influenced by sulphur levels	92
24	Potassium content in leaf and bulb of garlic as influenced by sulphur levels	93
25	Sulphur content in leaf and bulb of garlic as influenced by sulphur levels	95
26	Nutrient uptake by leaf and bulb of garlic as influenced by sulphur levels	98
27	Total uptake of nutrients by garlic as influenced by sulphur levels	100
28	Residual nutrient status after the harvest of garlic crop as influenced by sulphur levels	102
29	Economics of garlic cultivation as influenced by sulphur levels	104

LIST OF FIGURES

Figure No.	Title	Between pages
1	A map of Kittur Rani Channamma College of Horticulture, Arabhavi.	31-32
2	Plan of layout of the experiment	38-39
3	Bulb yield and total drymatter content of onion as influenced by sulphur levels	111-112
4	Total uptake of nutrients by onion as influenced by sulphur levels.	115-116
5	Bulb yield and total drymatter content of garlic as influenced by sulphur levels	118-119
6	Total uptake of nutrients by garlic as influenced by sulphur levels.	120-121

INTRODUCTION

I. INTRODUCTION

Sulphur is one of the essential plant nutrients and its contribution in increasing crop yields is well documented. Sulphur is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. It is a constituent of three essential amino acids, namely cysteine, cystine and methionine and thus vital for protein synthesis. Sulphur is a component of glucosinolates which imparts flavour in crucifers. Sulphoxides are responsible for both the lachrymatory factor in onion and the odour in garlic. It improves crop management through its favourable effect on drought tolerance, winter hardiness, control of pest and diseases and decomposition of crop residues. Sulphur is associated with the superior nutritional and marketing quality of crops.

Plant nutrient sulphur is required by plants in amounts similar to phosphorus. Deficiency of sulphur is becoming widespread due to continuous use of sulphur-free fertilizers, high yielding crop varieties, intensive multiple cropping system and high sulphur requiring crops. Sulphur deficiencies have been reported from over 70 countries world wide (Tandon, 1991).

Sulphur deficiencies are wide spread in India. At present, about 51 million hectares of cultivated land in 15 states and 120 districts are believed to have various degrees of sulphur deficiency (Tandon, 1995). In

India, sulphur deficient soils are wide spread in coarse textured soils of Indo-Gangetic alluvial plains, red and lateritic soils of Andhra Pradesh, Karnataka, Kerala and West Bengal, black soils of Madhya Pradesh, Gujarat, and Maharashtra, tea growing soils of Himachal Pradesh and red yellow soils of Bundelkhand regions.

In Karnataka sulphur deficiencies have been reported from Bangalore, Dakshina Kannada, Uttar Kannada, Malnad areas (Ananthanarayana *et al.*, 1986), Malaprabha command area (Balagoudar and Satyanarayana, 1990a) and coffee growing soils of Chikmagalur and Coorg. Merely 30 per cent of growing soils are reported to be deficient in sulphur (Rao, 1988).

In recent years, sulphur has been receiving increasing attention throughout the world and India is no exception. However, the interesting point to be noted here is that while reports of sulphur deficiency and crop response to its use are increasing the addition of sulphur through traditional fertilizers is decreasing.

The sulphur content of soils varies according to parent materials, climate, organic matter, particle size distribution, degree of weathering and management practices. Available sulphur fraction consisting largely of easily extractable $\text{SO}_4\text{-S}$ is the immediate supplier of SO_4 ions to the roots. The term available sulphur includes water soluble sulphur, adsorbed sulphur and easily hydrolysable sulphur. Available sulphur is

available for crop uptake, immobilisation and for leaching as well. Factors like soil properties, method of extraction and the crops grown are some of the important ones to determine the critical level of sulphur. Soil having less than 10 ppm (20 kg per ha) available sulphur is generally considered to be deficient in sulphur.

The sulphur compounds undergo many transformations as a result of activities of plants, animals and micro-organisms and to a lesser extent due to non-biological action. Sulphur levels in soils are subjected to considerable fluctuations because of mineralisation of organic matter, leaching of soluble sulphate, uptake by plants and sulphate addition through irrigation water and fertilizers. The fate of applied sulphur through fertilizer ingredient or amendment needs to be looked thoroughly to understand the possible availability of sulphur to crops from the native or applied

Onion(*Allium cepa* L.) and garlic (*Allium sativum* L.) are two most important bulb crops commercially grown in India. The genus *Allium* belongs to the family Alliaceae. They are grown in India as vegetables or spice crops.

Onion is an indispensable item of every kitchen and dining table as it is an additive to flavour and has good medicinal properties. Onions are used in salads and cooked in various ways in curries, fried, boiled and baked vegetables, in soups and pickles. It is a rich source of vitamins,

i.e., ascorbic acid 11 mg, thiamine 0.08 mg and riboflavin 0.01 mg per 100 g of edible portion. It also contains proteins 1.2 g, calcium 180 mg and phosphorous 50 mg per 100 g of edible portion (Choudhury, 1996).

India ranks first in area under onion (4.21 lakh ha) and second in production (5.97 million tonnes) after China and third after Netherlands and Spain in exports (Chadha, 1999). India's share in the total world production of onion is 13 per cent (Anon., 1997b). The major onion growing states are Maharashtra, Gujarat, Karnataka and Andhra Pradesh. Exports of onion is canalised through National Agricultural and Cooperative Marketing Federation of India Ltd. In the year 1995-96 India exported about 4.4 lakh metric tonnes of onion fetching about Rs.30.9 crores besides its high internal consumption (Anon., 1997b).

Garlic is the second most widely cultivated and used *Allium* after onion. Garlic has higher nutritive value with high ascorbic acid content of 13 mg per 100 g of clove (Pradan *et al.*, 1977). The dietary garlic is very effective as hypocholesterolaemic agent and has high additional effects in reducing the activity of antioxidative enzymes (Sklan *et al.*, 1992). It has insecticidal, fungicidal and bactericidal properties apart from its indispensable value in upkeep of human health.

In India, garlic occupies an area of 96,000 hectares with production of 412,000 tonnes (Anon., 1997c). The major garlic growing states in India are Madhya Pradesh, Gujarat, Maharashtra, Orissa,

Rajasthan and Uttar Pradesh (Anon., 1997a). The productivity of garlic is markedly low in India as compared to other countries.

For sustainable high crop yields, balanced fertilization with all the nutrients which are deficient in soils must be adopted. Like NPK, sulphur is an essential plant nutrient. In intensive cropping, sulphur removal by crops ranges from 30 to 70 kg S/ha/annum. The type of crop grown and the yield level are the important factors to determine the sulphur removal. Injudicious use of organic manure and sulphur containing fertilizers leads to low S content of soils.

Onion requires judicious manuring on account of its heavy feeding nature. It has been shown in many fertilizer trials that all the three major nutrients *viz.*, nitrogen, phosphorus and potassium are essential for high yield and quality of onion. In addition to N,P and K nutrients, sulphur has been found to be very beneficial for onion (Balasubramanian *et al.*, 1978). Pungency of onion is one of the most important character from fresh consumption, dehydration and storage point of view. Sulphur has a special significance for onion as sulphur occurs in plant tissues chiefly in the form of Allyl-propyl-disulphide due to which onion has characteristic pungency. Sulphur is associated with formation of flavour compounds in *Alliums*. Sulphur responses have been observed for bulb crops (Rohal and Kalra, 1986) and its application to sulphur deficient soils has been found to increase the crop yield and improve the quality of crop produce.

Onion removes more sulphur than phosphorus from the soil (Crocker,1923). The nutrient supplying capacity of any soil is the most powerful factor responsible for crop yield. Availability of sulphur is influenced by various soil factors and hence sulphur status of soils varies widely with the soil type (Balanagoudar and Satyanarayana, 1990b).

Since the information is not available on the properties and sulphur status of soils of Kittur Rani Chennamma College of Horticulture (KRCCH), Arabhavi, Ghataprabha Left Bank Command Area (GLBC), it is felt necessary for the quantitative assessment of the contribution of added sulphur from different levels of sulphur to the available pool and their effect on onion and garlic in sulphur deficient soil. Keeping this in view, the present investigation was conducted with the following objectives:

1. To study the available sulphur status of soils of KRCCH, Arabhavi and its relationship with soil properties.
2. To study the effect of different levels of sulphur on growth, yield and quality of onion and garlic.
3. To study the uptake of nutrients by onion and garlic as influenced by sulphur levels.
4. To know the residual available sulphur status of soils as influenced by sulphur levels.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Sulphur is considered as the fourth major nutrient, because of its involvement in vital functions in the plant metabolism, deficiency of which would lead to adverse growth and yield reduction in many crops. Till recently its value as a plant nutrient through fertilizer has been totally underestimated. Availability of sulphur would be expected to be influenced by various soil factors. Thus, a brief review of the available literature pertaining to the present investigation on the sulphur status of soils of KRCCH, Arabhavi (GLBC Area) and their relationship with soil properties and effect of different levels of sulphur application on the growth, yield, quality, nutrient uptake and residual available sulphur status is presented in this chapter under the following headings:

2.1 Status of available sulphur in soils.

2.2 Relationship between available sulphur and some soil properties.

2.3 Effect of sulphur application on the growth parameters of onion.

2.4 Effect of sulphur application on the yield parameters of onion.

2.5 Effect of sulphur application on the quality parameters of onion.

- 2.6 Tissue composition of onion as influenced by sulphur application.**
- 2.7 Nutrient uptake of onion as influenced by sulphur levels.**
- 2.8 Growth, yield and quality of garlic as influenced by sulphur application.**
- 2.9 Tissue composition and nutrient uptake of garlic as influenced by sulphur application.**
- 2.10 Effect of sulphur application on residual nutrient status of onion and garlic grown soils.**

2.1 STATUS OF AVAILABLE SULPHUR IN SOILS

Plants absorb sulphur as sulphate ions from the soil to meet their requirements. The sulphate sulphur pool includes water soluble, adsorbed and easily releasable sulphur from the soil organic matter. Sulphate sulphur is the most important form of sulphur from the view point of plant nutrition, which may prove to be a suitable index in evaluating the amount of sulphur available to the plants (White, 1958).

The results obtained by Williams and Steinbergs(1959) showed that sulphate S, water soluble S and heat soluble S were all correlated with the uptake of sulphur by plants. They further observed that any one of them might prove to be an index of available S.

Naik and Das (1964) analysed available sulphur in sixty-four surface soil samples belonging to main soil types in India (black, alluvial, red and laterite) and reported that a large number of laterite, red and alluvial soils were found to contain less than 10 ppm of available sulphur. Black and coastal alluvial soils were reported to be richer in available sulphur, whereas saline and alkali soils showed extremely high values. Similarly in soils under Chotanagapur area of Bihar, available sulphur was higher in alkaline group of soils than other soils as reported by Ahmed and Jha (1969).

While studying on distribution and forms of sulphur in soil profiles from different agroclimatic regions of Punjab, Haryana and Himachal Pradesh, Virmani and Kanwar (1971) reported that sulphate sulphur constituted very small fraction of the total sulphur.

Based on the available sulphur content Singh *et al.* (1981) concluded that about 31 per cent of soils of Bundelkhand region seemed to be deficient in available sulphur. Considering the total sulphur reserve and sulphate sulphur contents, soils of this region might not be able to fulfil sulphur requirements of oil seed crops.

Reddy *et al.* (1985) reported that sulphate sulphur in red, black and alluvial soils of Andhra Pradesh ranged from traces to 173.3 ppm and the distribution of this form of sulphur did not follow any definite pattern in the soils of different textural classes.

Available sulphur was low in light textured soils of Haryana and constituted 2.7 to 17.2 per cent of the total sulphur (Singh *et al.*, 1985). Arora *et al.* (1988) reported that sulphate sulphur content in bench mark soils of Punjab varied from 5.1 to 46.0 ppm with an average of 10.2 ppm in surface soils of Ludhiana, Punjab.

The sulphate sulphur content of soils of South Bihar plains ranged from 0.3 to 7077 ppm with an average of 143.6 ppm and higher amount of sulphate sulphur was noticed in medium to heavy textured tal land soils compared to light to medium textured Catenary soils (Ahmad and Umar, 1989).

Balanagoudar and Satyanarayana (1990a) observed sulphate sulphur content ranging from 2.8 to 250.0 ppm with an average of 29.3 ppm and accounted for only small fraction of the total S in some Vertisols and Alfisols of North Karnataka.

Padmaja *et al.* (1993) reported that the inorganic sulphate sulphur content extracted with 0.15 per cent CaCl_2 ranged from 8 to 19 mg kg^{-1} among the soils of Nalgonda and Mahaboobnagar districts.

The soluble sulphate sulphur (0.15% CaCl_2 extractable) in some Ranchi soils of Chotanagpur formed a smaller fraction (1.25%) of total S. On the basis of 10ppm $\text{SO}_4\text{-S}$ as critical limit, nearly 60 per cent of the

soils were reported to be deficient in sulphur, which was due to leaching losses of sulphate sulphur (Singh *et al.*, 1993).

Kumar *et al.* (1994) reported that the 0.15 per cent CaCl_2 extractable S ranged from 0.85 to 34.6, 2.6 to 85.5 and 2.6 to 45.1 mg kg^{-1} in soils of Debatoli, Dumka and Laxmipur series of south Chotanagpur of Bihar, respectively.

Singh *et al.* (1995c) reported that sulphate sulphur content of some alluvial soils of Uttar Pradesh ranged from 7.0 to 22.0 ppm and constituted 9.2 per cent of total soil-S. Taking 10 ppm as the critical limit, 59 per cent of the soils were concluded to be deficient in sulfur.

Adiga and Ananthanarayana (1996) reported that the available sulphur content of surface soils of some base unsaturated rice fallow profiles of Karnataka constituted about 3.9 per cent of total sulphur.

Raju and Sreemannarayana (1997) reported that the inorganic sulphate sulphur content in certain alfisols and vertisols ranged from 2.5 to 20.0 per cent of the total sulphur. Unlike total sulphur contents, the inorganic sulphate contents of alfisols were higher as compared to vertisols.

Aggarwal and Nayyar (1998) analysed the coarse textured surface soils of Ludhiana, Punjab and reported that the available sulphur

content varied between 14.0 to 35.2 ppm with a mean value of 22.2 ppm soil.

Gowrishankar and Shukla (1998) reported that the available S content of five hundred surface soils of Delhi belong to Inceptisols varied from 3.5 to 135.4 mg kg⁻¹ with a mean value of 50.34 mg kg⁻¹. Considering the critical level of 13 mg kg⁻¹ suggested by Palaskar and Ghosh (1985) for the soils of Delhi, the soils deficient in available S are found to be only 6.6 per cent.

While studying the sulphur status of soils in different agro-ecological regions of India, Ganeshamurthy and Saha (1999) reported that the available S content of Vertisols of Dharwad region ranged from 3.1 to 55.0 ppm with a mean value of 11.9 ppm.

2.2 RELATIONSHIP BETWEEN AVAILABLE SULPHUR AND SOME SOIL PROPERTIES

The content of sulphate sulphur in five soil series of Punjab was shown to be a function of the silt plus clay fraction (Aulakh and Dev, 1976).

Sulphate sulphur was found to have no consistent relation with organic carbon, pH and clay content in some soils of West Bengal (Dolui and Saha, 1983). Arora *et al.* (1988) showed that sulphate sulphur

positively correlated with EC, organic matter and silt plus clay but negatively with pH in some benchmark soils of Punjab.

Pandey *et al.* (1989) reported that sulphate sulphur correlated significantly and positively with organic carbon, EC and silt plus clay but negatively with pH in some alluvial soils of UP.

Ganeshamurthy *et al.* (1989) reported that sulphate sulphur extracted by CaCl_2 correlated positively with pH and organic carbon contents in some soils of Andaman and Nicobar islands.

Mashi *et al.* (1989) observed that sulphate sulphur correlated positively with organic carbon and calcium carbonate content in some soils of Rajasthan.

Vageesh *et al.* (1989) observed significant positive correlation between pH and available sulphur. Positive correlation was also observed between organic carbon and available sulphur content of soils of Shimoga.

Balasubramaniam *et al.* (1989) reported significant positive correlation between sulphate sulphur and electrical conductivity in some benchmark soils of Chidambaram of Tamilnadu.

Misra *et al.* (1990) reported that sulphate sulphur correlated positively and significantly with clay content in some soils of Orissa.

Sulphate sulphur correlated significantly and positively with pH, EC, CaCO_3 and clay content in some Vertisols and Alfisols of North Karnataka. Significant negative correlation was observed between sulphate sulphur and organic carbon content (Balanagoudar and Satyanarayana, 1990b).

Sulphate sulphur was found to have no significant correlations with pH, EC, CaCO_3 , clay and organic carbon contents in some Vertisols of Andhra Pradesh (Padmaja *et al.*, 1993).

The $\text{SO}_4\text{-S}$ extracted by CaCl_2 correlated significantly with pH and organic carbon content in some soils of Andaman and Nicobar islands (Ganeshamurthy *et al.*, 1995).

Bhogal *et al.* (1996) reported that 0.15 per cent CaCl_2 extractable sulphur correlated significantly and positively with EC in calciorrhents of North Bihar.

Calcium chloride extractable-S showed significant and positive correlation with organic carbon and total N in some soils of Uttar Pradesh (Sharma and Gangwar, 1997).

Raju and Sreeramannarayana (1997) reported that inorganic SO_4 extracted by 0.15 per cent CaCl_2 had a positive correlation with pH and clay in some Alfisols and Vertisols of Andhra Pradesh.

Sulphate sulphur showed positive and significant correlation with organic carbon content in some soils of Northern Madhya Pradesh (Trivedi *et al.*, 1998).

Available sulphur content showed significant positive correlation with EC and organic carbon content and significant negative correlation with soil pH in some surface soils of Punjab (Aggarwal and Nayyar, 1998).

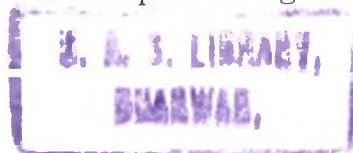
The available S content correlated positively and significantly with EC and organic carbon content in some Inceptisols of Delhi (Gowrishankar and Shukla, 1998).

2.3 EFFECT OF SULPHUR APPLICATION ON THE GROWTH PARAMETERS OF ONION

Kumar and Sahay (1954) applied four doses of elemental sulphur @ 50, 100, 200, 400 lb per acre to onion crop and found that the doses of 100 and 200 lb sulphur per acre were most effective in increasing the plant growth of the onion.

Misra and Prasad (1966) conducted a field experiment to see the effect of sulphur nutrition on onion, revealed that sulphur at 100 lb per acre had a marked effect on all the growth attributes.

Balasubramonian *et al.* (1978) reported that onion straw yield responded to sulphur application up to 20 kg ha⁻¹.



In a field experiment, Rohal and Kalra (1986) reported that sulphur application @ 60kg S/ha increased the dry weight of tops (leaves) significantly at early stages of growth in both the years of study.

Jana and Kabir (1990) observed maximum plant height (48.62 cm), maximum number of leaves (9.14), maximum weight of leaf sheath (0.49 kg) and maximum root length (13.78 cm) when the plants received sulphur @ 30 kg/ha followed by 40 kg/ha. Minimum plant height (38.91 cm), lowest number of leaves (6.80), minimum leaf sheath weight (0.38 kg) and minimum root length (10.21 cm) was observed in control plots that received no sulphur. It was revealed that sulphur at 30 kg/ha had a marked effect on all the growth attributes.

Salimath (1990) tried different levels of S viz., 0, 25 and 50 kg per ha and observed significant increase in dry matter accumulation in leaf from 8.06 g /pot (control) to 9.2 g/pot (50 kg S/ha). Significant increase in dry matter accumulation in bulb was noticed from 12.77 g/pot (control) to 14.75 g/plot (50 kg S/ha). Total dry matter accumulation increased significantly from 20.84 g/plot (control) to 26.10 g/plot (at 50 kg S/ha). Sources of sulphur did not show significant effect on total dry matter production.

Sachdev *et al.* (1991) reported that sulphur applications significantly increased the total dry matter yield of onion (bulbs + leaves).

In a pot culture experiment, Kumar and Singh (1992) tried two treatments *viz.*, complete nutrient solution containing sulphur and other one not containing sulphur and observed that dry matter accumulation in leaves, roots and bulbs were significantly higher in sulphur supplied plants compared to sulphur deficient plants.

Thippeswamy (1993) tried four levels of sulphur *viz.*, 0, 20, 40 and 80 kg S/ha and observed highest plant height (53.69 cm) at 20 kg S/ha and lowest plant height (49.75 cm) at 80 kg S/ha. Similarly maximum number of leaves was noticed at 20 kg S/ha and minimum number of leaves was noticed at 80 kg S/ha.

Sumantrakar and Tiwari (1993) reported that the best morphological characters (number, length, fresh weight and dry weight of leaves and roots) and maximum dry weight of bulbs was obtained with CaSO_4 @ 24 kg/ha.

In a pot culture experiment, Kumar and Singh (1995) reported that plant height and length of leaves were significantly higher from 66 days after transplanting to 110 days after transplanting in sulphur supplied plants compared to sulphur deficient plants. Number of leaves and length of roots were significantly higher from 44 days after transplanting till 110 days after transplanting in sulphur supplied plants compared to sulphur deficient plants. Number of roots was significantly higher in sulphur supplied plants compared to sulphur deficient plants at all the stages of crop growth.

2.4 EFFECT OF SULPHUR APPLICATION ON THE YIELD PARAMETERS OF ONION

Kumar and Sahay (1954) applied four doses of elemental sulphur @ 50, 100, 200, 400 lb per acre to onion crop and found that the doses of 100 and 200 lb S per acre were most effective in increasing the yield of onion.

Jordan and Ensminger (1958) reported that application of higher levels Sulphur significantly decreased the yield of bulb onions.

Pandey (1965) conducted a field trial on sulphur fertilization along with nitrogen, phosphorus and potassium on onion crop. He found that sulphur at 100 lb/acre increased the yield by 8.5 per cent.

Misra and Prasad (1966) conducted a field trial to study the effect of sulphur nutrition on onion. It was revealed that sulphur at 100 lb per acre had a marked effect on all the growth attributes and finally increased the yield of the crop.

Narang and Dastane (1971) conducted a field experiment in high available S (73.5 ppm) soil, tried 3 levels of sulphur *viz.*, 0, 55 and 110 kg/ha and observed no significant yield differences due to S treatments. The lowest yield was observed at 110 kg S/ha level.

Balasubramonian *et al.* (1978) reported that black soil recorded significantly higher bulb yield of onion compared to red soil. There was

no response to sulphur beyond the level of 20 kg/ha with respect to bulb yield.

Paterson(1979) reported that the application of 10-20 lb per acre of sulphur as calcium sulphate increased the yield of onion bulbs and size of bulbs.

Sulphur application @ 60 kg S/ha increased the bulb diameter significantly during both the years of study at early stages of growth (Rohal and Kalra, 1986) .

Salimath (1990) conducted a pot culture experiment and tried 3 levels of sulphur *viz.*, 0,25 and 50 kg S/ha . He reported an increase in bulb diameter with increase in S levels. Bulb diameter was maximum (4.74 cm) at 50 kg S/ha and minimum (3.84 cm) at control. Bulb yield also increased significantly with increased sulphur levels. Bulb yield was maximum (151.31 g/pot) at 50 kg S/ha and minimum (118.45 g /pot) in control.

In a field experiment, Jana and Kabir (1990) reported that maximum weight of 10 bulbs (1.02 kg), diameter of bulb (6.13 cm) and yield (30.69 t/ha) were noted in the plots received sulphur @ 30 kg/ha followed by 40 kg/ha. Minimum bulb weight, bulb diameter and yield were recorded in the plots received no sulphur.

Sachdev *et al.* (1991) reported that highest yield of onion bulbs was obtained when 120 kg N/ha was applied along with 40 kg S/ha.

Thippeswamy (1993) tried 4 levels of sulphur *viz.*, 0, 20, 40 and 80 kg S/ha and observed that with increase in sulphur levels no definite trend was noticed with respect to equitorial length of bulb. However highest equitorial length of bulb (20.29 cm) was noticed at 40 kg S/ha and lowest (19.60 cm) at 80 kg S/ha. Polar length of bulbs increased with increase in sulphur levels up to 40 kg S/ha. Maximum polar length (9.21cm) was noticed in 40 kg S/ha and minimum polar length (8.59 cm) was noticed in control. Similarly neck thickness of bulbs increased with increase in sulphur levels up to 40 kg S/ha. Highest neck thickness (1.99cm) was noticed in 40 kg S/ha and lowest neck thickness (1.73 cm) was noticed in 80 kg S/ha. Similarly bulb yield increased with increase in sulphur levels up to 40 kg S/ha. Highest bulb yield was noticed in 40 kg S/ha (43.75 t/ha) and lowest bulb yield was noticed in control (34.64 t/ha).

Sumantrakar and Tiwari (1993) observed significant increase in yield over control with different forms of sulphur applied. CaSO_4 @ 24 kg ha⁻¹ gave the best results (328.57 q/ha) superseding control by 28.18 per cent.

Kumar and Singh (1995) reported that the weight of 10 bulbs of onion averaged 466.28 g for sulphur deficient plants and 498.26 g for those supplied with sulphur.

Singh and Pandey (1995) reported that applied sulphur had no significant effect on onion yield.

Anez *et al.* (1996) reported that sulphur application increased the bulb yield from an average of 28.36 t ha⁻¹ with no S application to 33.84 t ha⁻¹ at 100 kg S/ha. Sulphur application significantly increased the bulb size.

Hamilton *et al.* (1997) reported that bulb weight was significantly reduced by the low S nutrition.

2.5 EFFECT OF SULPHUR LEVELS ON THE QUALITY PARAMETERS OF ONION

Kumar and Sahay (1954) applied four doses of elemental sulphur @ 50, 100, 200, 400 lb/acre to onion crop and found that the doses of 100 and 200 lb sulphur/acre were most effective in increasing the pungency of onion.

In a sand culture experiment, Freeman and Mossadeghi (1970) observed an increase in the flavour strength of onion in proportion to sulphate concentration in the medium. Significant correlation was found between sulphate concentration of medium and flavour strength.

Balasubramonian *et al.* (1978) reported that the amino acid content of onion bulb (cystine and methionine) increased with increased doses of sulphur. Red soil was found to be significantly superior to black

soil with respect to amino acid content of the bulb. The pyruvic acid content of the bulbs also increased with increase in doses of sulphur. Application of 30 kg S/ha was found to be superior and it was on par with 20 kg S/ha. There was no significant difference between red and black soils with reference to the pyruvic acid content of the bulb.

Paterson (1979) reported that the application of 10-20 lb per acre of sulphur as calcium sulphate increased the pungency of onion bulbs.

In a field experiment, Rohal and Kalra (1986) tried two levels of sulphur *viz.*, 0 and 60 kg/ha and found that sulphur application of 60 kg/ha increased the pungency of the onion bulbs during both the years of study as compared to no sulphur application.

Rajas *et al.* (1992) reported that volatile sulphur content significantly increased by increasing the doses of sulphur.

In a pot culture experiment, Kumar and Singh (1992) observed that the total soluble solids in onion bulbs at maturity averaged 15.0 and 13.4 per cent for sulphur supplied and sulphur deficient plants. The difference between them was significant.

Thippeswamy (1993) tried 4 levels of sulphur *viz.*, 0, 20, 40 and 80 kg S/ha and reported an increase in TSS (%) with increase in sulphur levels. TSS (%) was highest (12.36%) in 80 kg S/ha and lowest (11.81%) in control. Pungency also increased with increased sulphur levels up to

80 kg S/ha. Maximum pungency (0.3 $\mu\text{g/g}$) was noticed in 80 kg S/ha and minimum pungency (0.2 $\mu\text{g/g}$) was noticed in control.

In a sand culture experiment, Kumar and Singh (1994) found that catalase activity was significantly higher in leaves of sulphur supplied plants compared to sulphur deficient plants at all the stages of crop growth.

Randle *et al.* (1995) reported that enzymatically developed pyruvic acid and soluble solid content of onion cultivars increased with increased S fertility levels.

In a greenhouse study Hamilton *et al.* (1997) found that onion bulbs grown under low S treatment (2 ppm S) contained 1.9 $\mu\text{mol g}^{-1}$ fresh weight pyruvic acid, while those under the high S treatment (123 ppm S) contained 5.5 $\mu\text{mol g}^{-1}$ fresh weight. Total sugar content was higher in the low S treatment (45.2 mg g^{-1}) than the high S treatment (43.1 mg g^{-1}).

2.6 TISSUE COMPOSITION OF ONION AS INFLUENCED BY SULPHUR

In a sand culture experiment, Freeman and Mossadeghi (1970) tried five levels of sulphate *viz.*, 0, 0.05, 0.1, 1 and 3 me/litre and found that total sulphur content of edible portion (bulb) increased with increased SO_4 levels from 0.015 per cent in control to 0.477 per cent in 3

me/litre. Nitrogen content of the bulb was highest (4.68%) in control and lowest (3.68%) in 1 me/litre and SO₄ level. Potassium content of bulb was highest (7.57%) in 3 me/litre of SO₄ and lowest (3.13%) in 0.05 me/litre of SO₄. Phosphorus content of bulb was highest (0.80%) both at control and 3 me/litre of SO₄ and lowest at 1 me/litre of SO₄ level.

Paterson (1979) reported that the application of S @ 10-20 lb/acre as calcium sulphate increased the S concentration of the dried leaves.

In a field experiment, Sachdev *et al.* (1991) tried three levels of sulphur *viz.*, 0, 20 and 40 kg/ha and found that N, P and S content of both onion bulbs and leaves did not show any consistent trend.

Randle and Bussard (1993) evaluated sixteen short day onion cultivars with high (4.0 me/litre) and low S (0.1 me/litre) fertility for sulphur content of the bulb. Bulb S varied from 0.68 per cent to 0.47 per cent with high S fertility and from 0.14 per cent to 0.37 per cent with low S fertility.

In a sand culture experiment, Kumar and Singh (1994) observed that total nitrogen content of onion bulbs were significantly higher in sulphur deficient plants than in sulphur supplied plants. There was an increase in the total phosphorus and total potassium content of the bulbs under sulphur deficiency condition. There was a definite reduction

of sulphur content in the bulb of sulphur deficient onion plants at all the stages and crop growth.

Bulb S content increased linearly in response to increasing S fertility (Randle *et al.*, 1995). Increasing levels of S significantly increased the S content of the bulb as reported by Singh *et al.* (1996).

2.7 NUTRIENT UPTAKE OF ONION AS INFLUENCED BY SULPHUR LEVELS

In a pot culture experiment, Salimath (1990) tried three levels of sulphur *viz.*, 0, 25 and 50 kg S/ha and reported significant increase in the uptake of N, P and S at harvest by onion leaf with increase in S levels. Fifty kg S/ha recorded highest N uptake (178.87 mg/pot), P uptake (17.20 mg/pot), K uptake (105.29 mg/pot) and S uptake (66.25 mg/pot) by leaf which was significantly superior over control. Nutrient uptake by bulb increased significantly with increased levels of sulphur application. Fifty kg S/ha recorded highest uptake of N (453.72 mg/pot), P (41.4 mg/pot), K (224.5 mg/pot) and S (131.50 mg/pot) by bulb, which differed significantly over control.

Sachdev *et al.* (1991) reported that highest nitrogen and phosphorus uptake was observed when 60 kg N/ha and 40 kg S/ha applied. But sulphur uptake was highest when 120 kg N/ha was applied along with 40 kg S/ha.

Thippeswamy (1993) tried four levels of sulphur *viz.*, 0, 20, 40 and 80 kg/ha along with N, P and K. He found that the nitrogen uptake by leaf and bulb increased up to 40 kg S/ha. Lowest N uptake was observed in control. Similar results were noticed for P, K and S uptake.

Singh and Pandey (1995) reported that S uptake increased with increased levels of S. S uptake was significantly affected by soil type. The highest S uptake (118.9 mg/pot) was observed on a sandy loam soil amended with 40 ppm S.

Singh *et al.* (1996) reported that nitrogen and sulphur uptake by onion bulbs increased significantly with increased levels of sulphur.

2.8 GROWTH, YIELD AND QUALITY OF GARLIC AS INFLUENCED BY SULPHUR APPLICATION

Chung (1987) reported that application of CuSO_4 or K_2SO_4 reduced the number of cracked bulbs of plants grown in base soil.

Khalaf and Taha (1988) reported that sulphur was beneficial for plant growth, total yield and quality of garlic.

Cho *et al.* (1994) reported that the application of poultry manure plus CaSO_4 to garlic plants increased the pyruvic acid content in the bulbs. Less storage decay was exhibited by bulbs from plants grown with poultry manure plus CaSO_4 (38.4%) compared to plants grown only with poultry manure (43.8%).

Singh *et al.* (1995a) reported that the bulb yield of garlic increased significantly with successive increase in S application up to 25 mg kg⁻¹ and further increase in S rate (50 mg kg⁻¹) decreased the garlic yield.

Singh *et al.* (1995b) reported that application of sulphur through different sources increased the bulb yield of garlic significantly over control during both the years of study.

2.9 TISSUE COMPOSITION AND NUTRIENT UPTAKE OF GARLIC AS INFLUENCED BY SULPHUR APPLICATION

Khalaf and Taha (1988) reported that sulphur application was beneficial with reference to N, P and K content in the plant tissues.

Cho *et al.* (1994) reported that application of poultry manure plus CaSO₄ to plants increased the concentration of sulphate in the bulbs.

Singh *et al.* (1995a) reported that the S content in garlic bulbs and S uptake increased with increasing doses of sulphur up to 50 mg S kg⁻¹ soil. The highest mean S content and S uptake was noticed in 50 mg S kg⁻¹ soil.

Singh *et al.* (1995b) reported that the nitrogen content of garlic bulbs increased with increased doses of S and it was highest with the application of 100 kg S ha⁻¹. The uptake of N by garlic bulb due to S application was significantly higher than in control. The P content and P uptake by garlic bulbs increased with increasing doses of S upto 100 kg

S ha⁻¹. There was a significant increase in S content of bulbs with its application. Increasing doses of sulphur increased the uptake of S by garlic bulbs and 100 kg S ha⁻¹ showed significantly higher S uptake over lower levels and control.

2.10 EFFECT OF SULPHUR APPLICATION ON RESIDUAL NUTRIENT STATUS OF ONION AND GARLIC GROWN SOILS

Jaggi and Minhas (1989) conducted a field experiment on Raya and observed no change in soil pH, available N and K contents of a soil as a result of sulphur application. Application of elemental sulphur resulted in 23.4 kg/ha residual P which was significantly more than the one obtained due to gypsum application (19.7 kg P/ha). At the end of three years of experimentation a substantial decrease in the CaCl₂ extractable sulphur from 23.6 kg/ha to 7.2 kg/ha was noticed in control plots. Similar was the case with other treatments.

Singh and Tiwari (1989) conducted a pot experiment to study the response of sesamum to applied S and mustard to residual S left after harvesting *kharif* sesamum crop. They observed that available S status of soils was higher in S applied pots than in control. But after harvesting mustard which was grown on residual S, the S levels were lower than levels of S just after sesamum crop but remained significantly more than the sulphur levels of original as well as control pot soils.

Yadav and Desai (1989) conducted a field experiment on mustard and tried 4 levels of sulphur *viz.*, 9, 30, 60 and 90 kg/ha and reported that with increase in sulphur levels the residual sulphur content increased significantly. Higher residual sulphur was noticed in 90 kg S/ha (77.72 ppm S) and lowest residual sulphur was noticed in control (24.31 ppm S). With increase in sulphur levels, increase in residual phosphorus was noticed up to 60 kg S/ha. Lowest residual P was noticed in 30 kg S/ha.

Sreemannarayana and Raju (1994) conducted field experiments on Vertisols and Alfisols with sunflower based cropping systems and showed that there was maximum depletion in the sulphate S fraction in control plots to the extent of 17 per cent and 64 per cent in Vertisols and Alfisols, respectively. They also observed that in the Alfisols, while there was no improvement in the sulphate S content in plots applied with 20 kg S/ha, application of S beyond 20 kg/ha significantly improved the sulphate status at the sunflower harvest. In the Vertisol, however there was no improvement in the sulphate status with application of S at all levels. Due to the application of S as gypsum, significantly greater sulphate S was left behind in soil compared to that of ammonium sulphate and single superphosphate applications.

Randhawa and Arora (1997) conducted an incubation experiment on sandy and loam soils and reported that available sulphur increased significantly with increased sulphur application rates and increased incubation period.

Poongothai *et al.* (1999) reported that sulphur fertilization increased the available sulphur content of post harvest soil significantly.

MATERIAL AND METHODS

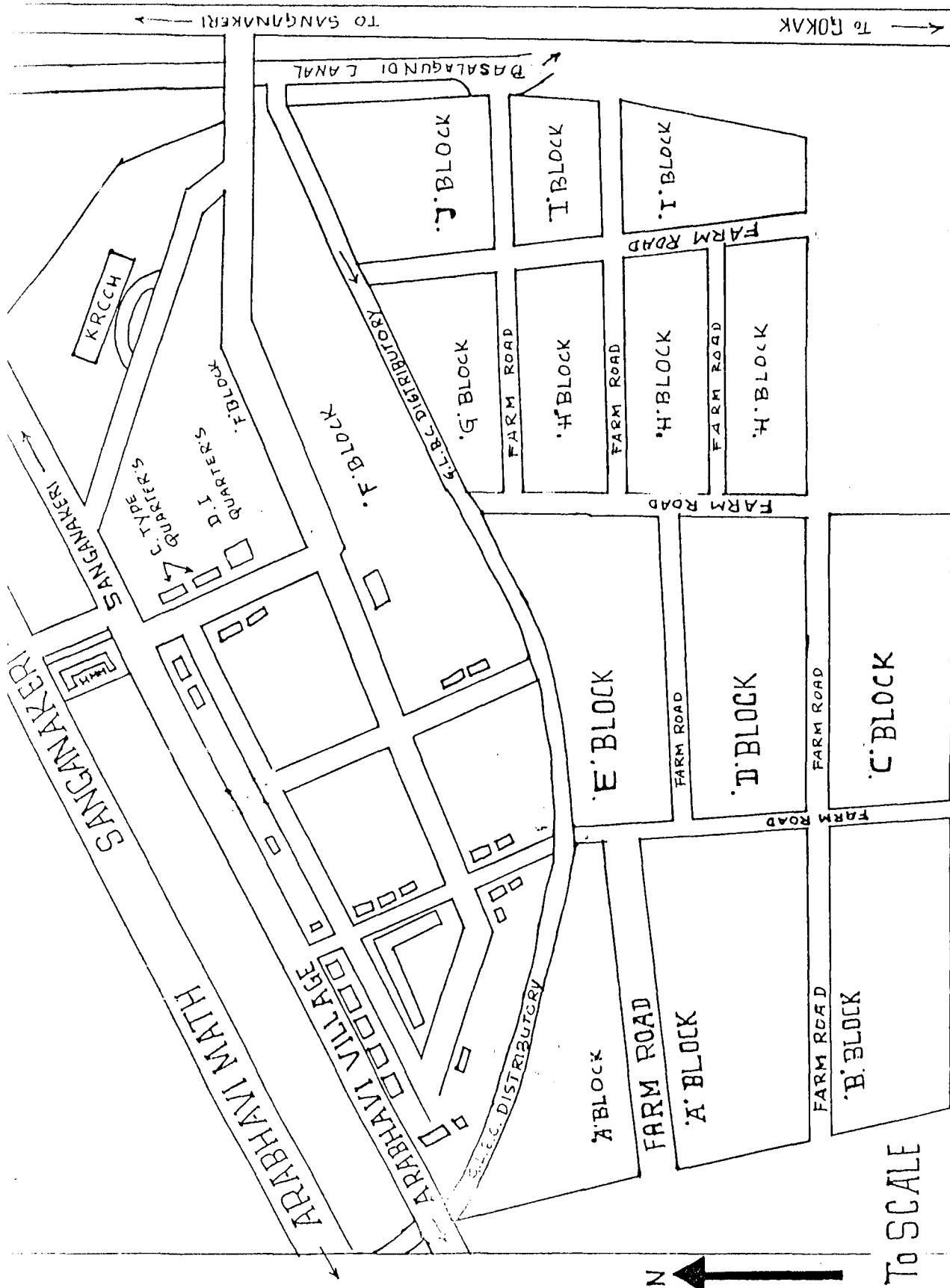
III. MATERIAL AND METHODS

The objectives of the present investigation were studying the status of available sulphur of KRCCH soils, Arabhavi and their relation with some soil properties and the response of onion and garlic to different levels of sulphur. The materials used and methods employed in the investigations were as follows:

3.1 COLLECTION OF SOIL SAMPLES

The surface soil samples were collected from different sites representing five blocks of Kittur Rani Chennamma College of Horticulture (KRCCH), Arabhavi. The map of KRCCH, Arabhavi is depicted in fig.1. The description of soil samples collected from 5 blocks of KRCCH are given below:

SL.NO	NAME OF THE BLOCK	No. OF SAMPLES
1.	Olericulture block (G block)	8
2.	Pomology block (A,B,C,D and E blocks)	17
3.	Medicinal and aromatic plants block (J and I blocks)	7
4.	Spices and plantation crops block (H and I blocks)	12
5.	Floriculture block (F block)	5



NOT TO SCALE

Fig.1. A MAP OF KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE
ARABHAVI

The soil samples were air-dried in shade, mixed and powdered with wooden mallet, passed through 2 mm sieve and preserved for further analytical work.

3.2 METHODS OF SOIL ANALYSIS

3.2.1 Soil colour

Soil colour was determined using Munsell colour chart

3.2.2 Particle size analysis (%)

The Particle size fractions of the soils were estimated by Hydrometer method as outlined by Piper (1966).

3.2.3 Soil reaction

Soil pH was determined in 1:2.5 soil : water ratio using pH meter (Jackson, 1967).

3.2.4 Electrical conductivity (dS m^{-1})

Electrical Conductivity was determined in the supernatant solution of 1:2.5 soil : water suspension using conductivity bridge. (Jackson, 1967).

3.2.5 Organic carbon (g kg^{-1})

Organic carbon was determined by Walkley and Black wet oxidation method by oxidizing the organic matter in finely ground soil

with chromic acid making use of heat of dilution of sulphuric acid for the reaction as described by Jackson (1967).

3.2.6 Cation exchange capacity [cmol (p+) kg⁻¹]

The cation exchange capacity of soils was estimated by sodium saturation method (Black, 1965).

3.2.7 Exchangeable cations [cmol (p+) kg⁻¹]

The Exchangeable cations Na⁺, K⁺, Ca⁺⁺ and Mg⁺⁺ were determined in the ammonium acetate extract as described by Black (1965). Exchangeable Na⁺ and K⁺ were estimated by using flame photometer. Exchangeable Ca⁺⁺ and Mg⁺⁺ were estimated by Versenate titration method.

3.2.8 Available nitrogen

Available nitrogen was determined by modified alkaline permanganate method (Sahrawat and Burford, 1982).

3.2.9 Available phosphorous

Available phosphorous was extracted using 0.5 N NaHCO₃ (Olsen *et al.*, 1954) and P in solution was determined by Chlorostannous reduced molybdophosphoric acid in HCl system.

3.2.10 Available potassium

Available potassium was extracted by neutral normal ammonium acetate (Jackson, 1967) and solution K was estimated by flame photometry.

3.2.11 Available sulphur

Available Sulphur was extracted by treating the soil with 0.15 per cent CaCl_2 solution as described by Williams and Steinbergs (1959). sulphur in the extract was estimated turbidimetrically (Chesnin and Yien, 1951).

3.2.12 CaCO_3 equivalent

CaCO_3 content in the soil was determined by rapid titration method using standard HCl (Hesse, 1994).

2.3 STATISTICAL ANALYSIS

The relationship of available Sulphur with soil properties was worked out by simple correlation.

3.4 DETAILS OF THE FIELD EXPERIMENT

A field experiment was laid out at Plot No.4 of Olericulture block of Kittur Rani Channamma College Horticulture, Arabhavi, Gokak

taluk, Belgaum district (UAS, Dharwad) during the *kharif* season of 1998, to study the effect of different levels of sulphur application on growth, yield, quality, nutrient content and uptake by onion and garlic and residual sulphur status of soils. The details of the experiment are presented in the table 1.

3.4.1 Experimental site

Arabhavi is situated in Northern dry tract of Karnataka state at 16° 15' North latitude and 94° 45' East longitude, at an altitude of 612.03m above mean sea level. Arabhavi which lies on Zone-3 of region-2 of agroclimatic zones of Karnataka is considered to have the benefit of both south-west and north-east monsoons. The mean rainfall of this area is about 530mm which is distributed over a period of six to seven months (May to November) with peaks during June and October. Meteorological data for the experimental period were recorded at the meteorological observatory of the Agricultural Research Station, Arabhavi which is two km away from the experimental site is presented in table 2.

3.4.2 Treatments

In both onion and garlic, treatments consist of five levels of sulphur (gypsum as S source) and were replicated four times. Recommended dose of NPK as shown in table-1 was applied to soil for all the treatments at the time of planting. N and P was supplied through

Table 1. Details of the experiment

SL.NO.	PARTICULARS		
		ONION	GARLIC
1	Variety	Bellary Red	Rajalle gadde
2	Design	RBD	RBD
3	Treatments	5	5
4	Replications	4	4
5	Plot Size	2.0m X 1.5m =3m ²	2.0m X 1.5m =3m ²
6	Spacing	15cm X 7.5cm	15cm X 7.5cm
7	Fertilizers (N, P ₂ O ₅ and K ₂ O kg ha ⁻¹)	125 : 50 : 120	125 : 62.5 : 62.5
8	Date of planting	28-08-1998	31-08-1998
9	Date of harvest	25-11-1998	28-12-1998

Table 2. Mean monthly meteorological data (1998-99) recorded at the meteorological observatory of the Agricultural Research Station, Arabhavi

Month	Temperature (°C)		Relative Humidity (%)	Rainfall (mm)
	Maximum	Minimum		
1998				
July	28.71	24.07	79.45	100.6
August	29.00	23.91	82.85	101.6
September	28.52	22.90	80.93	176.6
October	28.48	22.26	80.42	119.0
November	29.56	17.56	67.82	27.8
December	27.04	12.98	63.47	-----
1999				
January	27.00	12.10	63.00	-----
February	29.33	16.00	61.30	-----

DAP and urea and K through muriate of potash. Following are the common treatments for onion and garlic.

T₁ - Control

T₂ - 20 kg S ha⁻¹

T₃ - 40 kg S ha⁻¹

T₄ - 60 kg S ha⁻¹

T₅ - 80 kg S ha⁻¹

3.4.3 Design and layout

The experiment was laid out in Randomised Block Design. The plan of lay out is given in fig.2.

3.4.4 Crop variety

Onion : Bellary Red is an important variety in Karnataka, yield medium sized bulbs.

Garlic : Rajalle gadde is a popular variety which is being cultivated extensively in Karnataka.

3.5 SOIL SAMPLING

The experiment was conducted on shallow black soil (clay loam texture). Before the initiation of the experiment, composite soil sample from the experimental site was collected from 0 to 15 cm depth. Soil sample was air-dried, powdered and allowed to pass through 2 mm sieve

ONION :

R ₁	R ₂	R ₃	R ₄
T ₄	T ₁	T ₅	T ₂
T ₅	T ₂	T ₃	T ₄
T ₃	T ₄	T ₁	T ₅
T ₁	T ₅	T ₂	T ₃
T ₂	T ₃	T ₄	T ₁

GARLIC :

R ₁	R ₂	R ₃	R ₄
T ₁	T ₂	T ₃	T ₅
T ₃	T ₅	T ₁	T ₄
T ₄	T ₁	T ₂	T ₃
T ₅	T ₃	T ₄	T ₂
T ₂	T ₄	T ₅	T ₁

Figure 2. Plan of Layout of the experiment

and was analysed for physical and chemical properties which are presented in table 3.

3.6 CULTURAL OPERATIONS FOLLOWED IN ONION AND GARLIC

3.6.1 Preparation of land

The land was brought to a fine tilth by ploughing followed by two harrowings and then the plots were laid out as per the plan.

3.6.2 Fertilizer application

Fertilizers were applied in the form of urea, DAP and muriate of potash as source of NPK. Fifty per cent of nitrogen and full dose of phosphorous and potassium were applied at the time of transplanting and remaining 50 per cent of nitrogen was applied at 30 days after transplanting.

3.6.3 Transplanting/sowing

Forty-five days old seedlings of onion were transplanted with the spacing of 15cm x 7.5cm. Garlic cloves were sown at a space of 15cm x 7.5 cm.

3.6.4 Irrigation and weeding

Irrigation was given during long dry spell and weeding was carried out to keep the plots free of weeds.

Table 3. Physical and chemical properties of the experimental site

Properties	Value
Particle size analysis	
Coarse sand (%)	7.7
Fine sand (%)	12.2
Silt (%)	42.4
Clay (%)	37.7
Textural class	silty clay loam
Chemical properties	
PH	8.3
EC (dS m ⁻¹)	0.24
Organic carbon (g kg ⁻¹)	5.8
CEC (cmol (p+) kg ⁻¹)	38.75
Exchangeable cations (cmol (p+) kg⁻¹)	
Ca ⁺⁺ + Mg ⁺⁺	32.24
Na ⁺	2.290
K ⁺	1.00
Available nutrients	
Available N (kg ha ⁻¹)	280.00
Available P (kg ha ⁻¹)	26.65
Available K (kg ha ⁻¹)	875.0
Available S (mg kg ⁻¹)	5.37

3.6.5 Plant protection

The recommended plant protection measures were taken up during experimentation in order to control the insect pests and diseases.

3.6.6 Harvesting

After complete maturity plants were uprooted from the net plot area and kept in field for two days, then the bulbs were separated from the rest of the plant parts and dried under shade.

3.7 OBSERVATIONS RECORDED IN ONION

3.7.1 Growth parameters

3.7.1.1 Fresh weight and dry weight

On the day of harvest, ten plants from each plot were uprooted and the aerial portion was separated from the bulb. Fresh weight of aerial part (foliage) and bulb of ten plants were recorded separately and the average of these was taken as fresh weight of foliage and bulb. Later the same samples were oven-dried at 75°C and weighed to note the dry matter accumulation. Average was calculated and expressed as dry matter accumulation in grams.

3.7.2 Yield parameters

3.7.2.1 Average weight of the bulb (g)

The weight of ten individual bulbs were noted down and the average of these was expressed as average weight of the bulb in grams.

3.7.2.2 Bulb diameter (cm)

The diameter was determined by using a Vernier calipers and then average bulb diameter was worked out and expressed in cm.

3.7.2.3 Bulb density (g cm^{-3})

The weight of the ten bulbs were noted down and were put in 1000 cc jar containing water to know the volume of ten bulbs. Then average density of bulb was calculated and expressed in g cm^{-3} .

3.7.2.4 Bulb yield (t/ha)

The bulbs from net plot area were removed and the weight of bulbs in each plot was recorded and yield was expressed in tonnes per hectare.

3.7.3 Quality parameters

3.7.3.1 Total soluble solids (%)

The fresh onion sample was put in a squeezer and juice was extracted and observed for total soluble solids (Brix Value) in percentage with the help of a hand refractometer.

3.8 OBSERVATIONS RECORDED IN GARLIC

3.8.1 Growth parameters

3.8.1.1 Fresh weight and dry weight

On the day of harvest, ten plants from each plot was separated from the bulb. Fresh weight of aerial part (foliage) and bulb of ten plants were recorded separately and the average of these was taken as fresh weight of foliage and bulb. Later the same samples were oven-dried at 75° and weighed to note the dry matter accumulation . Average was calculated and expressed as dry matter accumulation in g.

3.8.2 Yield parameters

3.8.2.1 Average weight of the bulb (g)

The weight of ten individual bulbs were noted down and the average of these was expressed as average weight of the bulb in g.

3.8.2.2 Length of bulb (cm)

Length of the bulb was recorded using vernier calipers. Average of five plants was worked out and expressed in cm.

3.8.2.3 Bulb diameter (cm)

The diameter was determined by using a vernier calipers and then average bulb diameter was worked out and expressed in cm.

3.8.2.4 Bulb yield (t/ha)

The bulbs from the net area were cured completely and weighed. On the basis of bulb yield per net plot, the total bulb yield was computed and expressed in tonnes per hectare.

3.9 NUTRIENT CONTENT AND UPTAKE BY ONION AND GARLIC

3.9.1 Collection and preparation of plant samples

Plant samples were collected at thirty days after planting and at harvest. Five plants were collected from each net plot, washed thoroughly with tap water, dipped in dilute HCl and washed with tap water and with distilled water and dried in hot air oven at 65° C for 24 hours. Dried samples were powdered in a Willey grind mill and stored in plastic containers, which were used for further chemical analysis.

3.9.2 Nitrogen estimation in the plant samples

To determine the nitrogen content in plant samples, one gram of plant sample was treated with concentrated sulphuric acid and digested with digestion mixture ($\text{CuSO}_4 + \text{K}_2\text{SO}_4 + \text{selenium powder}$). After complete digestion, contents were transferred to volumetric flask and volume was made up to 100 ml. A known amount of aliquot was transferred to distillation unit (micro kjeldhal) 40 per cent NaOH was added to make the contents alkaline. The liberated ammonia was trapped

in boric acid- mixed indicator solution, which was titrated against standard acid. The nitrogen percentage in plant parts (leaf and bulb) was estimated (Jackson, 1967). N uptake by leaf was calculated by multiplying the N concentration with the dry matter yield.

3.9.3 Digestion of plant samples for P,K and S estimation

Powdered plant samples were transferred to digestion tubes and treated with HNO_3 for pre-digestion. The pre-digested samples were treated with diacid ($\text{HNO}_3 : \text{HClO}_4 :: 10 : 4$ ratio) mixture and digested on a tecator digestion unit at a temperature of 300° to 350°C . After the completion of digestion, the digestion tubes were cooled and volume was made up to 100 ml using 6 N HCl (Jackson, 1967).

3.9.4 Estimation of phosphorous content (%) and phosphorous uptake (kg ha^{-1}) in plant samples

Phosphorous content in plant samples was determined by vanadomolybdophosphoric acid yellow colour method (Jackson, 1967) using the aliquot of the digested sample by wet oxidation method. Phosphorous uptake was calculated by multiplying the P concentration with the dry matter yield.

3.9.5 Estimation of potassium content (%) and potassium uptake (kg ha^{-1}) in plant samples

Potassium content in aerial portion and bulbs was estimated with the help of flame photometer (Jackson, 1967). Potassium uptake by leaf and bulb was calculated by multiplying the K concentration with the dry matter yield.

3.9.6 Estimation of sulphur content (%) and sulphur uptake (kg ha^{-1}) in the plant samples

Sulphur analysis in the digested samples was carried out by turbidimetric method using spectrophotometer (Chesnin and Yien, 1951). Sulphur uptake of leaf and bulb was calculated by multiplying the S concentration with the dry matter yield.

3.10 CHEMICAL ANALYSIS OF SOIL AFTER THE HARVEST OF ONION AND GARLIC

Soil samples from 0-15 cm depth were collected after the harvest of onion and garlic crop from each treatment in all the replications. The soil samples were air-dried in shade, mixed and powdered with wooden pestle and mortar, passed through 2 mm sieve and preserved for further analytical work. Available nutrients in soil samples were estimated by following standard procedures mentioned from 3.2.5 to 3.2.10.

3.11 ECONOMICS

The prices of the inputs in rupees prevailing at the time of experimentation were considered for working out the cost of cultivation (Appendix II). Net returns per hectare was calculated by deducting the cost of cultivation from gross returns per hectare. Benefit cost ratio was worked out as follows :

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

3.12 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

Fisher's method of analysis of variance was applied for analysis and the data was interpreted as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was $P = 0.05$.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the research work done are presented in this chapter under the following headings:

4.1 Physical and chemical properties of soils of KRCCH, Arabhavi

4.2 Available nutrients status of soils of KRCCH, Arabhavi

4.3 Correlation between available sulphur and soil properties

4.4 Effect of sulphur application on onion

4.5 Effect of sulphur application on garlic

4.1 PHYSICAL AND CHEMICAL PROPERTIES OF SOILS OF KRCCH, ARABHAVI

4.1.1 Physical properties of soils of KRCCH, Arabhavi

Some of the physical properties of soils under the investigation are furnished in table 4.

4.1.1.1 Soil colour

Soil colour ranged from 7.5YR 5/4 to 7.5 YR 3/2 in coarse textured soils and 10 YR 3/2 to 10 YR 4/4 in fine textured soils.

4.1.1.2 Particle size analysis

The percentage distribution of coarse sand ranged from 6.6 to 15.8 in olericulture block, 6.0 to 21.7 in pomology block, 6.4 to 11.3 in medicinal and aromatic plants block, 4.5 to 16.5 in spices and plantation

Table 4: Soil colour and particle size analysis of soils of KRCCH, Arabhavi

Block	Plot No.	Soil colour	Particle size distribution (%)				Textural class
			Coarse sand	Fine sand	Silt	Clay	
Olericulture	1	10YR 3/2	11.1	15.7	28.5	44.7	Clay
	2	10YR 3/3	14.3	18.7	29.5	37.5	Clay loam
	3	10YR 4/2	6.6	13.6	42.5	37.3	Silty clay loam
	4	10YR 4/2	7.7	12.2	42.4	37.7	Silty clay loam
	5	10YR 3/2	8.9	10.7	42.6	37.8	Silty clay loam
	6	7.5 YR 4/2	13.7	31.0	23.7	31.6	Sandy clay loam
	7	7.5 YR 3/2	15.8	32.9	20.6	30.7	Sandy clay loam
	8	7.5 YR 4/2	14.6	31.1	23.5	30.8	Sandy clay loam
Pomology	1	10YR 4/3	8.9	25.9	26.7	38.5	Clay loam
	2	10YR 3/3	9.9	19.6	26.9	43.7	Clay
	3	10YR 4/2	10.6	20.3	27.3	41.8	Clay
	4	10YR 3/2	12.8	14.8	30.1	42.3	Clay
	5	10YR 4/3	8.7	16.3	32.0	43.0	Clay
	6	10YR 3/4	7.9	17.8	30.0	44.3	Clay
	7	10YR 4/2	6.6	15.7	34.3	43.4	Clay
	8	10YR 4/3	7.7	16.3	33.4	42.6	Clay
	9	10YR 3/4	6.1	12.7	42.6	38.6	Silty clay loam
	10	10YR 4/3	6.0	13.8	41.2	39.0	Silty clay loam
	11	10YR 3/4	17.7	29.3	22.3	30.7	Sandy clay loam
	12	10YR 4/2	19.7	30.2	21.6	28.5	Sandy clay loam
	13	10YR 4/3	17.7	28.7	20.0	33.6	Sandy clay loam
	14	10YR 3/4	8.6	12.8	43.0	35.6	Silty clay loam
	15	10YR 4/2	9.0	14.7	31.7	44.6	Clay
	16	7.5 YR 4/4	21.7	26.8	21.9	30.5	Sandy clay loam
	17	7.5 YR 3/2	20.8	28.7	21.5	29.0	Sandy clay loam
Medicinal & aromatic plants	1	10YR 4/3	6.9	16.8	32.7	43.6	Clay
	2	10YR 4/4	9.1	17.6	27.6	45.7	Clay
	3	10YR 3/3	7.3	13.7	33.1	45.9	Clay
	4	10YR 4/2	11.3	15.3	28.5	44.6	Clay
	5	10YR 3/3	11.0	14.8	31.5	42.7	Clay
	6	10YR 3/2	6.4	10.7	35.6	47.3	Clay
	7	10YR 4/3	10.9	15.9	28.5	44.7	Clay
Spices & plantation crops	1	10YR 4/1	11.0	14.4	28.2	46.4	Clay
	2	10YR 4/2	9.2	10.2	42.1	38.5	Silty clay loam
	3	10YR 3/2	4.5	18.7	27.5	49.3	Clay
	4	10YR 4/2	9.1	16.0	30.3	44.6	Clay
	5	10YR 4/3	12.7	15.1	33.6	38.6	Clay loam
	6	10YR 3/3	12.3	15.5	33.7	38.5	Clay loam
	7	10YR 4/2	13.9	19.9	28.6	37.6	Clay loam
	8	10YR 3/2	13.0	21.5	30.8	34.7	Clay loam
	9	10YR 4/2	11.6	18.1	34.7	35.6	Clay loam
	10	10YR 4/2	12.4	18.8	30.3	38.5	Clay loam
	11	10YR 3/3	13.5	17.3	38.5	30.7	Clay loam
	12	7.5 YR 4/2	16.5	29.3	20.6	33.6	Sandy clay loam
Floriculture	1	7.5 YR 5/4	22.6	25.9	19.8	31.7	Sandy clay loam
	2	7.5 YR 4/4	22.7	25.5	19.7	31.9	Sandy clay loam
	3	7.5 YR 5/4	20.5	27.3	19.8	32.4	Sandy clay loam
	4	7.5 YR 4/2	21.5	26.3	20.6	31.6	Sandy clay loam
	5	7.5 YR 3/2	17.5	28.1	21.7	32.7	Sandy clay loam

crops block and 17.5 to 22.7 in floriculture block. The distribution of fine sand ranged from 10.7 to 32.9 per cent, 12.7 to 29.3 per cent, 10.7 to 17.6 per cent, 10.2 to 29.3 per cent and 25.5 to 28.1 per cent in olericulture block, pomology block, medicinal and aromatic plants block, spices and plantation crops block and floriculture block, respectively. The percentage distribution of silt ranged from 20.6 to 42.6 in olericulture block, 20.0 to 42.6 in pomology block, 27.6 to 35.6 in medicinal and aromatic plants block, 20.6 to 42.1 in spices and plantation crops block and 19.7 to 21.7 in floriculture block. And the percentage distribution of clay ranged from 30.7 to 44.7, 29.0 to 44.6, 42.7 to 47.3, 30.7 to 49.3 and 31.6 to 32.7 in olericulture block, pomology block, medicinal and aromatic plants block, spices and plantation crops block and floriculture block, respectively.

The textural class of the soils of olericulture block were clay, clay loam, silty clay loam and sandy clay loam. The textural class of the soils of pomology block were mainly of clay and sandy clay loam and some soils were silty clay loam and clay loam. In medicinal and aromatic plants block all soils were clay in texture. The soils of spices and plantation crops block were mainly clay loam in texture. All the soils of floriculture block were sandy clay loam in texture.

4.1.2 Chemical properties of soils of KRCCH, Arabhavi (cf. Table 5)

4.1.2.1 Soil reaction

The pH of the soils ranged from 8.0 to 8.6 in olericulture block, 8.0 to 8.6 in pomology block, 8.5 to 8.9 in medicinal and aromatic plants block, 8.3 to 8.8 in spices and plantation crops block and 7.8 to 8.4 in floriculture block.

4.1.2.2 Electrical conductivity

The electrical conductivity of soils ranged from 0.18 to 0.38, 0.15 to 0.53, 0.18 to 0.26, 0.20 to 0.43 and 0.12 to 0.15 dS m⁻¹ in olericulture block, pomology block, medicinal and aromatic plants block, spices and plantation crops block and floriculture block, respectively.

4.1.2.3 Organic carbon

The amount of organic carbon varied from low to high in the soils of KRCCH, Arabhavi. The amount of organic carbon ranged from 2.7 to 8.5 g kg⁻¹ in olericulture block, 3.5 to 12.4 g kg⁻¹ in Pomology block, 12.0 to 15.5 g kg⁻¹ in medicinal and aromatic plants block, 5.4 to 13.6 g kg⁻¹ in spices and plantation crops block and 4.6 to 9.3 g kg⁻¹ in soils of floriculture block.

4.1.2.4 Calcium carbonate content

The amount of CaCO₃ content of soil ranged from 46.5 to 172.0 g kg⁻¹ in olericulture block, 27.9 to 158.1 g kg⁻¹ in pomology block 102.3 to

144.1 g kg⁻¹ in medicinal and aromatic plants block, 41.8 to 153.4 g kg⁻¹ in spices and plantation crops block and 55.8 to 93.0 g kg⁻¹ in soils of floriculture block.

4.1.2.5 Cation exchange capacity (CEC)

The cation exchange capacity ranged from 35.06 to 48.61 cmol (p+) kg⁻¹, 32.28 to 50.51 cmol (p+) kg⁻¹, 47.57 to 55.36 cmol (p+) kg⁻¹, 35.33 to 55.82 cmol (p+) kg⁻¹ and 33.31 to 37.87 cmol (p+) kg⁻¹ in soils of olericulture block, pomology block, medicinal and aromatic plants block, spices and plantation crops block and floriculture block, respectively.

4.1.2.6 Exchangeable cations

Among the exchangeable cations, calcium and magnesium were dominant. The exchangeable Ca²⁺ plus Mg²⁺ varied from 27.23 to 42.12 cmol (p+) kg⁻¹ in olericulture block, 28.78 to 44.5 cmol (p+) kg⁻¹ in pomology block, 41.92 to 48.28 cmol (p+) kg⁻¹ in medicinal and aromatic plants block, 30.41 to 46.82 cmol (p+) kg⁻¹ in spices and plantation crops block and 29.48 to 34.33 cmol (p+) kg⁻¹ in floriculture block.

The exchangeable sodium content ranged from 1.33 to 3.08 cmol (p+) kg⁻¹, 0.91 to 3.01 cmol (p+) kg⁻¹, 1.57 to 5.97 cmol (p+) kg⁻¹, 0.95 to 4.54 cmol (p+) kg⁻¹ and 0.91 to 1.43 cmol (p+) kg⁻¹ in soils of olericulture block, pomology block, medicinal and Aromatic plants block, spices and plantation crops block and floriculture block, respectively.

Table 5: Some chemical properties of soils of KRCCH, Arabhavi

Block	Plot No.	pH	EC (dS m ⁻¹)	Organic carbon (g kg ⁻¹)	CaCO ₃ (g kg ⁻¹)	CEC (cmol (p ⁺) kg ⁻¹)	Exchangeable cations (cmol (p ⁺) kg ⁻¹)		
							Ca ²⁺ + mg ²⁺	Na ⁺	K ⁺
Olericulture	1	8.4	0.22	8.5	172.0	48.61	42.12	2.57	0.93
	2	8.2	0.38	5.8	106.9	40.51	35.82	2.15	0.81
	3	8.2	0.29	7.4	125.5	41.89	37.19	1.86	0.78
	4	8.3	0.24	5.8	91.6	38.75	32.24	2.29	1.00
	5	8.4	0.22	2.7	55.8	36.00	30.75	1.67	1.11
	6	8.6	0.19	4.3	69.7	35.09	27.23	3.23	0.90
	7	8.0	0.19	6.6	46.5	36.69	32.08	1.33	0.88
	8	8.5	0.18	5.4	65.1	35.06	28.73	3.68	0.65
Pomology	1	8.5	0.23	5.8	102.3	42.23	37.08	1.72	0.50
	2	8.8	0.40	6.6	148.8	47.63	40.04	3.00	0.57
	3	8.3	0.22	4.3	79.0	43.01	38.50	1.19	0.55
	4	8.5	0.27	7.8	144.1	47.92	44.25	0.95	0.53
	5	7.8	0.24	6.6	32.5	46.61	42.35	1.43	0.54
	6	7.8	0.24	7.8	139.5	49.73	44.50	1.33	0.56
	7	8.6	0.44	7.8	125.5	48.21	43.30	2.00	1.13
	8	8.3	0.25	5.8	83.7	44.62	40.98	0.91	0.59
	9	8.8	0.40	3.5	139.5	43.75	38.33	2.19	0.93
	10	8.5	0.33	12.0	83.7	44.90	41.38	0.95	0.60
	11	8.1	0.28	4.3	27.9	36.37	31.52	2.29	0.50
	12	8.1	0.15	6.5	83.7	33.33	31.23	0.86	0.59
	13	8.1	0.21	7.8	109.3	35.80	31.48	1.34	0.50
	14	8.3	0.53	12.0	158.1	41.32	36.75	1.67	0.86
	15	8.5	0.48	12.4	51.1	50.51	43.98	3.01	0.94
	16	8.0	0.16	6.2	74.4	37.23	33.19	1.34	0.78
	17	8.5	0.30	3.9	97.6	32.28	28.78	2.00	0.53
Medicinal & aromatic plants	1	8.8	0.25	15.5	134.8	47.57	41.92	3.68	0.78
	2	8.9	0.26	12.4	130.2	51.92	43.31	5.97	0.86
	3	8.5	0.24	12.8	102.3	52.28	47.12	2.15	1.00
	4	8.6	0.20	12.0	144.1	50.59	45.38	2.29	0.94
	5	8.5	0.18	12.4	139.5	48.34	43.81	1.57	0.90
	6	8.5	0.25	15.5	106.9	53.36	48.28	2.29	0.79
	7	8.7	0.23	12.0	116.2	49.18	42.98	3.20	1.01
Spices & plantation crops	1	8.7	0.25	12.0	116.2	50.29	45.21	2.48	0.72
	2	8.8	0.32	12.4	167.4	43.51	36.58	4.30	0.65
	3	8.8	0.43	13.6	153.4	55.82	46.82	5.97	1.08
	4	8.6	0.21	11.7	120.9	49.90	42.18	4.54	1.00
	5	8.5	0.21	9.8	91.7	43.01	37.98	2.72	0.62
	6	8.3	0.30	7.4	55.8	42.78	38.61	1.67	0.47
	7	8.4	0.40	9.3	55.8	44.31	39.02	2.58	0.65
	8	8.3	0.23	9.7	93.0	39.85	37.21	2.05	0.72
	9	8.5	0.22	6.2	51.1	38.67	33.82	1.96	0.90
	10	8.4	0.27	9.3	41.8	43.43	39.43	1.48	0.93
	11	8.5	0.21	10.9	97.6	35.33	30.41	1.91	1.00
	12	8.5	0.20	5.4	55.8	36.75	32.85	0.95	1.08
Floriculture	1	8.4	0.12	6.6	55.8	33.31	29.48	0.91	0.93
	2	7.8	0.13	6.6	67.1	34.61	30.41	1.24	0.86
	3	8.4	0.12	7.8	68.2	35.52	31.42	1.36	0.78
	4	8.4	0.12	9.3	55.8	38.37	34.33	1.43	0.61
	5	8.4	0.15	4.6	93.0	37.87	33.18	1.38	0.54

The exchangeable potassium content ranged from 0.65 to 1.11 cmol (p+) kg⁻¹ in olericulture block 0.5 to 1.13 cmol (p+) kg⁻¹ in pomology block, 0.78 to 1.01 cmol (p+) kg⁻¹ in medicinal and aromatic plants block, 0.47 to 1.08 cmol (p+) kg⁻¹ in spices and plantation crops block and 0.54 to 0.93 cmol (p+) kg⁻¹ in floriculture block.

4.2 AVAILABLE NUTRIENTS STATUS OF SOILS OF KRCCH, ARABHAVI (cf. Table 6)

4.2.1 Nitrogen

The soils were low to medium in available nitrogen content. The soils of olericulture block were medium in available N content with values ranging from 280.0 to 315.0 kg ha⁻¹. The available N content of soils of pomology block was low to medium with values ranged between 227.5 and 402.5 kg ha⁻¹. The soils of medicinal and aromatic plants block, spices and plantation crops block and floriculture block were medium in available nitrogen content with values ranged between 297.5 and 455.0 kg ha⁻¹.

4.2.2 Phosphorus

The available phosphorus content of the soils were low to high. The soils of olericulture block were medium to high in available P content with values ranging from 10.11 to 31.25 kg ha⁻¹. The available P content of pomology block were low to high with values ranged from 7.42 to 39.52 kg ha⁻¹. The soils of medicinal and aromatic plants block were

medium to high in available phosphorus (P) content with values varied from 13.79 to 33.27 kg ha⁻¹. The soils of spices and plantation crops block were medium to high in available phosphorus (P) content with values ranged from 11.70 to 26.84 kg ha⁻¹. The available P content of floriculture block soils was medium to high with values ranged from 19.85 to 33.82 kg ha⁻¹.

4.2.3 Potassium

The soils were high in available potassium content. The available K content of soils ranged from 562.5 to 1125.0 kg ha⁻¹, 437.5 to 812.5 kg ha⁻¹, 687.5 to 875.0 kg ha⁻¹, 468.75 to 937.5 kg ha⁻¹ and 468.75 to 812.5 kg ha⁻¹ in olericulture block, pomology block, medicinal and aromatic plants block, spices and plantation crops block and floriculture block, respectively.

4.2.4 Sulphur

The available S content of about 46 per cent of the soils were below 10 mg kg⁻¹. In olericulture block, out of eight plots, seven plots were below 10 mg kg⁻¹ in available sulphur with values ranged between 5.5 and 7.07 mg kg⁻¹. Available S content of soils of pomology block varied from 5.62 to 24.00 mg kg⁻¹. Around 59 per cent of soils were below 10 mg kg⁻¹ in pomology block. In medicinal and aromatic plants block, around 72 per cent of the soils were below 10 mg kg⁻¹. All the soils of plantation crops block were above 10 mg kg⁻¹ except fourth plot with

Table 6: Available nutrient status of soils of KRCCH, Arabhavi

Block	Plot No.	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Potassium (kg ha ⁻¹)	Sulphur (mg kg ⁻¹)
Olericulture	1	315.0	31.25	812.5	6.25
	2	280.0	10.11	750.0	5.50
	3	315.0	10.66	687.5	6.25
	4	280.0	26.65	875.0	5.37
	5	280.0	10.84	1125.0	5.50
	6	297.5	10.81	797.07	12.06
	7	315.0	14.88	781.25	6.25
	8	315.0	12.13	562.5	7.07
Pomology	1	280.0	15.99	437.5	8.03
	2	315.0	26.47	500.0	14.5
	3	297.0	31.98	495.98	6.5
	4	262.5	9.19	468.75	9.00
	5	350.0	9.55	498.70	8.55
	6	350.0	12.86	500.0	23.50
	7	315.0	20.00	1000.0	16.50
	8	315.0	15.25	531.25	8.12
	9	402.5	7.42	812.5	24.00
	10	227.5	8.45	531.25	8.12
	11	262.5	17.46	437.5	5.87
	12	297.5	12.68	531.25	23.43
	13	262.5	12.50	437.5	6.25
	14	280.0	9.00	750.0	5.93
	15	262.5	15.07	812.5	23.0
	16	262.5	39.52	687.5	14.06
	17	297.5	23.89	468.5	5.62
Medicinal & aromatic plants	1	402.5	16.54	687.5	6.29
	2	402.5	31.07	750.0	9.93
	3	367.5	18.57	875.0	9.93
	4	402.5	31.67	812.5	8.71
	5	385.0	33.27	781.25	8.12
	6	402.5	18.38	687.5	16.56
	7	393.7	13.79	875.0	19.68
Spices & plantation crops	1	437.5	18.01	625.0	15.31
	2	350.0	13.97	562.5	17.18
	3	420.0	26.84	937.5	10.37
	4	350.0	11.76	875.0	8.75
	5	350.0	14.34	535.25	29.00
	6	350.0	14.88	468.75	11.71
	7	437.0	25.92	562.25	15.06
	8	315.0	25.18	625.0	16.41
	9	455.0	15.14	781.25	12.81
	10	437.5	20.77	812.50	10.46
	11	350.0	12.87	875.0	10.00
	12	386.5	21.14	937.5	11.56
Floriculture	1	332.5	29.78	812.5	15.31
	2	297.5	33.82	750.0	12.90
	3	315.0	19.85	687.5	14.50
	4	332.5	23.16	531.25	11.09
	5	367.5	24.08	468.75	11.71

values ranged from 10.00 to 16.41 mg kg⁻¹. Available S content of all soils of floriculture block were above 10 mg kg⁻¹ with values ranged from 11.09 to 15.31 mg kg⁻¹.

4.3 CORRELATION BETWEEN SOIL PROPERTIES AND AVAILABLE SULPHUR (cf. Table 7)

Correlation coefficient values were computed between soil properties and available sulphur. Perusal of the data given indicated that there exists a positive correlation between available sulphur and pH (0.079), EC (0.033), available N (0.229), available K (0.114), CaCO₃ content (0.074), exchangeable Ca + Mg (0.48), exchangeable Na (0.036), exchangeable K (0.070), CEC (0.043), Silt (0.060) and Clay content (0.040) of soils. But it was not significant. There was significant positive correlation between available sulphur and organic carbon (0.289*).

A negative correlation was noticed between available S and available P (-0.025), coarse sand (-0.005), fine sand content (-0.125) of soils. But this correlation was not significant.

4.4 EFFECT OF SULPHUR APPLICATION ON ONION

4.4.1 Drymatter accumulation (cf. Table 8)

4.4.1.1 Fresh weight of foliage

The fresh weight of foliage increased significantly with increased levels of S application. An increase in fresh weight was noticed up to 40 kg S/ha application. Beyond that the decrease was not significant.

Table 7: Correlation coefficients between some soil properties and available sulphur of soils of KRCCH, Arabhavi

Sl. No.	Soil properties	Available sulphur
1.	pH	0.079
2.	Electrical conductivity	0.033
3.	Organic carbon	0.289*
4.	Available nitrogen	0.229
5.	Available phosphorus	-0.025
6.	Available potassium	0.114
7.	CaCO ₃	0.074
8.	Exchangeable Ca ²⁺ + mg ²⁺	0.048
9.	Exchangeable Na ⁺	0.036
10.	Exchangeable K ⁺	0.070
11.	CEC	0.043
12.	Coarse sand	-0.005
13.	Fine sand	-0.125
14.	Silt	0.060
15.	Clay	0.040

* - Significant at 5%

Table 8 : Drymatter accumulation in leaf and bulb of onion as influenced by sulphur levels

Treatments	Leaf		Bulb	
	Fresh weight (g/plant)	Dry weight (g/plant)	Fresh weight (g/bulb)	Dry weight (g/bulb)
Control	14.25	1.23	37.95	4.09
20 kg S/ha	15.25	1.32	42.00	4.53
40 kg S/ha	17.50	1.52	45.05	4.86
60 kg S/ha	17.25	1.50	44.00	4.75
80 kg S/ha	16.27	1.40	43.00	4.64
S.Em.±	0.502	0.042	1.295	0.139
C.D. at 0.05	1.547	0.130	3.992	0.431

Highest fresh weight was noticed in T₃ (17.50 g/plant) and it was at par with T₁ (17.25 g/plant) and T₅ (16.27 g/plant). Lowest fresh weight was recorded in control (14.25 g/plant) and it was statistically on par with T₂ (15.25 g/plant).

4.4.1.2 Dry weight of foliage

A significant increase in dry weight of foliage was noticed with increased levels of S application up to 40 kg S/ha. Beyond that the decrease was not significant. Lowest dry weight was noticed in control (1.23 g/plant) and it was at par with T₂ (1.32 g/plant). Highest dry weight was noticed in T₃ (1.52 g/plant) which was on par with T₁ (1.50 g/plant) and T₅ (1.40 g/plant).

4.4.1.3 Fresh weight of bulb

Fresh weight of bulb increased significantly with successive increase in levels of S application up to 40 kg S/ha. Further increase in S rate decreased the fresh weight of bulb. Highest fresh weight of bulbs was observed in T₃ (45.05 g/bulb) which was statistically at par with T₁ (44.00 g/bulb) and T₅ (43.00 g/bulb). Lowest fresh weight of bulb was noticed in control (37.95 g/bulb).

4.4.1.4 Dry weight of bulb

The data on dry weight of bulb showed that there was an increase in dry weight of bulb significantly with increased levels of sulphur

application up to 40 kg sulphur per ha. Further increase in sulphur application decreased the dry weight of bulb. Highest dry weight of bulb was recorded in 40 kg S/ha (4.86 g/bulb) which was at par with T₄ (4.75 g/bulb) and T₅ (4.64 g/bulb). Lowest dry weight of bulb was recorded in control (4.09 g/bulb).

4.4.2 Bulb characteristics and bulb yield (cf. Table 9)

4.4.2.1 Bulb diameter

Bulb diameter increased significantly with increased levels of sulphur application up to 40 kg S/ha. Further increase in S application decreased the bulb diameters. Highest bulb diameter was observed in T₃ (4.26 cm) which was on par with T₄ (4.16cm) and T₅ (4.12 cm). Lowest bulb diameter was noticed in control (3.67cm).

4.4.2.2 Bulb density

An increase in bulb density with increased levels of sulphur application was noticed. But it was not significant. Highest bulb density was noticed in T₅ (0.836 g/cc) and lowest bulb density was noticed in control (0.810 g/cc).

4.4.2.3 Total soluble solids content (TSS)

A significant increase in TSS content with increased levels of sulphur application was observed. Highest TSS content was noticed in 80 kg S/ha (13.0 %) which was on par with 60 kg S/ha (12.6 %). Lowest TSS content was recorded in control (9.2 %) which was at par with 20 kg S/ha (9.6 %).

Table 9 : Bulb characteristics and yield of onion as influenced by sulphur levels

Treatments	Bulb diameter (cm)	Bulb density (g/cc)	Total soluble solids (%)	Bulb yield (t/ha)
Control	3.67	0.810	9.2	28.46
20 kg S/ha	4.13	0.824	9.6	31.50
40 kg S/ha	4.26	0.826	12.0	33.78
60 kg S/ha	4.16	0.826	12.6	33.00
80 kg S/ha	4.12	0.836	13.0	32.25
S.Em.±	0.104	0.027	0.234	0.969
C.D. at 0.05	0.321	NS	0.721	2.98

Perusal of the data on bulb yield indicate that bulb yield increased significantly with increased levels of sulphur application up to 40 kg S/ha. Further increase in S application decreased the bulb yield. Highest bulb yield was recorded in 40 kg S/ha (33.78 t/ha) which was on par with 60 kg S/ha (33.00 t/ha) and 80 kg S/ha (32.25 t/ha). Lowest bulb yield was recorded in control (28.46 t/ha).

4.4.4 Biomass production (*cf.* Table 10)

4.4.4.1 Total fresh weight of leaves

A significant increase in total fresh weight of leaves with increased levels of sulphur application was noticed up to 40 kg S/ha. Further increase in sulphur application decreased the total fresh weight of leaves. Highest total fresh weight of leaves was recorded in 40 kg S/ha (13.12 t/ha) which was at par with 60 kg S/ha (12.93 t/ha) and 80 kg S/ha (12.10 t/ha) and lowest fresh weight of leaves was observed in control (10.68 t/ha) which was at par with 20 kg S/ha (11.42 t/ha).

4.4.4.2 Total drymatter of leaves

Total drymatter content of leaves increased significantly with increased levels of sulphur application up to 40 kg S/ha and further increase in sulphur application decreased the total drymatter content of leaves. Highest total drymatter content of leaves was noticed in 40 kg S/ha (1.14 t/ha) which was on par with T₄ (1.12 t/ha) and T₅ (1.05 t/ha). Lowest total drymatter content

Table 10 : Biomass production of onion as influenced by sulphur levels

Treatments	Leaf (t/ha)		Bulb (t/ha)	
	Fresh weight	Drymatter	Fresh weight	Drymatter
Control	10.68	0.92	28.46	3.06
20 kg S/ha	11.42	0.99	31.50	3.39
40 kg S/ha	13.12	1.14	33.78	3.64
60 kg S/ha	12.93	1.12	33.00	3.56
80 kg S/ha	12.10	1.05	32.25	3.47
S.Em.±	0.383	0.032	0.969	0.106
C.D. at 0.05	1.179	0.097	2.98	0.324

was noticed in control (0.92 t/ha) which was on par with 20 kg S/ha (0.99 t/ha).

4.4.4.3 Total fresh weight of bulb (cf. 4.4.3)

4.4.4.4 Total drymatter content of bulb

A significant increase in total drymatter content of bulb with increased levels of sulphur application was noticed up to 40 kg S/ha and further increase in S application decreased the total drymatter content of bulb. Highest total drymatter content of bulb was noticed in 40 kg S/ha (3.64 t/ha) which was at par with 60 kg S/ha (3.56 t/ha) and 80 kg S/ha (3.47 t/ha). Lowest total drymatter content of bulb was noticed in control (3.00 t/ha).

4.4.5 Leaf and bulb tissue composition

4.4.5.1 Nitrogen (cf. Table 11)

Nitrogen content of leaf increased with increased levels of sulphur application up to 60 kg S/ha both at 30 Days after planting and at harvest. Further increase in levels of sulphur application decreased the nitrogen content of leaf. At 30 DAP, highest nitrogen content was noticed in 60 kg S/ha (4.32%) which was on par with 80 kg S/ha (4.31%) and 40 kg S/ha (4.29%) and lowest nitrogen content was noticed in control (4.07%) and it was statistically on par with 20 kg S/ha (4.15%). At harvest, highest nitrogen content in leaf was noticed in 60 kg S/ha (1.85%) which was on par with 80 kg S/ha (1.82%) and 40 kg S/ha (1.80%) and lowest nitrogen content of leaf was noticed in control (1.62%).

Table 11 : Nitrogen content in leaf and bulb of onion as influenced by sulphur levels

Treatments	Nitrogen (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	4.07	1.62	2.24
20 kg S/ha	4.15	1.79	2.61
40 kg S/ha	4.29	1.80	2.63
60 kg S/ha	4.32	1.85	2.70
80 kg S/ha	4.31	1.82	2.71
S.Em.±	0.054	0.046	0.099
C.D. at 0.05	0.168	0.144	0.305

DAP - Days after planting

A significant increase in nitrogen content of bulb with increased levels of sulphur application was observed up to 80 kg S/ha. Highest nitrogen content of bulb was noticed in 80 kg S/ha (2.71%) which was on par with 60 kg S/ha (2.70%), 40 kg S/ha (2.63%) and 20 kg S/ha (2.61%).

4.4.5.2 Phosphorus (cf. Table 12)

An increase in phosphorus content of leaf with increased levels of sulphur application was noticed up to 40 kg S/ha at both 30 days after planting and harvest. Further increase in levels of sulphur application decreased the phosphorus content of leaf, but it was not significant. At 30 DAP, highest phosphorus content of leaf was noticed in 40 kg S/ha (0.452%) and lowest phosphorus content of leaf was noticed in control (0.400%). At harvest highest phosphorus content of leaf was noticed in 40 kg S/ha (0.340%) and lowest phosphorus content was noticed in control (0.303%). An increase in phosphorus content of bulb with increased levels of sulphur application was observed up to 40 kg S/ha. Further increase in levels of S application decreased the phosphorus content of bulb. Highest phosphorus content of bulb was noticed in 40 kg S/ha (0.290%) and lowest phosphorus content of bulb was noticed in control (0.235%).

Table 12 : Phosphorus content in leaf and bulb of onion as influenced by sulphur levels

Treatments	Phosphorus (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	0.400	0.303	0.235
20 kg S/ha	0.414	0.322	0.285
40 kg S/ha	0.452	0.340	0.290
60 kg S/ha	0.441	0.327	0.288
80 kg S/ha	0.440	0.310	0.260
S.Em.±	0.013	0.010	0.015
C.D. at 0.05	NS	NS	NS

DAP - Days after planting

4.4.5.3 Potassium (*cf.* Table 13)

An increase in potassium content of leaf and bulb with increased levels of sulphur application was noticed up to 60 kg S/ha and further increase in levels of S application decreased the potassium content of leaf both at 30 days after planting and at harvest. At 30 days after planting, highest potassium content of leaf was noticed in 60 kg S/ha (2.33%) and lowest potassium content of leaf was noticed in control (2.23%). At harvest, highest potassium content of leaf was noticed in 60 kg S/ha (1.135%) and lowest potassium content of leaf was observed in control (1.082%).

The potassium content of bulb increased with increased levels of sulphur application up to 60 kg S/ha. Further increase in S application decreased the potassium content of the bulb. Highest potassium content of the bulb was recorded at 60 kg S/ha (1.275%) and lowest potassium content was noticed in control (1.180%).

4.4.5.4 Sulphur (*cf.* Table 14)

A significant increase in sulphur content of leaf and bulb with increased levels of sulphur application at all the levels of sulphur application over control was noticed. At 30 days after planting highest sulphur content of leaf was noticed in 80 kg S/ha (0.468%) which was on par with 60 kg S/ha (0.452%) and lowest sulphur content of leaf was noticed in control (0.163%). At harvest, highest sulphur content of leaf

Table 13 : Potassium content in leaf and bulb of onion as influenced by sulphur levels

Treatments	Potassium (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	2.23	1.082	1.180
20 kg S/ha	2.24	1.102	1.202
40 kg S/ha	2.30	1.120	1.227
60 kg S/ha	2.33	1.135	1.275
80 kg S/ha	2.31	1.090	1.220
S.Em.±	0.026	0.098	0.048
C.D. at 0.05	NS	NS	NS

DAP – Days after planting

Table 14 : Sulphur content in leaf and bulb of onion as influenced by sulphur levels

Treatments	Sulphur (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	0.163	0.176	0.210
20 kg S/ha	0.295	0.330	0.370
40 kg S/ha	0.336	0.415	0.520
60 kg S/ha	0.452	0.515	0.600
80 kg S/ha	0.468	0.550	0.680
S.Em.±	0.010	0.012	0.046
C.D. at 0.05	0.032	0.037	0.141

DAP – Days after planting

was recorded in 80 kg S/ha (0.550%) which was at par with 60 kg S/ha (0.515%) and lowest sulphur content of leaf was noticed in control (0.176%).

The sulphur content of bulb increased significantly with increased levels of sulphur application. Highest sulphur content of bulb was recorded in 80 kg S/ha (0.68%) which was statistically on par with 60 kg S/ha (0.60%). Lowest sulphur content of bulb was noticed in control (0.210%).

4.4.6 Nutrient uptake by leaf and bulb of onion (cf. Table 15)

4.4.6.1 Nitrogen

The nitrogen uptake by leaf and bulb increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in sulphur application decreased the uptake of nitrogen by leaf and bulb.

Highest nitrogen uptake by leaf was noticed at 60 kg S/ha (20.78 kg/ha) which was on par with 40 kg S/ha (20.48 kg/ha) and 80 kg S/ha (19.11 kg/ha). Lowest nitrogen uptake was noticed in control (14.92 kg/ha) and it was on par with 20 kg S/ha (17.70 kg/ha).

Whereas in bulb, highest nitrogen uptake was noticed in 60 kg S/ha (96.12 kg/ha) which was at par with 80 kg S/ha (94.041 kg/ha) and 40 kg S/ha (95.73 kg/ha). Lowest nitrogen uptake was recorded in control (68.54 kg/ha).

4.4.6.2 Phosphorus

The phosphorus uptake by leaf and bulb increased significantly with increased levels of sulphur application up to 40 kg S/ha. Further increase in levels of sulphur application decreased the uptake of phosphorus both by leaf and bulb significantly.

Highest phosphorus uptake by leaf was noticed at 40 kg S/ha (3.91 kg/ha) which was at par with 60 kg S/ha (3.67 kg/ha). Lowest phosphorus uptake was noticed in control (2.79 kg/ha).

Highest phosphorus uptake by bulb was recorded at 40 kg S/ha (10.55 kg/ha) which was at par with 60 kg S/ha (10.25 kg/ha) and lowest phosphorus uptake was noticed in control (7.19 kg/ha).

4.4.6.3 Potassium

The data regarding uptake of potassium by leaf and bulb increased with increased levels of sulphur application up to 60 kg S/ha. Highest potassium uptake by leaf was noticed in 60 kg S/ha (12.75 kg/ha) which was at par with 40 kg S/ha (12.74 kg/ha). Lowest potassium uptake by leaf was recorded in control (9.96 kg/ha).

Highest potassium uptake by bulb was recorded in 60 kg S/ha (45.39 kg/ha) which was at par with 40 kg S/ha (44.67 kg/ha). Lowest potassium uptake was observed in control (36.10 kg/ha).

Table 15 : Nutrient uptake by leaf and bulb of onion as influenced by sulphur levels

Treatments	Nutrient uptake (kg ha ⁻¹)									
	Leaf					Bulb				
	Nitrogen	Phosphorus	Potassium	Sulphur	Nitrogen	Phosphorus	Potassium	Sulphur		
Control	14.92	2.79	9.96	1.620	68.54	7.19	36.10	6.43		
20 kg S/ha	17.70	3.18	10.88	3.260	88.48	9.67	40.75	12.54		
40 kg S/ha	20.48	3.91	12.74	4.720	95.73	10.55	44.67	18.93		
60 kg S/ha	20.78	3.67	12.75	5.768	96.12	10.25	45.39	21.36		
80 kg S/ha	19.11	3.26	11.47	5.775	94.04	9.02	42.33	23.60		
S.Em.±	0.999	0.103	0.119	0.114	2.540	0.152	0.751	0.747		
C.D. at 0.05	3.009	0.317	0.367	0.350	7.629	0.468	2.316	2.303		

4.4.6.4 Sulphur

Perusal of the data pertaining to uptake of sulphur by leaf and bulb of onion indicates that sulphur uptake increased significantly with increased levels of sulphur application.

Highest sulphur uptake by leaf was noticed in 80 kg S/ha (5.775 kg/ha) which was at par with 60 kg S/ha (5.708 kg/ha) and lowest sulphur uptake was recorded at control (1.62 kg/ha).

Whereas in case of bulb, highest sulphur uptake was noticed in 80 kg S/ha (23.60 kg/ha) which was at par with 60 kg S/ha (21.30 kg/ha) and lowest sulphur uptake was recorded in control (6.43 kg/ha).

4.4.7 Total uptake of nutrients (cf. Table 16)

4.4.7.1 Nitrogen

Total uptake of nitrogen increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in sulphur application decreased the total uptake of nitrogen. Highest uptake of nitrogen was recorded at 60 kg S/ha (116.90 kg/ha) which was at par with 40 kg S/ha (116.21 kg/ha) and 80 kg S/ha (113.15 kg/ha). Lowest total uptake of nitrogen was recorded in control (83.40 kg/ha).

4.4.7.2 Phosphorus

A significant increase in the uptake of total phosphorus with increased levels of sulphur application was observed up to 40 kg S/ha.

Table 16: Total uptake of nutrients by onion as influenced by sulphur levels

Treatments	Total uptake (kg ha ⁻¹)			
	Nitrogen	Phosphorus	Potassium	Sulphur
Control	83.46	9.98	46.06	8.05
20 kg S/ha	106.17	12.85	51.63	15.80
40 kg S/ha	116.21	14.46	57.41	23.65
60 kg S/ha	116.90	13.92	58.14	27.12
80 kg S/ha	113.15	12.28	53.80	29.37
S.Em.±	2.611	0.261	0.866	1.083
C.D. at 0.05	8.048	0.805	2.668	3.339

Further successive increase in levels of sulphur application decreased the total uptake of phosphorus. Highest uptake of total phosphorus was noticed in 40 kg S/ha (14.40 kg/ha) which was at par with 60 kg S/ha (13.92 kg/ha). Lowest uptake of total phosphorus was noticed in control (9.98 kg/ha).

4.4.7.3 Potassium

Total uptake of potassium increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in sulphur application decreased the total uptake of potassium. Highest uptake of total potassium was noticed in 60 kg S/ha (58.14 kg/ha) which was at par with 40 kg S/ha (57.41 kg/ha). Lowest uptake of total potassium was recorded in control (46.00 kg/ha).

4.4.7.4 Sulphur

A significant increase in the total sulphur uptake with increased levels of sulphur application was recorded. Highest total sulphur uptake was observed at 80 kg S/ha (29.37 kg/ha) which was at par with 60 kg S/ha (27.12 kg/ha). Lowest total sulphur uptake was recorded in control (8.05 kg/ha).

4.4.8 Residual nutrient status (cf. Table 17)

4.4.8.1 Nitrogen

A significant decrease in residual nitrogen status with increased levels of sulphur application was noticed up to 60 kg S/ha. Further increase in sulphur application increased the residual nitrogen status. Highest residual available

Table 17: Residual nutrient status after the harvest onion crop as influenced by sulphur levels

Treatments	Residual nutrients (kg ha ⁻¹)			
	Nitrogen	Phosphorus	Potassium	Sulphur
Control	244.37	25.83	866.40	2.15
20 kg S/ha	232.18	23.85	860.36	8.75
40 kg S/ha	220.41	22.50	852.50	16.89
60 kg S/ha	217.03	22.54	853.46	23.93
80 kg S/ha	227.99	24.48	855.96	27.53
S.Em.‡	4.623	0.923	9.450	0.961
C.D. at 0.05	14.267	NS	NS	2.962

nitrogen was recorded in control (244.37 kg/ha) which was at par with 20 kg S/ha (232.18 kg/ha). Lowest residual available nitrogen was recorded in 60 kg S/ha (217.03 kg/ha) which was at par with 80 kg S/ha (227.99 kg/ha).

4.4.8.2 Phosphorus

A decrease in residual available phosphorus with increased levels of sulphur application was recorded up to 40 kg S/ha. Further increase in sulphur application increased the residual status of phosphorus. Highest residual phosphorus was noticed in control (25.83 kg/ha) and lowest residual phosphorus was recorded in 40 kg S/ha (22.50 kg/ha).

4.4.8.3 Potassium

A decrease in the residual status of available potassium with increased levels of sulphur application was noticed up to 40 kg S/ha and further increase in sulphur application increased the residual status of available potassium. Highest residual available potassium was recorded in control (866.40 kg/ha) and lowest residual available potassium was recorded at 40 kg S/ha (852.50 kg/ha).

4.4.8.4 Sulphur

A significant increase in residual status of available sulphur with increased levels of sulphur application was noticed. Highest residual available sulphur was recorded at 80 kg S/ha (27.53 kg/ha). Lowest residual available sulphur was recorded in control (2.15 kg/ha).

Table 18: Economics of onion cultivation as influenced by sulphur levels

Treatment	Yield (t/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Control	28.46	24020.00	99610.00	75590.00	4.15
20 kg S/ha	31.50	27895.00	110250.00	86230.00	4.43
40 kg S/ha	33.78	25595.00	118230.00	92635.00	4.62
60 kg S/ha	33.00	25520.00	115500.00	89980.00	4.52
80 kg S/ha	32.25	25470.00	112875.00	87405.00	4.43

4.4.9 Economics of onion (cf. Table 18)

Highest cost of cultivation was recorded in T₃ (Rs.25595.00/ha) followed by T₄ (Rs.25520.00/ha), T₅ (Rs.25470.00/ha) and T₂ (Rs.24895.00/ha). Lowest cost of cultivation was recorded in control (Rs.24020.00/ha).

The net returns was found to be highest in T₃ (Rs.92635.00/ha) followed by T₄ (Rs.89980.00/ha), T₃ (Rs.87405.00/ha) and T₂ (Rs.86230.00/ha). Lowest net returns was recorded in control (Rs.75590.00/ha).

Benefit cost ratio (B:C ratio) was highest in T₃ (4.62) followed by T₄ (4.52), T₅ (4.43) and T₂ (4.43). Lowest B:C ratio was noticed in control (4.15).

4.5 EFFECT OF SULPHUR APPLICATION ON GARLIC

4.5.1 Drymatter accumulation (cf. Table 19)

4.5.1.1 Fresh weight of foliage

The fresh weight of foliage increased significantly with increased level of S application. The increase in fresh weight of foliage was noticed up to 60 kg S/ha. Further increase in S application decreased the fresh weight of foliage. Highest fresh weight of foliage was recorded in 60 kg S/ha (9.4 g/plant) which was on par with 40 kg S/ha (9.35 g/plant) and 80 kg S/ha (9.30 g/plant). Lowest fresh weight of foliage was recorded in control (8.85 g/plant) which was on par with 20 kg S/ha (8.90 g/ plant).

4.5.1.2 Dry weight of foliage

A significantly increase in dry weight of foliage was noticed with increased levels of S application up to 60 kg S/ha. Further increase in S application decreased the dry weight of foliage. Highest dry weight of foliage was recorded in 60 kg S/ha (1.88 g/plant) which was on par with 40 kg S/ha (1.87 g/plant). Lowest dry weight of foliage was recorded in control (1.77 g/plant) which was at par with 20 kg S/ha (1.78 g/plant).

4.5.1.3 Fresh weight of bulb

Fresh weight of bulb increased significantly with successive increase in levels of S application up to 60 kg S/ha. Further application of S decreased the fresh weight of bulb. Highest fresh weight of bulb was noticed in 60 kg S/ha (7.69 g/bulb) followed by 40 kg S/ha (7.48 g/bulb) and 80 kg S/ha (7.38 g/bulb). Lowest fresh weight of bulb was noticed in control (6.70 g/bulb) which was on par with 20 kg S/ha (7.03 g/bulb).

4.5.1.4 Dry weight of bulb

The data on dry weight of bulb showed that there was an increase in dry weight of bulb significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in S application decreased the dry weight of bulb. Highest dry weight of bulb was noticed in 60 kg S/ha (4.60 g/bulb) which was on par with 40 kg S/ha (4.48 g/ bulb) and 80 kg S/ha (4.43 g/bulb). Lowest dry weight of bulb was noticed in control (4.02 g/bulb) which was on par with 20 S/ha (4.21 g/bulb).

Table 19 : Drymatter accumulation in leaf and bulb of garlic as influenced by sulphur levels

Treatments	Leaf		Bulb	
	Fresh weight (g/plant)	Dry weight (g/plant)	Fresh weight (g/bulb)	Dry weight (g/bulb)
Control	8.85	1.77	6.70	4.02
20 kg S/ha	8.90	1.78	7.03	4.21
40 kg S/ha	9.35	1.87	7.48	4.48
60 kg S/ha	9.40	1.88	7.67	4.60
80 kg S/ha	9.30	1.87	7.38	4.43
S.Em.±	0.123	0.024	0.184	0.126
C.D. at 0.05	0.372	0.073	0.560	0.383

4.5.2 Bulb characteristics and bulb yield (cf. Table 20)

4.5.2.1 Bulb diameter.

Bulb diameter increased significantly with increased levels of sulphur application up to 60 kg S/ha. Beyond 60 kg S/ha the decrease in bulb diameter was not significant. Highest bulb diameter was noticed in 60 kg S/ha (2.43 cm) which was statistically on par with 40 kg S/ha (2.415 cm) and 80 kg S/ha (2.238 cm). Lowest bulb diameter was noticed in control (2.176 cm) which was at par with 20 kg S/ha (2.227cm).

4.5.2.2 Bulb length

An increase in bulb length with increased levels of sulphur application was noticed up to 40 kg S/ha. But it was not significant. Further increase in sulphur levels decreased the bulb length. But is was not significant. Highest bulb length was noticed in 40 kg S/ha (2.690 cm) and lowest bulb length was observed in control (2.390 cm).

4.5.2.3 Number of cloves per bulb

The data on number of cloves per bulb showed that there was no definite trend about the number of cloves per bulb. Highest number of

Table 20 : Bulb characteristics and yield of garlic as influenced by sulphur levels

Treatments	Bulb diameter (cm)	Bulb length (cm)	No. of cloves/bulb	Bulb yield (t/ha)
Control	2.176	2.390	13.07	5.02
20 kg S/ha	2.227	2.582	11.52	5.27
40 kg S/ha	2.415	2.690	15.47	5.61
60 kg S/ha	2.430	2.582	11.82	5.75
80 kg S/ha	2.238	2.487	10.57	5.53
S.Em.±	0.064	0.071	1.118	0.138
C.D. at 0.05	0.197	NS	NS	0.42

cloves per bulb was noticed in 40 kg S/ha (15.47) and lowest number of cloves per bulb was observed in 80 kg S/ha (10.57).

4.5.3 Bulb yield

Perusal of the data on bulb yield indicate that bulb yield increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in sulphur application decreased the bulb yield. Highest bulb yield was recorded in 60 kg S/ha (5.75 t/ha) which was at par with 40 kg S/ha (5.61 t/ha) and 80 kg S/ha (5.53 t/ ha). Lowest bulb yield was recorded in control (5.02 t/ha) which was at par with 20 kg S/ha (5.27 t/ha).

4.5.4 Biomass production (cf. Table 21)

4.5.4.1 Total fresh weight of leaves

A significant increase in total fresh weight of leaves with increased levels of sulphur application was observed up to 60 kg S/ha and further increase in S application decreased the total fresh weight of leaves. Highest total fresh weight of leaves was recorded in 60 kg S/ha (7.05 t/ha) which was at par with 40 kg S/ha (7.01 t/ha) and 80 kg S/ha (6.98 t/ha). Lowest total fresh weight of leaves was recorded in control (6.64 t/ha) which was at par with 20 kg S/ha (6.67 t/ha).

4.5.4.2 Total drymatter of leaves

Total drymatter content of leaves increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in sulphur application decreased the total dry weight of leaves. Highest total drymatter of leaves was recorded in 60 kg S/ha (1.41 t/ha) which was at par with 40 kg S/ha (1.40 t/ha) and 80 kg S/ha (1.35 t/ha). Lowest total drymatter yield of leaves was recorded in control (1.33 t/ha) which was at par with 20 kg S/ha (1.34 t/ha).

4.5.4.3 Total fresh weight of bulb (cf. 4.5.3)

4.5.4.4 Total drymatter content of bulb

A significant increase in total drymatter content of bulb with increased levels of sulphur application was noticed up to 60 kg S/ha. Further increase in S application decreased the total drymatter content of bulb. Highest total drymatter content of bulb was recorded in 60 kg S/ha (3.45 t/ha) which was at par with 40 kg S/ha (3.36 t/ha) and 80 kg S/ha (3.32 t/ha). Lowest total drymatter content of bulb was observed in control (3.01 t/ha) which was at par with 20 kg S/ha (3.16 t/ha).

Table 21 : Biomass production of garlic as influenced by sulphur levels

Treatments	Leaf (t/ha)		Bulb (t/ha)	
	Fresh weight	Drymatter	Fresh weight	Drymatter
Control	6.64	1.33	5.02	3.01
20 kg S/ha	6.67	1.34	5.27	3.16
40 kg S/ha	7.01	1.40	5.61	3.36
60 kg S/ha	7.05	1.41	5.75	3.45
80 kg S/ha	6.98	1.36	5.53	3.32
S.Em.±	0.092	0.018	0.138	0.094
C.D. at 0.05	0.279	0.055	0.420	0.287

4.5.5 Leaf and bulb tissue composition

4.5.5.1 Nitrogen (cf. Table 22)

Nitrogen content of leaf increased with increased levels of sulphur application up to 60 kg S/ha. Further S application decreased the nitrogen content of leaf. At 30 days after planting, highest nitrogen content was recorded in 60 kg S/ha (5.20%) and lowest nitrogen content was recorded in control (4.77%). At harvest, highest nitrogen content in leaf was recorded in 60 kg S/ha (2.03%) which, was at par with 40 kg S/ha (1.99%), 80 kg S/ha (1.98%) and 20 kg S/ha (1.93%). Lowest nitrogen content in leaf was recorded in control (1.80%).

A significant increase in nitrogen content of bulb with increased levels of sulphur application was noticed up to 60 kg S/ha (2.87%) which was at par with 40 kg S/ha (2.80%), 20 kg S/ha (2.76%) and 80 kg S/ha (2.78%). Lowest nitrogen content of bulb was recorded in control (2.54%).

4.5.5.2 Phosphorus (cf. Table 23)

An increase in phosphorus content of leaf with increased levels of sulphur application was noticed up to 40 kg S/ha and further successive increase in sulphur levels decreased the phosphorus content of leaf but it was not significant. At 30 days after planting, highest phosphorus

Table 22 : Nitrogen content in leaf and bulb of garlic as influenced by sulphur levels

Treatments	Nitrogen (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	4.77	1.80	2.54
20 kg S/ha	5.02	1.93	2.76
40 kg S/ha	5.10	1.99	2.80
60 kg S/ha	5.20	2.03	2.87
80 kg S/ha	4.92	1.98	2.75
S.Em.±	0.21	0.047	0.062
C.D. at 0.05	NS	0.146	0.191

DAP - Days after planting

content of leaf was noticed in 40 kg S/ha (0.554%) and lowest phosphorus content of leaf was noticed in control (0.518%). At harvest, highest phosphorus content of leaf was noticed in 40 kg S/ha (0.387%) and lowest phosphorus content of leaf was noticed in control (0.370%).

An increase in phosphorus content of bulb with increased levels of S application was recorded up to 40 kg S/ha. Further increase in levels of sulphur application decreased the phosphorus content of bulb. Highest phosphorus content of bulb was noticed in 40 kg S/ha (0.519%) and lowest phosphorus content of bulb was noticed in control (0.429%).

4.5.5.3 Potassium (cf. Table 24)

An increase in potassium content of leaf and bulb with increased levels of sulphur application was noticed up to 60 kg S/ha and further increase in sulphur application decreased the potassium content of leaf at both 30 days after planting and harvest. At 30 days after planting, highest potassium content of leaf was noticed in 60 kg S/ha (3.18%) and lowest potassium content of leaf was noticed in control (2.85%). At harvest, highest potassium content of leaf was noticed in 60 kg S/ha (0.980%) and lowest potassium content of leaf was observed in control (0.918%).

Table 23 : Phosphorus content in leaf and bulb of garlic as influenced by sulphur levels

Treatments	Phosphorus (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	0.518	0.370	0.429
20 kg S/ha	0.520	0.382	0.447
40 kg S/ha	0.554	0.387	0.519
60 kg S/ha	0.544	0.385	0.480
80 kg S/ha	0.530	0.372	0.460
S.Em.±	0.012	0.014	0.022
C.D. at 0.05	NS	NS	NS

DAP - Days after planting

Table 24 : Potassium content in leaf and bulb of garlic as influenced by sulphur levels

Treatments	Potassium (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	2.85	0.918	1.050
20 kg S/ha	2.90	0.925	1.08
40 kg S/ha	3.17	0.937	1.10
60 kg S/ha	3.18	0.980	1.13
80 kg S/ha	2.92	0.960	1.17
S.Em.±	0.105	0.017	0.043
C.D. at 0.05	NS	NS	NS

DAP – Days after planting

The potassium content of bulb increased with increased levels of sulphur application up to 60 kg S/ha further increase in S application decreased the potassium content of the bulb. Highest potassium content of the bulb was recorded in 60 kg S/ha (1.13%) and lowest potassium content was noticed in control (1.05%).

4.5.5.4 Sulphur (cf. Table 25)

A significant increase in sulphur content of leaf and bulb with increased levels of sulphur application at all the levels of sulphur application over control was noticed. At 30 days after planting, highest sulphur content of leaf was noticed in 80 kg S/ha (0.528%) which was at par with 60 kg S/ha (0.520%) and lowest sulphur content of leaf was noticed in control (0.217%).

At harvest, highest sulphur content of leaf was recorded in 80 kg S/ha (0.445%) which was at par with 60 kg S/ha and lowest sulphur content of leaf was noticed in control (0.151%). The sulphur content of bulb increased significantly with increased levels of sulphur application. Highest sulphur content of bulb was recorded in 80 kg S/ha (0.763%). Lowest sulphur content of bulb was noticed in control (0.220%).

4.5.6 Uptake of nutrients by leaf and bulb (cf. Table 26)

4.5.6.1 Nitrogen

The nitrogen uptake by leaf and bulb increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further

Table 25 : Sulphur content in leaf and bulb of garlic as influenced by sulphur levels

Treatments	Sulphur (%)		
	Leaf		Bulb
	At 30 DAP	At harvest	
Control	0.217	0.151	0.220
20 kg S/ha	0.362	0.292	0.450
40 kg S/ha	0.408	0.421	0.575
60 kg S/ha	0.520	0.443	0.630
80 kg S/ha	0.528	0.445	0.763
S.Em.±	0.016	0.014	0.034
C.D. at 0.05	0.049	0.043	0.104

DAP – Days after planting

increase in sulphur application decreased the uptake of nitrogen by leaf and bulb.

Highest nitrogen uptake by leaf was noticed at 60 kg S/ha (28.62 kg per ha) which was at par with 40 kg S/ha (27.86 kg/ha). Lowest nitrogen uptake was noticed in control (23.97 kg/ha).

Highest nitrogen uptake by bulb was observed at 60 kg S/ha (99.01 kg/ha) and lowest nitrogen uptake was recorded in control (76.45 kg/ha).

4.5.6.2 Phosphorus

The phosphorus uptake by leaf increased significantly with increased levels of sulphur application up to 60 kg S/ha. Further increase in sulphur application decreased the uptake of phosphorus by leaf. Highest phosphorus uptake by leaf was noticed in 60 kg S/ha (5.43%) which was at par with 40 kg S/ha (5.42%). Lowest phosphorus uptake was noticed in control (4.92%) which was at par with 80 kg S/ha (5.02%).

The phosphorus uptake by bulb increased significantly with increased levels of sulphur application up to 40 kg S/ha. Further increase in levels of sulphur application decreased the uptake of phosphorus. Highest phosphorus uptake was noticed in 40 kg S/ha (17.44 kg/ha) which was on par with 60 kg S/ha (16.50 kg/ha). Lowest

phosphorus uptake was noticed in control (12.91 kg/ha) which was at par with 20 kg S/ha (14.12 kg/ha).

4.5.6.3 Potassium

The data regarding uptake of potassium by leaf increased with increased levels of sulphur application up to 60 kg S/ha. Further increase in S level decreased the potassium uptake but it was not significant. Highest K uptake by leaf was noticed in 60 kg S/ha (13.82 kg/ha) and lowest K uptake by leaf was noticed in control (12.21 kg/ha).

A significant increase in potassium uptake by bulb was noticed with increased levels of sulphur application up to 60 kg S/ha. Further application of S decreased the potassium uptake by bulb. Highest K uptake was noticed in 60 kg S/ha (38.98 kg/per ha) which was at par with 80 kg S/ha (38.84 kg/ha). Lowest K uptake was noticed in control (31.6 kg/ha).

4.5.6.4 Sulphur

The data pertaining to uptake of sulphur by leaf and bulb of garlic increased significantly with increased levels of sulphur application.

Highest S uptake by leaf was noticed in 60 kg S/ha (6.25 kg/ha) which was at par with 80 kg S/ha (6.00 kg/ha) lowest S uptake by leaf was noticed in control (2.01 kg/ha).

Table 26 : Nutrient uptake by leaf and bulb of garlic as influenced by sulphur levels

Treatments	Nutrient uptake (kg ha ⁻¹)									
	Leaf					Bulb				
	Nitrogen	Phosphorus	Potassium	Sulphur	Nitrogen	Phosphorus	Potassium	Sulphur		
Control	23.94	4.92	12.21	2.01	76.45	12.91	31.60	6.62		
20 kg S/ha	25.86	5.12	12.40	3.91	87.22	14.12	34.13	14.22		
40 kg S/ha	27.86	5.42	13.12	5.89	94.08	17.44	36.96	19.32		
60 kg S/ha	28.62	5.43	13.82	6.25	99.01	16.56	38.98	21.73		
80 kg S/ha	26.73	5.02	12.96	6.00	91.30	15.27	38.84	25.33		
S.E.m.±	0.458	0.044	0.684	0.082	1.103	0.422	0.656	0.297		
C.D. at 0.05	1.413	0.136	NS	0.251	3.399	1.301	2.020	0.916		

Highest S uptake by bulb was noticed in 80 kg S/ha (25.33 kg/ha) and lowest S uptake was noticed in control (6.62 kg/ha).

4.5.7 Total uptake of nutrients (cf. Table 27)

4.5.7.1 Nitrogen

Total uptake of nitrogen increased significantly with increased levels of sulphur application up to 40 kg per ha. Further increase in levels of S decreased the total N uptake. Highest total N uptake was noticed in 40 kg S/ha (121.94 kg/ha) which was at par with 60 kg S/ha (119.92 kg/ha) and 80 kg S/ha (118.03 kg/ha). Lowest total N uptake was noticed in control (100.39 kg/ha).

4.5.7.2 Phosphorus

Total uptake of phosphorus increased significantly with increased levels of S application up to 40 kg S/ha (22.80 kg/ha) which was at par with 60 kg S/ha (21.93 kg/ha). Lowest total P uptake was noticed in control (17.83 kg/ha).

4.5.7.3 Potassium

Total uptake of potassium increased significantly with increased levels of S application up to 60 kg S/ha (52.8 kg/ha) which was at par with 80 kg S/ha (51.8 kg/ha). Lowest total potassium uptake was noticed in control (43.8 kg/ha).

Table 27: Total uptake of nutrients by garlic as influenced by sulphur levels

Treatments	Total uptake (kg ha ⁻¹)			
	Nitrogen	Phosphorus	Potassium	Sulphur
Control	100.39	17.83	43.80	8.63
20 kg S/ha	113.08	19.24	46.53	18.13
40 kg S/ha	121.94	22.86	50.08	25.21
60 kg S/ha	119.92	21.93	52.80	27.98
80 kg S/ha	118.03	20.29	51.80	31.33
S.E.m. [±]	1.397	0.414	0.615	0.737
C.D. at 0.05	4.305	1.275	1.896	2.272

4.5.7.4 Sulphur

A significant increase in the total sulphur uptake with increased levels of sulphur application was recorded. Highest total uptake of sulphur was noticed in 80 kg S/ha (31.33 kg/ha) and lowest total S uptake was noticed in control (8.03 kg/ha).

4.5.8 Residual nutrients status (cf. Table 28)

4.5.8.1 Nitrogen

A decrease in residual available nitrogen status with increased levels of sulphur application was noticed up to 40 kg S/ha. Further increase in doses of S application increased the residual available nitrogen status. Highest residual nitrogen status was recorded at control (233.61 kg/ha) and lowest residual nitrogen status was recorded at 40 kg S/ha (207.94 kg/ha).

4.5.8.2 Phosphorus

A decrease in residual available phosphorus with increased levels of sulphur application was recorded up to 40 kg S/ha. Further increase in levels of S application decreased the residual available P. Highest residual available P was recorded at control (20.40 kg/ha) and lowest residual P was recorded at 40 kg S/ha (16.43 kg/ha).

4.5.8.3 Potassium

Table 28: Residual nutrient status after the harvest of garlic crop as influenced by sulphur levels

Treatments	Residual nutrients (kg ha ⁻¹)			
	Nitrogen	Phosphorus	Potassium	Sulphur
Control	233.61	20.40	831.0	1.8
20 kg S/ha	223.28	19.84	828.0	7.42
40 kg S/ha	207.94	16.43	823.4	16.64
60 kg S/ha	213.98	18.87	819.3	26.70
80 kg S/ha	218.99	19.30	822.7	29.46
S.Em.±	7.020	1.120	9.343	0.703
C.D. at 0.05	NS	NS	NS	2.166

A decrease in residual available K with increased levels of sulphur application was noticed up to 40 kg S/ha. Further increase in doses of S application decreased the residual K status. Lowest residual potassium was noticed in 40 kg S/ha (823.4 kg/ha). Highest residual K was noticed in control (831.0 kg/ha).

4.5.8.4 Sulphur

A significant increase in residual status of available sulphur with increased level of sulphur application was noticed. Higher residual S was recorded in 80 kg S/ha (29.40 kg/ha) and lowest residual S was recorded in control (1.8 kg/ha).

4.5.9 Economics of garlic (cf. Table 29)

Highest cost of cultivation was recorded in T₅ (Rs.33793.00/ha) followed by T₄ (Rs.33718.00/ha), T₃ (Rs.33508.00/ha) and T₂ (Rs.33343.00/ha). Lowest cost of cultivation was recorded in control (Rs.33168.00/ha).

Net returns was found to be highest in T₄ (Rs.127282.00/ha) followed by T₃ (Rs.123512.00/ha), T₅ (Rs.121047.00/ha) and T₂ (Rs.114217.00/ha). Lowest net returns was recorded in control (Rs.107392.00/ha). Benefit cost ratio (B:C ratio) was highest in T₄ (4.77) followed by T₃ (4.68), T₅ (4.58) and T₂ (4.42). Lowest B:C ratio was found in control (4.29).

Table 29: Economics of garlic cultivation as influenced by sulphur levels

Treatment	Yield (t/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Control	5.02	33168.00	140560.00	107392.00	4.24
20 kg S/ha	5.27	33343.00	147560.00	114217.00	4.42
40 kg S/ha	5.61	33568.00	157080.00	123512.00	4.68
60 kg S/ha	5.75	33718.00	161000.00	127282.00	4.77
80 kg S/ha	5.53	33793.00	154840.00	121047.00	4.58

DISCUSSION

V. DISCUSSION

Plant nutrient sulphur will be of growing world wide importance as food production continues to increase. Sulphur is one of the 16 nutrients mandatory for plant growth and ranks third or fourth in amount needed for optimal plant growth behind nitrogen, potassium, and some times, phosphorus. Its role in crop production is well documented. Sulphur will continue to challenge researchers into the 21st Century.

World wide interest in sulphur as a plant nutrient has increased greatly in the last two decades. Less than 20 years ago, only 36 countries reported sulphur deficiencies. Today more than 70 countries have found need to apply sulphur (Morris, 1988).

India first documented the need for sulphur addition in 1960's. Since that time, responses have been reported on 30 crops in many different regions of the country (Tandon, 1984).

In recent years, however, increased use of high analysis fertilizers coupled with high removal of S due to increased crop production has resulted in wide spread deficiency of S. And this sulphur deficiency affects both the yield and quality of food for human and animal consumption.

Bulb crops such as onion and garlic require heavy manuring. Besides N, P and K, sulphur has been found to be very beneficial for these crops.

The soils of Kittur Rani Chennamma College of Horticulture (KRCCH), Arabhavi are derived from sand stone with undulating topography. The soils of floriculture block, part of olericulture and part of pomology block are developed on up slope. These soils are coarse textured with light brown (7.5 YR 6/4) to dark brown (7.5 YR 4/4) in colour and low in organic carbon. The rest of the soils of olericulture and pomology block, soils of spices and plantation crops block and medicinal and aromatic plants block are developed on down slope. These soils are fine textured with dark yellowish brown (10 YR 3/4) to dark brown (10 YR 2/2) in colour and high in organic carbon. Fine texture and dark colour of the soils developed on down slope may be due to horizontal movement of finer material and organic matter from up slope soils and accumulation at down slope. Development of red, reddish brown and brown soils at up slope and black soils at down slope has been reported by many workers (Satyanarayana and Biswas, 1970).

The soils of KRCCH, Arabhavi were low to high in organic carbon content. Soils were low to medium in available N, low to high in available P and high in available K. The soils of KRCCH, Arabhavi were alkaline in pH, low in electrical conductivity with ESP ranging from 1.98 to 11.49

indicates that the soils are undergoing alkalization. Since the soils are under irrigation for more than 25 years (GLBC area), they have not yet been turned to saline or alkaline compared to soils of Malaprabha and Tungabhadra command area. The coarse textured nature of soils under study which have been developed on sand stone made them well drained and must have slowed down the process of alkalization.

The S deficiency in soils of KRCCH, Arabhavi may be mainly because the study area has been under irrigation for more than 25 years and subjected to intensive cropping. Tandon (1991) reported that the increasing incidences of S deficiency in Indian soils is due to:

- i) Increase in crop yields, uptake and removal of sulphur from the soil over years.
- ii) Wide gap between S removal and S application
- iii) Major shifts in the product pattern towards S free fertilizers
- iv) Coarse textured soils are inherently vulnerable to S deficiencies.
- v) Losses of S through leaching and erosion *etc.*

5.1 STATUS OF AVAILABLE SULPHUR IN SOILS OF KRCCH, ARABHAVI

Available sulphur content of soils of KRCCH, Arabhavi ranged from 5.37 to 29.00 mg kg⁻¹. Balanagoudar and Satyanarayana (1990a) observed sulphate sulphur content ranging from 2.8 to 250.0 mg kg⁻¹ with an average of 29.3 mg kg⁻¹ in some vertisols and alfisols of north

Karnataka. Available sulphur was extracted by using 0.15% CaCl_2 (Williams and Steinbergs, 1959). Padmaja *et al.* (1993) reported that the inorganic sulphate sulphur content extracted with 0.15 per cent CaCl_2 ranged from 8 to 19 mg kg^{-1} among the soils of Nalgonda and Mahaboob nagar districts. Kumar *et al.* (1994) reported that the 0.15 per cent CaCl_2 extractable S ranged from 0.85 to 34.6 mg kg^{-1} in soils of Debatoi, 2.6 to 85.5 mg kg^{-1} in soils of Dumka and 2.6 to 45.1 mg kg^{-1} in soils of Laxmipur series of South Chotanagpur of Bihar. Ganeshamurthy and Saha (1999) reported that the available S content of Vertisols of Dharwad region ranged from 3.1 to 55.0 mg kg^{-1} with a mean value of 11.9 mg kg^{-1} .

Out of 49 samples analysed, 23 samples were below 10 mg kg^{-1} . Considering less than 10 mg kg^{-1} of CaCl_2 extractable S soils as low status (Mehta *et al.*, 1988), about 46 per cent of soils of KRCCH, Arabhavi can be rated as deficient in available S. This shows an existence of widespread deficiency of sulphur in these soils suggesting relatively greater need of sulphur fertilization in crops grown on soils of KRCCH, Arabhavi. The S deficiency in soils of KRCCH, Arabhavi may be mainly because the study area has been under irrigation for more than 25 years and subjected to intensive cropping.

5.2 RELATIONSHIP BETWEEN AVAILABLE SULPHUR AND SOME SOIL PROPERTIES

The pH, EC, organic carbon, available nitrogen, available potassium, CaCO_3 , exchangeable Ca^{2+} plus Mg^{2+} , Exchangeable Na^+ , exchangeable K^+ , CEC, silt and clay content showed positive correlation with available sulphur.

Available P, coarse sand, fine sand content showed negative correlation with available sulphur.

Organic carbon content correlated positively and significantly with available sulphur. This suggests that high linkage of available sulphur with organic fraction of the soil. Vageesh *et al.* (1989) also reported significant positive correlation between pH and available sulphur and positive correlation between organic carbon and available sulphur content for soils of Shimoga.

Misra *et al.* (1990) also reported positive correlation between available sulphur and clay content for some soils of orissa. Sulphate sulphur correlated significantly and positively with pH, EC, CaCO_3 and clay content in some vertisols and alfisols of North Karnataka (Balanagoudar and Satyanarayana, 1990b). Sulphate sulphur was found to have no significant correlation with pH, EC, CaCO_3 , clay and organic carbon contents of some vertisols of Andhra Pradesh (Padmaja *et al.*, 1993).

5.3 EFFECT OF SULPHUR APPLICATION OF ONION

5.3.1 Influence of sulphur application on growth, yield and quality components of onion

Drymatter production in onion plants increased significantly with increased levels of sulphur application up to 40 kg S/ha (Fig. 3). Beyond that the decrease in drymatter production was not significant. This increase in drymatter production may be attributed to the increased synthesis of protein in plants due to sulphur which in turn resulted in healthy increase in xylem, collenchyma and sclerenchyma tissues (Singh, 1979). Kumar and Singh (1992) reported that the chloroplast synthesis is accelerated by a greater availability of sulphur to plants. Higher frequency of chloroplast increase the photosynthetic efficiency of plants and hence the drymatter content is increased. Application of sulphur helps in the availability of other nutrients along with its availability and therefore increases the drymatter production (Thippeswamy, 1993). Since nitrogen is a constituent of chlorophyll, the increased availability of which might have enhanced the photosynthesis which in turn resulted in better vigour of the onion plant. So also with P and K. Phosphorus being an essential constituent of cellular proteins and nucleic acids encouraged meristematic activities of onion plants and in turn plant growth. Thus the increase in drymatter accumulation may be attributed to better growth and increased uptake of all the nutrients at higher levels of sulphur application. Similar results have also been

reported by Kumar and Sahay (1954), Salimath (1990) and Sachdev *et al.* (1991).

Bulb diameter is an important yield parameter increased significantly with increased levels of sulphur application up to 40 kg S/ha. Beyond that the decrease in bulb diameter was not significant. Patil *et al.* (1989) reported positive and highly significant correlation of bulb weight with leaf weight and bulb diameter. Since leaf weight, bulb weight and bulb diameter are positively and significantly correlated each other, the increase in leaf weight and bulb weight might have direct influence on bulb diameter which inturn may be due to higher photosynthetic efficiency of onion due to sulphur application. Therefore photosynthates must have been translocated to the bulbs, the storage organ of onion plants. Further more sulphur application increased the uptake of N, P, K and S that might have influenced the synthesis and translocation of stored materials. These results are in accordance to Salimath (1990) who reported maximum bulb diameter at 50 kg S/ha. Similar results have also been reported by Paterson (1979), Thippeswamy (1993) and Sumantrakar and Tiwari (1993).

Bulb yield increased significantly with increased levels of sulphur application up to 40 kg S/ha. Beyond that the decrease in bulb yield was not significant. Since the bulb diameter has direct influence on yield of onion, the increase in bulb yield at higher levels of S may be due to

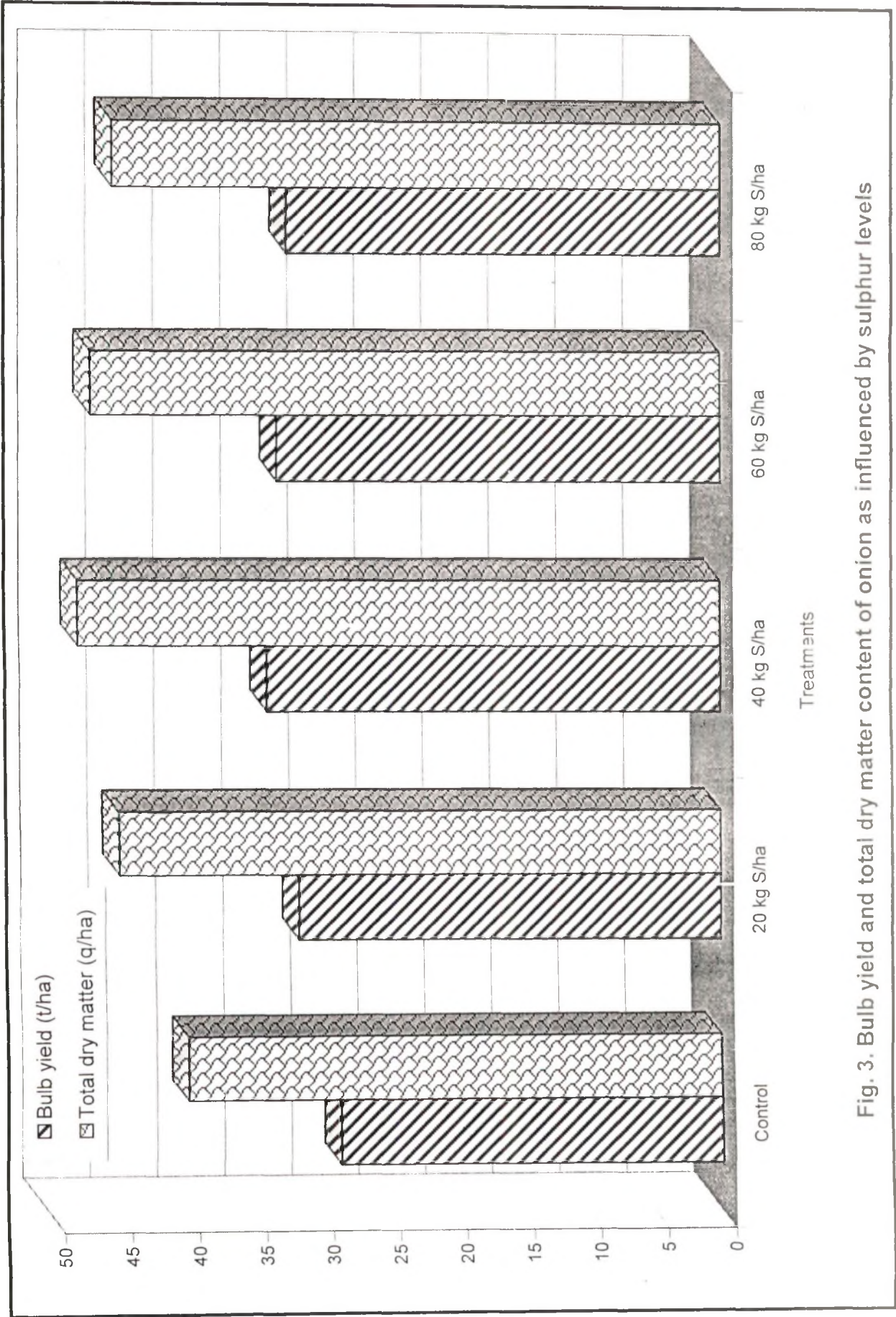


Fig. 3. Bulb yield and total dry matter content of onion as influenced by sulphur levels

increased uptake of N, P, K and S which might have increased the photosynthesis and translocation of photosynthates to the bulb, the storage organ of the onion. Salimath (1990) also obtained maximum bulb yield at 50 kg S/ha. Similar results were also reported by Paterson (1979) and Thippeswamy (1993).

Bulb density of onion bulbs increased with increased levels of sulphur application. But the increase was not significant. The increase in the bulb density may be due to increase in the accumulation of total soluble solids in the bulb.

Total soluble solids content of onion bulbs increased significantly with increased levels of sulphur application. Highest TSS content was noticed in 80 kg S/ha. The increase in TSS content over control was 4.3 per cent in 20 kg S/ha, 30.4 per cent in 40 kg S/ha. The varieties with high soluble solids and high drymatter content are considered suitable for processing purposes (Kapur *et al.*, 1976). The increase in TSS content with increase in levels of S application was reported by Kumar and Singh (1992). Total soluble solids, an important quality criteria for onions, contribute towards flavour (Sharma *et al.*, 1996). Primary flavour compounds in onion are S-containing organic compounds (Randle *et al.*, 1993). Similar results were also reported by Thippeswamy (1993) and Randle *et al.* (1995).

5.3.2 Influence of sulphur application on tissue composition of onion

Nitrogen content in leaf and bulb increased with increased levels of sulphur application up to 60 kg S/ha. Beyond that the decrease in N content was not significant. Further the values for nitrogen content of leaves were higher at early stages of growth and declined with age. Role of sulphur to bring a change in protein metabolism of plants has been reported (Vimal, 1972) as a result of change in nitrate reductase activity. An increase in the nitrate reductase activity by application of sulphur was reported by Kumar and Singh (1994). So to meet the substrate (NO_3^-) requirement, plants might have absorbed more nitrogen. Favourable effect of S on N absorption was also reported by Singh *et al.* (1995b) in garlic. In plants, N and S are present in a specific ratio, hence an increase in the concentration of S increases the concentration of N indicating favourable effect of S on N content in plants. Thus S at lower levels resulted in lower N concentration and at higher levels has favourable effect on N absorption. Thus with increase in S levels increase in N content was noticed. Similar results have also been reported by Singh *et al.* (1995b) and Singh *et al.* (1996). Thippeswamy (1993) also reported synergistic behaviour of N and S in onion.

Phosphorus content in leaf and bulb increased with increased levels of S up to 40 kg S/ha. Beyond that there was a decrease in P

content. Sulphur at lower levels might have synergistic effect on phosphorus content. At higher levels of S, phosphorus and sulphur showed antagonistic effect. The results are in accordance to Ali (1991), Aulakh (1989) and Pasricha (1987) for field crops.

Potassium content in leaf and bulb increased with increased levels of sulphur application up to 60 kg S/ha. Beyond that there was a decrease in K content. Application of S increased the concentration of N, P and S in plants, which are involved in the synthesis of plant metabolites. The role of K is well established in the activation of most of the enzymes involved in plant metabolism (Mengel and Kirkby, 1982). Potassium is also required for the synthesis of ATP which plays important role in translocation of photosynthates. Hence there may be increase in plant demand for K, which resulted in higher concentration of K in onion. Increase in K content with increase in S levels was reported by Thippeswamy (1993).

Sulphur content in leaf and bulb increased significantly with increased levels of sulphur application. Highest S content was noticed in 80 kg S/ha and lowest S content was noticed in control. This may be due to the rapid absorption and translocation of it by the plant with adequate supply of S to the soil deficient in sulphur. Similar results were also reported by Singh *et al.* (1996) in onion and Singh *et al.* (1995a), Singh *et al.* (1995b) and Pawar and Patil (1989) in garlic.

5.3.3 Influence of sulphur application on the uptake of nutrients

Uptake of nitrogen by leaf and bulb increased significantly with increased levels of S application up to 60 kg S/ha. Beyond that the decrease in N uptake was not significant (Fig.4). This is apparently the result of favourable effect of S on N absorption coupled with greater drymatter production. Similar results have also been reported by Thippeswamy (1993), Singh *et al.* (1996) in onion and Singh *et al.* (1995b) in garlic.

Phosphorus uptake by leaf and bulb increased significantly with increased levels of sulphur application up to 40 kg S/ha. This is due to increased P content with increased levels of S application up to 40 kg S/ha and greater drymatter production. This resulted in increased uptake of P with increased levels of S application up to 40 kg S/ha. Further increase in S levels decreased the P uptake both by leaf and bulb due to decrease in concentration of P as P and S showed antagonistic effect at higher S levels. The results are in conformity with there reported by Thippeswamy (1993) and Singh *et al.* (1995b).

Potassium uptake by leaf and bulb increased significantly with increased levels of S application up to 60 kg S/ha. Beyond that the decrease in K uptake was not significant. This may be attributed to increased K content and greater drymatter production at higher levels of

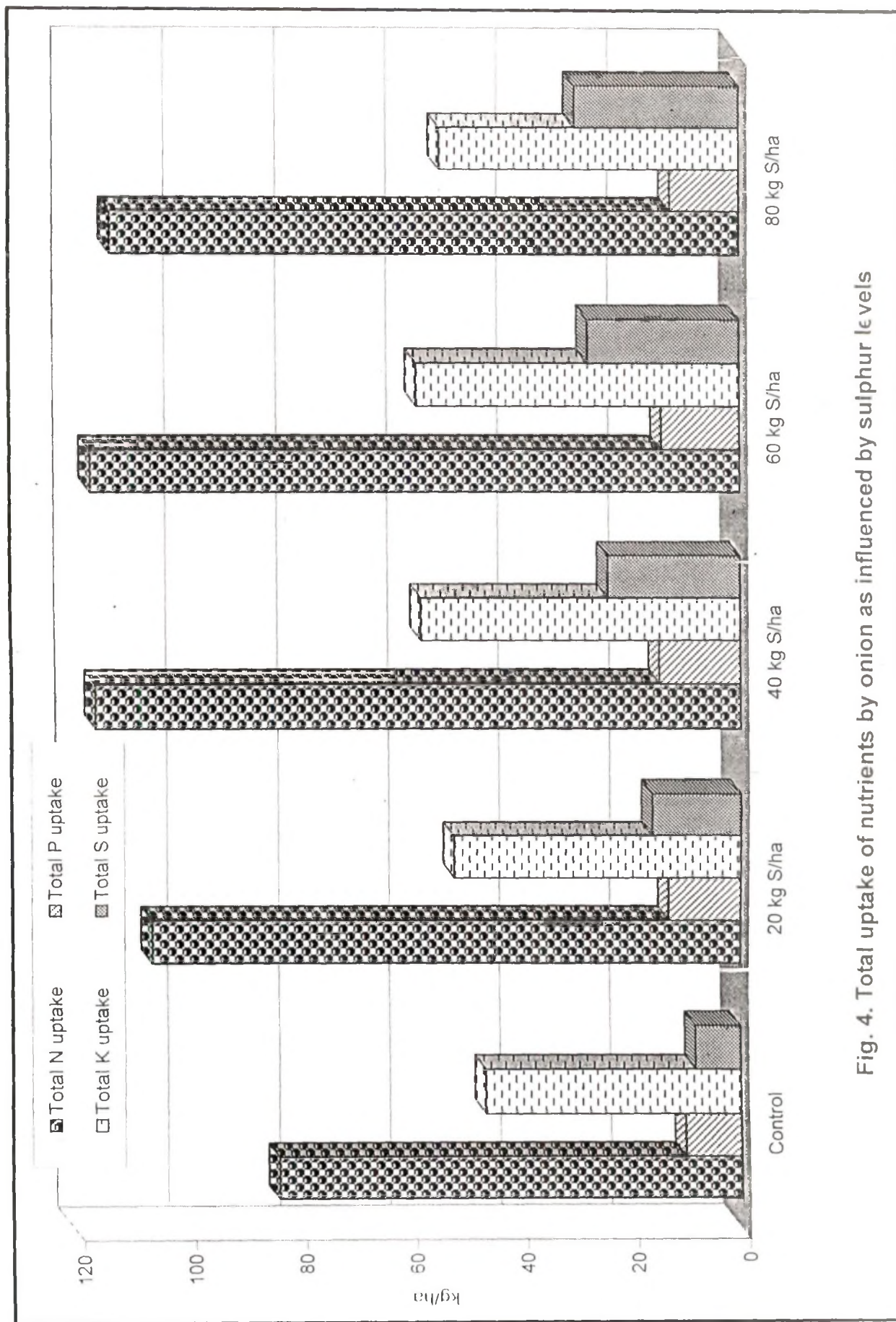


Fig. 4. Total uptake of nutrients by onion as influenced by sulphur levels

S application. Therefore, total uptake of potassium increased with increased levels of S up to 60 kg S/ha. Beyond that the decrease in K uptake was not significant. Similar results were observed by Salimath (1990) and Thippeswamy (1993).

Sulphur uptake by leaf and bulb increased significantly with increased levels of S application. Highest S uptake was noticed at 80 kg S/ha. This may be due to higher S content and higher drymatter production at higher levels of S application. Thus the total uptake of sulphur also increased significantly with increased levels of S application. The results are in conformity with those reported by Salimath (1990) and Thippeswamy (1993) in onion and Pawar and Patil (1989), Singh *et al.* (1995a) and Singh *et al.* (1995b) in garlic.

5.3.4 Influence of S application on residual status of nutrients

A significant decrease in residual available nitrogen with increased levels of sulphur application up to 60 kg S/ha was noticed. Beyond that the increase in residual available N status was not significant. Highest residual available N was observed in control where the total uptake of N is lowest. Lowest residual available N was noticed in 60 kg S/ha where the total uptake of N is highest. This also explains the effect of S on increasing N recovery by onion.

Residual available P decreased with increased levels of S application up to 40 kg S/ha. Highest residual available P was recorded in control where the total uptake of P is lowest. Lowest residual P was recorded in 40 kg S/ha where total uptake of P is highest. Higher residual P at higher S level (60 kg/ha) clearly shown the antagonistic effect of S on P at higher levels.

Residual available S increased significantly with increased levels of sulphur application. Highest residual available S was recorded at 80 kg S/ha and lowest residual available sulphur at control. The results are in confirmity with Poongothai *et al.* (1999) who reported that sulphur fertilization increased the available sulphur content of post harvest soil significantly. The residual S in soil was not in proportion to the applied S levels. This may be due to transformation of applied S into insoluble forms of sulphur which needs investigation.

5.4 EFFECT OF SULPHUR APPLICATION ON GARLIC

5.4.1 Influence of sulphur application on growth and yield components of garlic

Drymatter production in garlic plants increased significantly with increased levels of sulphur application up to 60 kg S/ha (Fig.5). Beyond that the decrease in drymatter production was not significant. This may be attributed to better growth and increased uptake of all the nutrients at higher levels of sulphur application. Similar results have also been

reported by Kumar and Sahay (1954), Salimath (1990) and Sachdev *et al.* (1991) in onion.

Bulb diameter is an important yield parameters increased significantly with increased levels of sulphur application up to 60 kg S/ha. Beyond that the decrease was not significant. Patil *et al.* (1989) reported positive and highly significant correlation of bulb weight with leaf weight and bulb diameter in onion. Therefore, increased bulb weight and leaf weight might have positive influence on bulb diameter which inturn may be due to higher photosynthetic efficiency of garlic due to sulphur application. Therefore, photosynthates must have been translocated to the bulb, the storage organ of garlic plants. Further more sulphur application increased the uptake of N, P, K and S that might have influenced the synthesis and translocation of stored materials. These results are in conformity with those reported by Paterson (1979), Salimath (1990) and Thippeswamy (1993) in onion.

Bulb length increased with increased levels of S application up to 40 kg S/ha. Beyond that there was a decrease in bulb length. It was statistically not significant. Highest bulb length was noticed in 40 kg S/ha and lowest bulb length was recorded in control.

Number of cloves per bulb did not show any consistent trend with the increase in levels of sulphur application. Maximum number of cloves

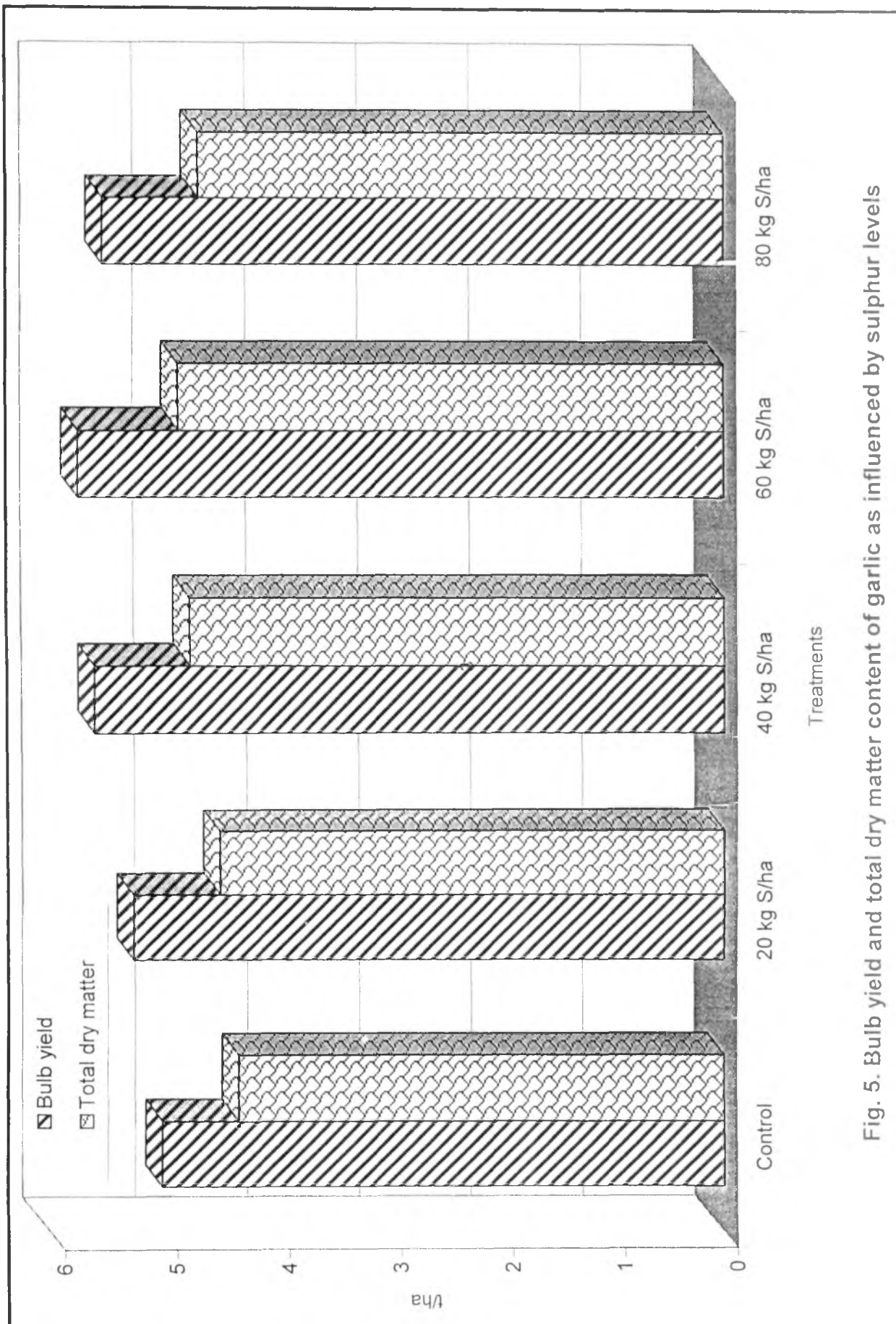


Fig. 5. Bulb yield and total dry matter content of garlic as influenced by sulphur levels

per bulb was recorded in control. Minimum number of cloves per bulb was recorded in 80 kg S/ha.

Bulb yield increased significantly with increased levels of sulphur application up to 60 kg S/ha. Beyond that the decrease in bulb yield was not significant. Since the bulb diameter has direct influence on yield of garlic, the increase in bulb yield at higher levels of S may be due to increased uptake of N, P, K and S which might have increased the photosynthesis and translocation of photosynthates to the bulb, the storage organ. Similar results have also been reported by Pawar and Patil (1989), Singh *et al.* (1995a) and Singh *et al.* (1995b).

5.4.2 Influence of sulphur application on tissue composition of garlic

Nitrogen content in leaf and bulb increased with increased levels of sulphur application up to 60 kg S/ha. Beyond that the decrease in N content was not significant. Further the values for nitrogen content of leaves were higher at early stages of growth and declined with age. Singh *et al.* (1995b) reported favourable effect of S on N absorption. Therefore, the increase in N content with increased S levels was due to synergistic behaviour of N and S. Similar results have been reported by Singh *et al.* (1995b) in garlic and Thippeswamy (1993) in onion.

Phosphorus content in leaf and bulb increased with increased levels of S up to 40 kg S/ha. Beyond that there was a decrease in P content. Sulphur at lower levels might have synergistic effect on phosphorus content. At higher levels of S, phosphorus and sulphur showed antagonistic effect. The results are in accordance with Ali (1991), Aulakh (1989) and Pasricha (1987) for field crops.

Potassium content of leaf and bulb increased with increased levels of sulphur application up to 60 kg S/ha. Beyond that there was a decrease in K content. Similar increase in K content with increased levels of S was reported by Thippeswamy (1993) in onion.

Sulphur content in leaf and bulb increased significantly with increased levels of sulphur application. Maximum S content was recorded in 80 kg S/ha and lowest S content was recorded in control. This may be due to the rapid absorption and translocation of it by the plant with adequate supply of S to the soil deficient in sulphur. Similar results were also reported by Pawar and Patil (1989), Singh *et al.* (1995a) and Singh *et al.* (1995b) and in garlic.

5.4.3 Influence of sulphur application on the uptake of nutrients

Uptake of nitrogen by leaf and bulb increased significantly with increased levels of S application up to 60 kg S/ha (Fig.6). Beyond that the decrease in N uptake was not significant. This is apparently the

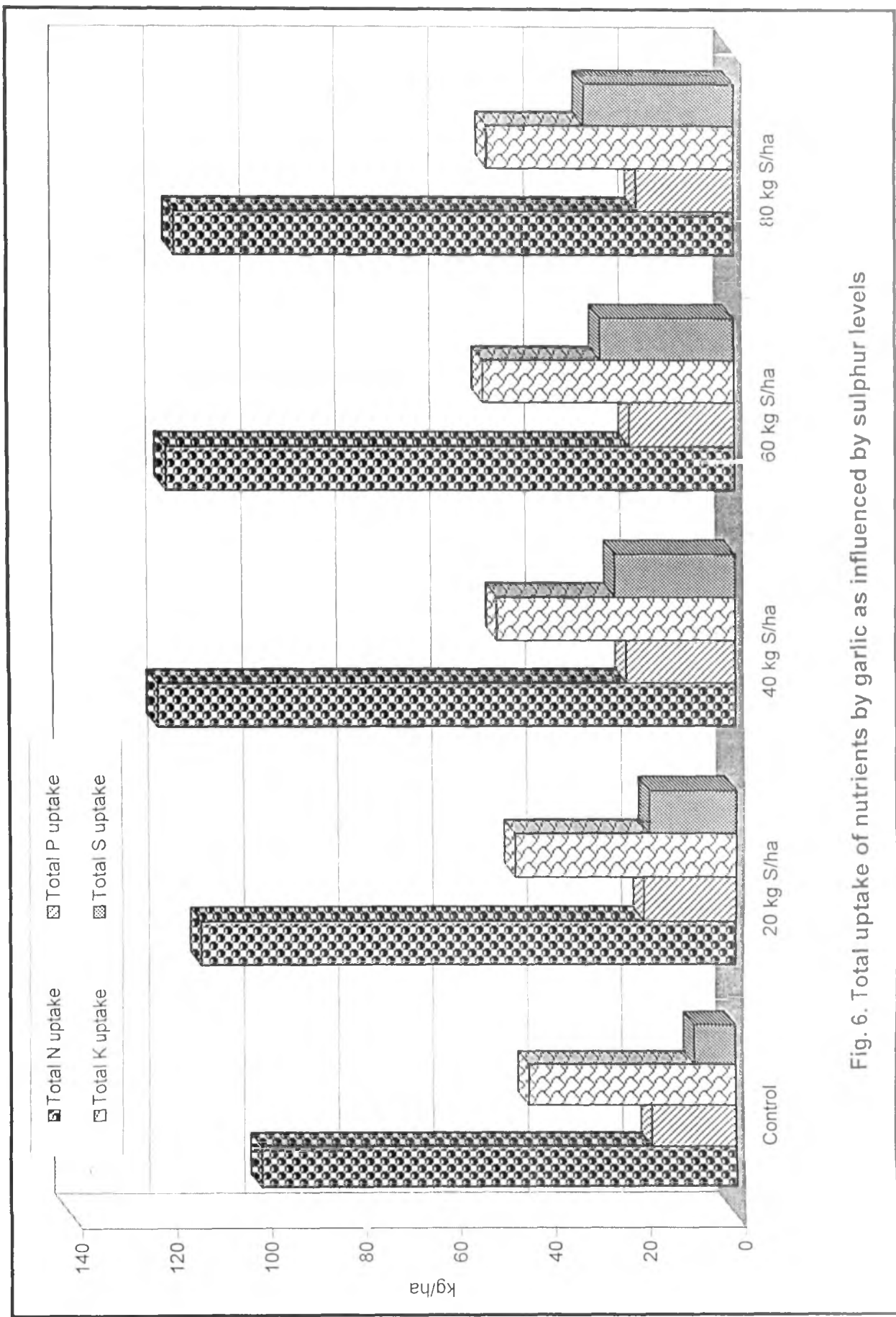


Fig. 6. Total uptake of nutrients by garlic as influenced by sulphur levels

result of favourable effect of S on N absorption coupled with greater dry matter production. Similar results have also been reported by Thippeswamy (1993), Singh *et al.* (1996) in onion and Singh *et al.* (1995b) in garlic.

Phosphorus uptake by leaf and bulb increased significantly with increased levels of sulphur application up to 40 kg S/ha. This is due to increased P content with increased levels of S application up to 40 kg S/ha and greater drymatter production. This resulted in increased P uptake with increased levels of S up to 40 kg S/ha. Further increase in S levels decreased the P uptake both by leaf and bulb due to decrease in concentration of P as P and S showed antagonistic effect at higher S levels. The results are in conformity with those reported by Singh *et al.* (1995b) in garlic and Thippeswamy (1993) in onion.

Potassium uptake by leaf and bulb increased with increased levels of S application up to 60 kg S/ha. Beyond that the decrease in K content was not significant. This may be attributed to increased K content and greater drymatter production at higher levels of S application. Similar results were also reported by Salimath (1990) and Thippeswamy (1993) in onion.

Sulphur uptake by leaf and bulb increased significantly with increased levels of S application. Maximum S uptake was noticed at 80 kg S/ha. This may be due to higher S content and higher drymatter production at higher levels of S application. The results are in conformity

with those reported by Salimath (1990), Thippeswamy (1993) and Singh *et al.* (1996) in onion and Pawar and Patil (1989), Singh *et al.* (1995a) and Singh *et al.* (1995b) in garlic.

5.4.4 Influence of S application on residual status of nutrients

A decrease in residual available nitrogen with increased levels of sulphur application up to 40 kg S/ha was noticed. Highest residual available N was observed in control where the total uptake of N is lowest. Lowest residual available N was noticed in 40 kg S/ha where the total uptake of N is highest. This explains the effect of S on increasing N recovery by garlic.

Residual available P decreased with increased levels of S application up to 40 kg S/ha. Highest residual available P was recorded in control where the total uptake of P is lowest. Lowest residual available P was recorded in 40 kg S/ha where the total uptake of P is highest.

Residual available S increased significantly with increased levels of sulphur application. Highest residual available S was recorded at 80 kg S/ha and lowest residual available S at control. The results are in conformity with Poongothai *et al.* (1999) who reported that the sulphur fertilization increased the available sulphur content of post harvest soil significantly. The residual S in soil was not in proportion to the applied S levels. This may be due to transformation of applied S into insoluble forms of sulphur which needs to be investigated.

Practical utility

The results of the field experiments indicated that, application of 40 kg S/ha to onion and 60 kg S/ha to garlic can be recommended in sulfur deficient soils of Ghataprabha Left Bank Command Area.

Future line of work

1. Response of onion and garlic to sulphur application may be studied in different soil types.
2. Effect of sulphur application on the keeping quality of onion and garlic may be studied.
3. Interaction of sulphur with other nutrients may be studied in onion and garlic.

SUMMARY

VI. SUMMARY

An investigation on status of available sulphur in soils of KRCCH, Arabhavi and studies of sulphur nutrition of onion and garlic in sulphur deficient soil was carried out in KRCCH, Arabhavi (Ghataprabha Left Bank Command Area), UAS, Dharwad. Forty nine soil samples from five blocks were collected for the present investigation. The results of the research work done are summarised as follows:

1. Available sulphur content of soils of KRCCH, Arabhavi ranged from 5.37 to 29.00 ppm. Out of 49 samples analysed, 23 samples were below 10 ppm. About 46 per cent of the soils of KRCCH, Arabhavi are considered as deficient in available sulphur.
2. pH, EC, organic carbon, available nitrogen, available potassium, CaCO_3 , exchangeable Ca^{2+} plus Mg^{2+} , exchangeable Na^+ , exchangeable K^+ , CEC, silt and clay content showed positive correlation with available sulphur. Available P, coarse sand, fine sand content showed negative correlation with available sulphur. Among all properties organic carbon content correlated (0.289*) positively and significantly with available sulphur.
3. Application of S at 40 kg S/ha registered maximum drymatter production of leaves and bulbs of onion (1140 and 3640 kg/ha, respectively) and it was at par with 60 kg S/ha (1120 and 3560 kg/ha, respectively) and 80 kg S/ha (1050 and 3470 kg/ha, respectively). Minimum dry matter production of leaves and bulbs of onion was recorded at control (920 and 3060 kg/ha, respectively).

4. Application of 40 kg S/ha registered the maximum bulb yield of onion 125 (33.78 t/ha) and it was at par with 60 kg S/ha (33.00 t/ha) and 80 kg S/ha (32.25 t/ha). Minimum bulb yield was recorded at control (28.46 t/ha).
5. Maximum TSS content of onion bulbs was recorded at 80 kg S/ha (13.0 per cent) and it was at par with 60 kg S/ha (12.5 per cent). Lowest TSS content was recorded at control (9.2 per cent).
6. Nitrogen content of leaf and bulb of onion increased significantly with increased levels of sulphur application up to 60 kg S/ha. Highest N content was recorded at 60 kg S/ha. Lowest N content was recorded at control.
7. Maximum sulphur content of leaf and bulb of onion was recorded at 80 kg S/ha and it was at par with 60 kg S/ha. Minimum sulphur content of leaf and bulb was recorded at control.
8. Total uptake of nutrients viz., N, P, K and S by onion increased significantly with increased levels of S application. Highest total uptake of N and K was recorded at 60 kg S/ha (116.90 and 58.14 kg/ha, respectively) and it was at par with 40 kg S/ha (116.21 and 57.41 kg/ha, respectively). Lowest total uptake of N and K was recorded at control (83.46 and 46.06 kg/ha, respectively). Highest total uptake of P was recorded at 40 kg S/ha (14.46 kg/ha) and it was par with 60 kg S/ha (13.92 kg/ha). Lowest total uptake of P was recorded at control (9.98 kg/ha). Highest total uptake of S was recorded at 80 kg S/ha (29.37 kg/ha) and it was at par with 60 kg

- S/ha (27.12 kg/ha). Lowest total uptake of S was recorded at control (8.05 kg/ha).
9. Residual status of available nitrogen after the harvest of onion decreased significantly with increased levels of S application up to 60 kg S/ha. Highest residual available N was recorded at control (244.37 kg/ha) and lowest residual available N was recorded at 60 kg S/ha (217.03 kg/ha).
 10. Residual status of available S after the harvest of onion increased significantly with increased levels of S application. Highest residual available S was recorded at 80 kg S/ha (27.53 kg/ha) and lowest residual available S was recorded at control (2.15 kg/ha).
 11. Application of S at 60 kg S/ha registered maximum drymatter production of leaves and bulbs of garlic (1410 and 3450 kg/ha, respectively) and it was at par with 40 kg S/ha (1400 and 3360 kg/ha, respectively) and 80 kg S/ha (1360 and 3320 kg/ha, respectively). Minimum drymatter production of leaves and bulbs of garlic was recorded at control (1330 and 3010 kg /ha, respectively).
 12. Application of 60 kg S/ha registered the maximum bulb yield of garlic (5.75 t/ha) and it was at par with 40 kg S/ha (5.61 t/ha) and 80 kg S/ha (5.53 t/ha). Minimum bulb yield was recorded at control (5.02 t/ha).
 13. Nitrogen contents of leaf and bulb of garlic increased significantly with increased levels of sulphur application up to 60 kg S/ha.

Highest N content was recorded at 60 kg S/ha and lowest N content was recorded at control.

14. Maximum sulphur content of leaf and bulb of garlic was recorded at 80 kg S/ha. Minimum sulphur content of leaf and bulb was recorded at control.
15. Total uptake of nutrients viz., N, P, K and S by garlic increased significantly with increased levels of S application. Highest total uptake of N and P was recorded at 40 kg S/ha (121.94 and 22.86 kg/ha, respectively) and it was at par with 60 kg S/ha (119.92 and 21.93 kg/ha, respectively). Lowest total uptake of N and P was recorded at control (100.39 and 17.83 kg/ha, respectively). Highest total K uptake was recorded at 60 kg S/ha (52.8 kg/ha) and it was at par with 80 kg S/ha (51.8 kg/ha). Lowest uptake of K was recorded at control (43.8 kg/ha). Highest total uptake of S was recorded at 80 kg S/ha (31.33 kg/ha). Lowest total uptake of S was recorded at control (8.63 kg/ha).
16. Residual status of available S after the harvest of garlic increased significantly with increased levels of S application. Highest residual available S was recorded at 80 kg S/ha (29.46 kg/ha) and lowest residual available S was recorded at control (1.8 kg/ha).

U. A. S.
University Library
DHARWAD.

Acc. No. Th-6532

REFERENCES

VII. REFERENCES

- ADIGA, S. AND ANANTHANARAYANA, R., 1996, Vertical distribution of sulphur in base unsaturated rice fallow profiles of Karnataka. *Journal of the Indian Society of Soil Science*, **44** : 652-656.
- AGGARWAL, V. AND NAYYAR, V.K., 1998, Available soil sulphur status and sulphur nutrition of wheat crop. *Journal of the Indian Society of Soil Science*, **46** : 71-75.
- AHMAD, M.S. AND UMAR, S.M., 1989, Available sulphur status and extent of deficiency in some soils of south Bihar plains. *Proceedings of the National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, pp.201-202.
- AHMED, S. AND JHA, K.K., 1969, Sulphur status of Bihar soils. *Journal of the Indian Society of Soil Science*, **17** : 197-202.
- ALI, M., 1991, Consolidated report on *kharif* pulses. Directorate of Pulse Research, Kanpur.
- ANANTHANARAYANA, R., REDDY, M.N., MITHYANTHA, M.S. AND PERUR, N.G., 1986, Status of available secondary nutrients in acid soils of Karnataka. *Journal of the Indian Society of Soil Science*, **34** : 614-616.
- ANEZ, B., TAVIRA, E. AND FIGUEREDO, C., 1996, Onion production in response to fertilizer applications on alkaline soils. *Revista de la Facultad de Agronomía*, **13** (5) : 509-520.

ANONYMOUS, 1997a, Directory of Indian Agriculture. CMIE, New Delhi, p.159.

ANONYMOUS, 1997b, Directory of Indian Agriculture. CMIE, New Delhi, p.166.

ANONYMOUS, 1997c, Food and Agriculture organisation. Quarterly bulletin of statistics, Rome, **10** : 93.

ARORA, B.R., GHAI, V.K. AND HUNDAL, H.S., 1988, Distribution of sulphur in benchmark soils of Punjab. *Journal of the Indian Society of Soil Science*, **36** : 367-368.

AULAKH, M.S., 1989, Response of linseed to fertilizer N, P and S and their effect on removal of soil S. *Soil Use and Management*, **5** : 194-198.

AULAKH, M.S. AND DEV, G., 1976, Profile distribution of sulphur in some soil series of Sangrur district, Punjab. *Journal of the Indian Society of Soil Science*, **24** (3) : 308-313.

BALANAGOUDAR, S.R. AND SATYANARAYANA, T., 1990a, Depth distribution of different forms of sulphur in vertisols and alfisols. *Journal of the Indian Society of Soil Science*, **38** : 634-640.

BALANAGOUDAR, S.R. AND SATYANARAYANA, T., 1990b, Correlations of different forms of sulphur with soil properties and with organic carbon and nitrogen in some vertisols and alfisols. *Journal of the Indian Society of Soil Science*, **38** : 641-645.

- BALASUBRAMANIAM, P., BABU, M., ARIVAZHGAN, K. AND RAGHUPATHY, B., 1989, Influence of soil parameters on the forms of sulphur in benchmark soils of Chidambaram taluk, Tamilnadu. *Proceedings of the National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, pp.165-168.
- BALASUBRAMONIAN, A.S., GOTHANDARAMAN, G.V. AND KRISHNAMOORTHY, K.K., 1978, Effect of sulphur application on the yield and quality of onion (*Allium cepa* L.). *Agriculture Research Journal Kerala*, **17** (1) : 139-140.
- BHOGAL, N.S., CHOUDHARY, K.V. AND SAKAL, R., 1996, Distribution of different forms of sulphur in Calcicrothents of North Bihar. *Journal of the Indian Society of Soil Science*, **44** : 65-69.
- BLACK, C.A., 1965, *Methods of soil analysis*, part-II, Agronomy monograph 9, American Society of Agronomy, Madison, Wisconsin, USA.
- CHADHA, K.L., 1999, New avenues for growth. *The Hindu Survey of Indian Agriculture 1999*, pp.159-160.
- CHESNIN, L. AND YIEN, C.H., 1951, Turbidimetric determination of available sulphur. *Soil Science Society of America Proceedings*, **15** : 149-151.
- CHO, K.R., PARK, C.K., KANG, C.S., YANG, J.S. AND KWAN, K.C., 1994, Effects of organic matters and lime materials on quality improvement of tissue cultured garlic (*Allium sativum* L.). *Journal of Agricultural Science*, **36** (2) : 282-288.

- CHOUDHURY, B., 1996, Bulb crops. pp.103-115. *Vegetables*. National Book Trust, India.
- CHUNG, H.D., 1987, Effect of polyethylene film mulching, sulphur application and different levels of nitrogen and potassium on growth, flower stalk elongation, bulbing and leaf tip yellowing of garlic, *Allium sativum* cv. Euisung. *Journal of Korean Society of Horticultural Science*, **28** (1) : 1-8.
- CROCKER, W.M., 1923, Response of onion to sulphur application. *Journal of American Society of Agronomy*, **15** : 129-141.
- DOLUI, A.K. AND SAHA, S.G., 1983, Studies on sulphur status of some soils of West Bengal. *Indian Journal of Agricultural Chemistry*, **16** (2) : 259-265.
- FREEMAN, G.G. AND MOSSADEGHI, N., 1970, Effect of sulphate nutrition on flavour components of onion (*Allium cepa*). *Journal of Science of Food and Agriculture*, **21** : 610-615.
- GANESHAMURTHY, A.N., MONGIA, A.D. AND SINGH, N.T., 1989, Forms of sulphur in soil profiles of Andaman and Nicobar islands. *Journal of the Indian Society of Soil Science*, **37** : 825-829.
- GANESHAMURTHY, A.N. AND SAHA, J.K., 1999, Sulphur status in soils of Agro-ecological regions of India. *Fertilizer News*, **44**(5):57-66.

- GANESHAMURTHY, A.N., SINGH, G. AND SINGH, N.T., 1995, Sulphur status and response of rice to sulphur on some soils of Andaman and Nicobar islands. *Journal of the Indian Society of Soil Science*, **43** : 637-641.
- GOMEZ, K.A. AND GOMEZ, A.A., 1984, *Statistical Procedure for Agricultural Research*, John Willy and Sons, New York.
- GOWRISHANKAR, D. AND SHUKLA, L.M., 1998, Sulphur status of Inceptisols of Delhi. *Fertilizer News*, **43** (10) : 45-48.
- HAMILTON, B.K., PIKE, L.M. AND YOO, K.S., 1997, Clonal variations of pungency, sugar content and bulb weight of onions due to sulphur nutrition. *Scientia Horticulture*, **71** : 131-136.
- HESSE, P.R., 1994, *A Text Book of Soil Chemical Analysis*. CBS Publishers and Distributors, New Delhi.
- JACKSON, M.L., 1967, *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.
- JAGGI, R.C. AND MINHAS, R.S., 1989, Raya yeild, S uptake and changes in soil properties as affected by levels and sources of sulphur. *Proceedings of the National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, pp.226-227.
- JANA, B.K. AND KABIR, J., 1990, Effect of sulphur on growth and yield of onion cv., Nasik Red. *Crop Research*, **3** (2) : 241-243.
- JORDAN, H.V. AND ENSMINGER, L.E., 1958, The role of sulfur in soil fertility. *Advances in Agronomy*, **10** : 407-434.

- KAPUR, K.L., GARG, R.C. AND TRIPATHI, M.P., 1976, Preliminary studies on screening of onion varieties for dehydration. *Progressive Horticulture*, **7** : 77-78.
- KHALAF, S.M. AND TAHA, E.M., 1988, Response of garlic plants grown on calcareous soil to organic manuring and sulfur application. *Annals of Agricultural Science*, **33** (2) : 1219-1232.
- KUMAR, A. AND SINGH, O., 1992, Drymatter accumulation in sulphur deficient onion plants. *Indian Journal of Agricultural Research*, **26** (2) : 107-109.
- KUMAR, A. AND SINGH, O., 1994, Role of sulphur in nutrient utilization and catalase activity in onion crop. *Indian Journal of Agricultural Research*, **28** (1) : 15-19.
- KUMAR, A. AND SINGH, O., 1995, Effect of sulphur deficiency on plant growth and yield of onion. *Indian Journal of Agricultural Research*, **29** (3) : 127-130.
- KUMAR, A., DATTA, S.P., SINGH, R.P., SINGH, K.P. AND SARKAR, A.K., 1994, Available sulphur and micronutrient status of dominant soil series of South Chotanagapur in Bihar. *Journal of the Indian Society of Soil Science*, **42** ; 649-651.
- KUMAR, K. AND SAHAY, R.K., 1954, Effect of sulphur fertilization on the pungence of onion. *Current Science*, **23** : 368-369.

- MASHI, M.R., SHARMA, S. AND SINGH, N., 1989, Status and supplying capacity of sulphur in soils of Rajasthan. *Proceedings of the National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, pp.172-177.
- MENGEL, K. AND KIRKBY E.A., 1982, *Principles of Plant Nutrition*. International Potash Institute, Bern, Switzerland.
- MEHTA, V.S., SINGH, V. AND SINGH, R.B., 1988, Evaluation of some soil test methods for available sulphur in some alluvial soils. *Journal of the Indian Society of Soil Science*, **36** : 743-746.
- MISRA, N.M. AND PRASAD, K., 1966, Effect of sulphur fertilization on yield of onion. *Fertilizer News*, **11** (10) : 18-19.
- MISRA, U.K., DAS, C.P. AND MITRA, G.N., 1990, Forms of sulphur in some soils of Orissa in relation to relevant soil properties. *Journal of the Indian Society of Soil Science*, **38** : 61-69.
- MORRIS, R.J., 1988, Markets for plant nutrient sulphur a global opportunity. *Sulphur in Agriculture*, **12** : 3-18.
- NAIK, M.S. AND DAS, N.B., 1964, Available sulphur status of Indian soils by *Aspergillus niger* method. *Journal of the Indian Society of Soil Science*, **12** : 151-155.
- NARANG, R.S. AND DASTANE, N.G., 1971, Effect of different plant nutrients on the yield of *Allium cepa* L. (Bulb-onion). *Indian Journal of Horticulture*, **28** : 288-292.

- OLSEN, S.R., COLE, C.V., WATANABE, F.S. AND DEAN, L.A., 1954, Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA circular, 939.
- PADMAJA, G., RAJU, A.S. AND RAO, K.V.S., 1993, Status and distribution of sulphur in some pedons of vertisols. *Journal of the Indian Society of Soil Science*, **41** : 560-561.
- PANDEY, K.N., 1965, Effect of different levels of sulphur on onion. *M.Sc. (Agri.) Thesis*, Banaras Hindu University.
- PANDEY, D.K., TIWARI, K.N. AND TIWARI, R.C., 1989, Different forms of sulphur in alluvial soils. *Journal of the Indian Society of Soil Science*, **37** : 161-163.
- PATERSON, D.R., 1979, Sulfur fertilization effects on onion yield and pungency. *Progress Report*, Texas Agricultural Experiment Station, No.3551, p.2.
- PALASKAR, M.S. AND GHOSH, A.B., 1982, An appraisal of some soil test procedures for available sulphur in alluvial soils. *Journal of the Indian Society of Soil Science*, **30** (2) : 194-199.
- PASRICHA, N.S., 1987, Nutritional requirements of oil seed and pulse crops in Punjab. *Research Bulletin*, Punjab Agricultural University, Ludhiana, 15, p.2
- PATIL, R.R., PRASAD, M AND SHARMA, R.P., 1989, Studies on the Inter-relationship between bulb yield and important plant characters of onion. *Vegetable Science*, **16** : 7-10.

- PAWAR, V.S. AND PATIL, B.R., 1989, Sulphur content and uptake in garlic (*Allium sativum* L.) as affected by application of single superphosphate. *Fertilizer News*, **34** : 29-30.
- PIPER, C.S., 1966, *Soil and Plant Analysis*. Hans Publishers, Bombay.
- POONGOTHAI, S., SAVITHRI, P., VENNILA, R.K. AND JOSEPH, B., 1999, Influence of gypsum and green leaf manure application on rice and on soil deficient in sulphur. *Journal of the Indian Society of Soil Science*, **47** (1) : 96-99.
- PRADAN, G.E., FLORESCU, E., MIHALACHE, M., VISARION, M., BACIU, E., DOROBANTU, N. AND TUDOR, T., 1977, Garlic composition. *Vegetable Crops in India* Eds. Bose, T.K. and Som. M.G., Nayaprakash, Calcutta, India, pp.583-597.
- RAJAS, R.N., GHULAXE, S.N. AND TAYDE, S.R., 1992, Study of different levels of sulphur, spacing and frequencies of irrigation on total volatile sulphur content of onion. *Journal of Science and Crops*, **2** (2) : 66-68.
- RAJU, A.S. AND SREEMANNARAYANA, B., 1997, Soils sulphur status and crop responses to applied sulphur in certain alfisols and vertisols of Andhra Pradesh, India. *Sulphur in Agriculture*, **20** : 54-59.
- RANDHAWA, P.S. AND ARORA, C.L., 1997, Effect of phosphorus and sulfur on their availabilities in soils. *Journal of the Indian Society of Soil Science*, **45** (2) : 306-310.

- RANDLE, W.M. AND BUSSARD, M.L., 1993, Pungency and sugars of short day onions as affected by sulfur nutrition. *Journal of American Society of Horticultural Science*, **118** (6) : 766-770.
- RANDLE, W.M., BUSSARD, M.L. AND WARNOCK, D.F., 1993, Ontogeny and sulfur fertility affect sulfur in short day onions. *Journal of American Society of Horticultural Science*, **118** (6) : 762-765.
- RANDLE, W.M., LANCASTER, J.E., SHAW, M.L., SUTTON, K.H., HAY, R.L. AND BUSSARD, M.L., 1995, Quantifying onion flavour compounds responding to sulfur fertility - sulfur increases levels of Alk(en)yl cysteine sulfoxides and biosynthetic intermediates. *Journal of American Society of Horticultural Science*, **120** (6) : 1075-1081.
- RAO, W.K., 1988, Sulphur usage in coffee and other plantation crops. TSI-FAI symposium on sulphur in Indian Agriculture, New Delhi, SII/5(1-9).
- REDDY, A.T., SUBBARAO, A. AND SUBBARAO, I.V., 1985, Status and forms of sulphur in soils of Andhra Pradesh. *Journal of the Indian Society of Soil Science*, **33** : 416-418.
- ROHAL, S.V. AND KALRA, G.S., 1986, Effect of different levels of nitrogen, phosphorus and sulphur on dry weight of leaves, bulb diameters and pungency (volatile sulphur) of onion bulbs. *Indian Journal of Agriculture Research*, **20** (1) : 47-50.

- SACHDEV, M.S., SACHDEV, P., MITTAL, R.B. AND LUTHRA, V.K., 1991, Fertilizer nitrogen recovery by onion (*Allium cepa*) as influenced by N and S application in a sulphur deficient soil. *Journal of Nuclear Agriculture and Biology*, **20** (4) : 248-254.
- SAHRAWAT, K.L. AND BURFORD, J.R., 1982, Modification of the alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. *Soil Science*, **133** : 53-57.
- SALIMATH, S.B., 1990, Studies on status of potassium and sulphur in soils and their effect on onion (*Allium cepa* L.) yield. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.
- SATYANARAYANA, T. AND BISWAS, T.D., 1970, Chemical and mineralogical studies of associated black and red soils. *Mysore Journal of Agricultural Sciences*, **4** : 254-264.
- SHARMA, S., BAL, S.S. AND BAJAJ, K.L., 1996, Chemical composition of some important varieties of onion (*Allium cepa* L.). *Vegetable Science*, **23** (1) : 48-51.
- SHARMA, Y.K. AND GANGWAR, M.S., 1997, Distribution of different forms of sulphur and their relationship with some soil properties in alfisols, inceptisols and mollisols of Moradabad district, Uttar Pradesh. *Journal of the Indian Society of Soil Science*, **45** : 480-485.

- SINGH, D. AND PANDEY, R.N., 1995, Effect of applied sulphur on drymatter yield and sulphur uptake by onion in different soil series of Delhi. *Annals of Agricultural Research*, **16**(3):348-350.
- SINGH, F., SINGH, V. AND MALIK, R.S., 1995a, Effect of different doses and sources of sulphur on yield and uptake of sulphur by garlic. *Journal of the Indian Society of Soil Science*, **43** : 130-131.
- SINGH, F., SINGH, V., MALIK, R.S. AND SINGH, M., 1995b, Forms of sulphur in some alluvial soils of Uttar Pradesh. *Annals of Agricultural Research*, **16** (3) : 367-368.
- SINGH, H., SINGH, S. AND SINGH, V., 1996, Response of onion (*Allium cepa* L.) to nitrogen and sulfur. *Annals of Agricultural Research*, **17** (4) : 441-444.
- SINGH, O., 1979, Sulphur deficiency and alkaloid contents in mustard (*Brassica campestris* L. var *Sarson frain*) plants. *Indian Journal of Plant Physiology*, **22** (1) : 132-134.
- SINGH, R.S., GUPTA, M.D. AND YADAV, A.D., 1981, Distribution of different forms of sulphur in the soils of Bundelkhand region. *Indian Journal of Agricultural Research*, **15** : 201-207.
- SINGH, S.K. AND TIWARI, R.C., 1989, Effect of applied and residual sulphur on sesamum-mustard. *Proceedings of the National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, p.208.

- SINGH, S., SINGH, K.P., RANA, N.K. AND SARKAR, A.K., 1993, Forms of sulphur in some Ranchi soils of Chotanagpur. *Journal of the Indian Society of Soil Science*, **41** : 562-563.
- SINGH, V., SINGH, A. AND MEHTA, V.S., 1995c, Effect of sulphur sources and levels on yield and uptake of nutrients by garlic. *Fertilizer News*, **40** (8) : 47-49.
- SKLAN, D., BERNER, Y.N. AND RABINOWITCH, H.D., 1992, The effect of dietary onion and garlic on hepatic lipid concentrations and activity of antioxidative enzymes in chicks. *Journal of Nutritional Biochemistry*, **3** (7) : 322-325.
- SREEMANNARAYANA, B. AND RAJU, A.S., 1994, Influence of different cropping sequences on status of sulphur fractions in vertisols and alfisols. *Annals of Agricultural Research*, **15** : 344-350.
- SUMANTRAKAR AND TIWARI, R.S., 1993, Effect of sulphur on growth and yield of onion (*Allium cepa*) cv. pusa red. *Vegetable Science*, **20** (2) : 118-120.
- TANDON, H.L.S., 1984, *Sulphur - Research and Agricultural Production in India*. Fertilizer Development and Consultation Organisation, New Delhi, India.
- TANDON, H.L.S., 1991, *Sulphur Research and Agricultural Production in India*. 3rd ed., TSI, Washington; DC, U.S.A.

- TANDON, H.L.S., 1995, *Sulphur Fertilizers for Indian Agriculture*. 2nd ed., FDCO, New Delhi, India.
- THIPPESWAMY, H.J., 1993, Leaf sampling guide and nutrient norms for yield and quality in relation to applied sulphur to onion. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bangalore.
- TRIVEDI, S.K., BANSAL, K.N. AND SINGH, V.B., 1998, Important forms of sulphur in profiles of some soil series of Northern Madhya Pradesh. *Journal of the Indian Society of Soil Science*, **46** : 579-583.
- VAGEESH, T.S., GAJANAN, G.N., SHETTY, Y.V. AND NAIDU, B.S., 1989, Sulphur status of the soils of Shimoga district. *Proceedings of National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, pp.169-171.
- VIMAL, O.P., 1972, The use of sulphur in soil studies - A review. *Indian Journal of Agronomy*, **17** (1) : 54-57.
- VIRMANI, S.M. AND KANWAR, J.S., 1971, Distribution of forms of sulphur in six soil profiles of North-East India. *Journal of the Indian Society of Soil Science*, **19** : 73-77.
- WHITE, J.G., 1958, Mineralisation of nitrogen and sulphur in sulphur deficient soils. *New Zealand Journal of Agricultural Research*, **2** : 255-258.

WILLIAMS, C.H. AND STEINBERGS, A., 1959, Soil sulphur fractions as chemical indices of available sulphur in some Australian soils.

Australian Journal of Agricultural Research, **10** : 342-352.

YADAV, B.S. AND DESAI, N.H., 1989, Yield , quality and chemical composition of mustard (*Brassica juncea* L.) as influenced by levels and sources of sulphur. *Proceedings of the National Seminar on Sulphur in Agriculture*, FACT and UAS, Bangalore, pp.124-128.

APPENDICES

Appendix I

List of crops proposed / planted in different blocks of KRCCH, Arabhavi

Sl.No.	Block	Crop
I.	Olericulture	
1.	G (1 & 2)	
2.	G (3)	
3.	G (4)	
4.	G (5)	
5.	G (6)	
6.	G (7)	
7.	G (8)	
8.	G (9 & 10)	
II.	Pomology	
9.		Sapota + Drumstick
10.		Sapota
11.		Citrus, Pomello, Grape fruit
12.		Guava
13.		Mango
14.		Pomegranate
15.		Viticulture
16.		Lime and Lemon
17.		Ber
18.		Annonaceous
19.		Papaya
20.		Gooseberry
21.		Fig
22.		Jack
23.		Temperate fruits
24.		Mango
25.		Sweet orange
III.	Medicinal and Aromatic plants	
26.	J I	
27.	J II	
28.	J III	
29.	J IV	
30.	J V	
31.	J VI	
IV.	Spices and plantation crops	
32.	H 109/1	
33.	H 109/2	Coconut
34.	H 109/3	
35.	H 109/4	Tamarind
36.	H 109/5	
37.	H 109/6	Coconut
38.	H 107/7	
39.	H 109/8	
40.	I 109/9	Cashew
41.	I 109/9	Cashew
42.	I 109/9	
43.	I 109/9	
V.	Floriculture	
44.	F 1	
45.	F2	
46.	F3	
47.	F4	
48.	F5	
49.	F6	

APPENDIX - II

Price of inputs and outputs

Particulars	Price (Rs.)
Inputs	
Onion seed material	200 per kg
Garlic seed material	35 per kg
Urea	3.75 per kg
Di-ammonium phosphate	8.30 per kg
Muriate of potash	3.70 per kg
Gypsum	100 per quintal
Nuvacron	330 per litre
Dithane -M 45	180 per kg
Men labour	30 per day
Women labour	25 per day
Outputs	
Onion bulbs	350 per quintal
Garlic bulbs	2800 per quintal

APPENDIX - III

Cost of cultivation of onion

Sl. No.	Operation	Cost (Rs./ha)
1.	Nursery preparation	1,000-00
2.	Land preparation	2,250-00
3.	Manuring	
	a) Cost	2,595-00
	b) Labour	240-00
4.	Planting	
	a) Seeds	1,200-00
	b) Labour	250-00
5.	Irrigation charges	1,500-00
6.	Intercultivation	445-00
7.	Hand weeding	725-00
8.	Plant protection	
	a) Cost of chemicals	990-00
	b) Labour	200-00
9.	Harvesting and curing	2,000-00
10.	Transporting and marketing cost @ Rs.25/q	T ₁ -7125-00 T ₂ -7875-00 T ₃ -8450-00 T ₄ -8250-00 T ₅ -8075-00
11.	Land rent	1,500-00
12.	Supervision and miscellaneous charges	2,000-00

APPENDIX - IV

Cost of cultivation of Garlic

Sl. No.	Operation	Cost (Rs./ha)
1.	Nursery preparation	1,000-00
2.	Land preparation	2,250-00
3.	Manuring	
	c) Cost	2,343-00
	d) Labour	240-00
4.	Planting	
	c) Seeds	17,500-00
	d) Labour	250-00
5.	Irrigation charges	1,500-00
6.	Intercultivation	445-00
7.	Hand weeding	725-00
8.	Plant protection	
	c) Cost of chemicals	990-00
	d) Labour	200-00
9.	Harvesting and curing	950-00
10.	Transporting and marketing cost	T ₁ -1275-00
	@ Rs.25/q	T ₂ -1325-00
		T ₃ -1425-00
		T ₄ -1450-00
		T ₅ -1400-00
11.	Land rent	1,500-00
12.	Supervision and miscellaneous charges	2,000-00

STUDIES ON SULPHUR NUTRITION OF ONION AND GARLIC IN SULPHUR DEFICIENT SOIL OF GHATAPRABHA LEFT BANK COMMAND AREA

SRINIDHI, N.

2000

Dr. P. L. PATIL
MAJOR ADVISOR

ABSTRACT

Th 6532

An investigation on status of available sulphur in soils of Kittur Rani Channamma College of Horticulture (KRCCH), Arabhavi and studies on sulphur nutrition of onion and garlic in sulphur deficient soil was carried out in KRCCH, Arabhavi (Ghataprabha Left Bank Command Area) during *kharif*, 1998-99. Forty-nine soil samples from five blocks were collected for the present investigation. Two field experiments were laid out in randomised block design for onion and garlic separately which consist of five levels of sulphur (0, 20, 40, 60 and 80 kg S/ha) and were replicated four times.

Available sulphur content of about 46 per cent of the soils of KRCCH, Arabhavi were below 10 ppm and are considered to be deficient in available sulphur. Organic carbon content correlated (0.289*) positively and significantly with available sulphur.

Onion recorded maximum dry matter production of leaves and bulbs, bulb yield (33.78 t/ha) and total uptake of P at 40 kg S/ha. Highest N content of leaf and bulb, total uptake of N and K were obtained at 60 kg S /ha. Application of 80 kg S/ ha registered highest TSS content (13.0%), S content of leaf and bulb, total uptake of S and residual available sulphur (27.53 kg/ha). Highest residual N was recorded at control.

Garlic obtained maximum dry matter production of leaves and bulbs, bulb yield (5.75 t/ha), N content and total uptake of K at 60 kg S/ha. Maximum total uptake of N and P was obtained at 40 kg S/ha. Application of 80 kg S/ha registered highest S content of leaf and bulb, total uptake of S and residual available S (29.46 kg/ha).