

**THE RESPONSE OF FODDER MAIZE (*Zea mays* L.)
TO POTASSIUM AND SULPHUR IN TWO
SELECTED SOIL SERIES OF SOUTH INDIA**

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BANGALORE

1993

**THE RESPONSE OF FODDER MAIZE (*Zea mays* L.)
TO POTASSIUM AND SULPHUR IN TWO
SELECTED SOIL SERIES OF SOUTH INDIA**

MARYAM VARAVIPOUR

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of
MASTER OF SCIENCE (Agriculture)
in
SOIL SCIENCE

BANGALORE

JULY 1993

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Affectionately Dedicated to

My Beloved Mother

and Sons


Ehsan and Arman


DEPARTMENT OF SOIL SCIENCE
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE


CERTIFICATE

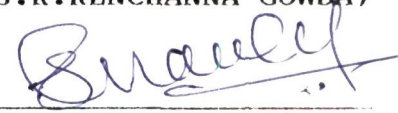
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ACKNOWLEDGEMENT

I wish to place on record my deep sense of gratitude and indebtedness to my Chairperson of my Advisory Committee Dr.(Mrs.) L. SUSEELA DEVI, Associate Professor of Soil Science, GKVK, Bangalore for her valuable guidance and encouragement bestowed on me during the period of study and sustained interest in preparing manuscript.

I avail this opportunity to express my sincere gratitude to my former Chairman of Advisory Committee Dr.A.S. PARASHIVAMURTHY, Professor and Head, Department of Soil Science and Agricultural Chemistry. GKVK, Bangalore who has been presently working as Advisor in Agriculture to the Government of Ethopia and support in conducting the research work.

I express my warm regards and sincere thanks to Dr.S.K.KENCHANNA GOWDA Associate professor, Soil Science, GKVK, Mr.G.N.GAJANAN, Soil Physicist, Dry Land Agril. Project GKVK and Dr.T.V.MUNIYAPPA Associate Professor of Agronomy for having served as members of my Advisory Committee and for their valuable guidance, suggestions and encouragements offered during my research work.

I acknowledge with thanks to Mr.NARASINHA MURTHY, Head of Agricultural Development Division, Zuari Agro Chemicals, Bangalore and his staff for extending help in micronutrient analysis of soil samples in their Soil Testing Laboratory

I thank all those concerned who helped me directly or

indirectly in carrying out field studies at Chagalhatti and Malanagatihalli villages.

I sincerely thank all those staff members and my colleagues in the department for their help and cooperation in carrying out research work in the laboratory.

It is my proud to express my heart felt thanks with gratitude to Mrs. B.MALATI, her husband Mr.B. MADHAVARAO, their sons and daughter-in-laws Smt.KANTA, Smt.MYTHREI and Smt. SUNITA who stood and encouraged me yo complete this task at ease. I have no words to express adequately my gratitude to my husband Dr.JAVAD MOINADDINI who not only toiled hard for me to keep things going on well on my homefront looking after my childern so well. I am beholden to express my deep appriciations to my sons EHSAN and ARMAN for bearing with me some hardship and their constant love and affections showered at me to keep on smiling, cheerful and active.

I acknowledge with sense of gratitude to the Government of Iran for my deputation to present higher studies leading to M.Sc.(Agri) by providing financial support during my study period at Bangalore

Lastly I would like to thank "A.V.COMPUTER SERVICES" for neat typing.

Bangalore 2-9-93

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INTRODUCTION

CHAPTER I

INTRODUCTION

In the present farming system, the balanced supply of plant nutrients is a key step in stepping up crop yields. In view of the usage of high analysis fertilizers either singly or in complex forms for highly fertilizer responsive short duration and high yielding crop varieties, occurrences of deficiencies of one or more nutrients in soils have become too frequent causing considerable depletion in crop yields. Studies conducted in some selected established soil series revealed the existence of deficiencies of potassium and sulphur in soils which in turn limit crop yields. These two nutrients are known to play vital roles in metabolic system in plants for increasing yield and quality of crop.

The multifarious role of potassium in the nutrition of plants are well known. Its magnificent performances in metabolism of plants such as promoting growth and increasing crop yields, strengthening plant tissues and preventing lodging, causing resistance to pests and diseases, regulating water utilisation by plant and improving quality of crops are some of its attributes. Besides it is responsible for improving colour, flavour, sugar content, keeping quality and weight of various agricultural products. There exists certain interrelationships notably with nitrogen, phosphorus,

calcium, magnesium and sulphur (Swaminathan, 1978). Balanced supply of nutrients is a key step for growth of healthy plants and to explore the full genetic yield potential. The harnessing of synergistic effect among these nutrients is a key step towards larger profits.

Numerous studies of soil potassium have been done in the past. But there is still sufficient scope to study the manifestation of soil potassium to a greater depth for plant growth. The recent trend is to generate information on the basis of taxonomically established soil series. Such an approach would help a great deal in deriving maximum benefits from the added fertilizers.

The other equally important nutrient sulphur aptly called as "fourth major nutrient" is causing concern in crop production due to its wide spread deficiency world over. Sulphur deficiency is not always easy to identify in growing plants. Moreover, significant yield depressions can occur without manifestation of visual deficiency symptoms. A fertilization programme is, therefore, needed to minimise the probability of sulphur deficiency which has now becoming a practical problem in farming system.

In view of the increasing demand for food and fibre to meet the needs of the burgoing population, crop productivity per unit area of agricultural land must rise. For this

purpose, all crop nutritional constraints should be minimised. This, in fact, implies that the scope of balanced plant nutritional practice must extend the application not only of N + P + K but to include also other nutrients which the soil may not be able to provide in sufficient quantity and at rates required for good crop growth.

As an essential nutrient, sulphur performs several function in plants. It is essential for protein formation, as a constituent of three aminoacids cystine, cysteine and methionine, its requirement in chlorophyll formation and for the activity of many enzymes involved in sulphur metabolism, its involvement is also in the synthesis of glutathione, coenzyme A and vitamin B.

These essential functions permit the production of healthy and productive plants which are capable of giving high yields as well as superior quality.

Sulphur deficiency in soils occur frequently under varied conditions. In coarse textured soils and soils low in organic matter, in areas where industrialisation is soant, intensive agricultural practice coupled with rotation of crops of high sulphur requirements, growing high yielding crop cultivars with high analysis fertilizers devoid of sulphur aggravate S-deficiency.

Tyamagondlu and Vijayapura soil series are known to be very low in available K and also S. The soils are put under intensive cultivation and major crops are heavy feeders of nutrients like vegetable and fodders.

Moreover, soil studies in respect of nutrients management on taxonomically established soil series would be helpful in extending findings to soils of similar nature for improving crop production.

Against this back ground of information, the present study is taken up with the following objectives:

1. To study the response of potassium and sulphur for fodder maize in Tyamagondlu and Vijayapura soil series by conducting field experiments and
2. To study the available sulphur status through fractionations of soil sulphur in three established soil series.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Though potassium exists in soils in substantial quantities, its availability to plants is governed by several factors. Usually, soil K exists in three states viz., water soluble, exchangeable and non exchangeable forms which are in dynamic state of equilibrium. Soils get depleted from potassium due to greater removal by plants in moderate and coarse textured soils, if it is not replenished.

In recent years, Sulphur deficiencies are known to occur world over. Sulphur deficiencies have become quite frequent in this country due to use of high analysis fertilizers containing little or no sulphur. There is greater removal of S from native source due to adoption of multi cropping farming system.

Since the present studies were carried out in soils of Tyamagondlu and Vijayapura series of Bangalore, Karnataka which are known to be deficient in K and S, pertinent reviews on K and S have been presented matching with the objectives of the present study.

2.1 Response of crop to potassium

Now a days farmers are keenly interested in increasing their crop production through judicious use of their limited resources. Use of hybrid and high yielding cultivars and fertilizers will help in increasing their production. Crop responses to fertilizer application including potassium and their economics, under varied cost and price structure of inputs are the foremost points in better food production.

The following review will give a brief idea about the response of maize crop to potassium in relation to nitrogen and Phosphorus Fertilizer application.

2.1.1 Response of maize to potash

Batra and Sood (1967) comparing the response of a local (Desi) and hybrid maize (Ganga-101) found that there was response to the highest dose of nitrogen, whereas there was moderate response to phosphorus and no response to potassium at all. In all the location trials at Narasingarh and Bajaura with no K_2O , 135 kg h^{-1} N and $90 \text{ kg per ha}^{-1}$ P_2O_5 proved optimum. This may be attributed to higher native K. Robertson, et al. (1968) stated that application of N, P and K fertilizers increased number of ears but ear weight and quantity were decreased.

Yield of hybrid maize is a very complex quantitative character and it is considerably influenced by the factors viz., fertility status of the soil (Verma and Singh, 1970 and Tiwary, et al., 1970) and plant population per unit area (Kaushik and Gupta, 1970). Optimum plant population and nutrient status of soil not only facilitates more dry matter production but also economises the cost of cultivation.

Prithviraj, et al. (1971) indicated that Deccan hybrid maize gave significantly higher grain yield with 135 N, 67 P₂O₅ and 45 K₂O kg ha⁻¹ in vertisols.

Krishnan (1972) collected the data for many years on the response of maize for fertilizer application, to find a suitable yard stick to predict the amount of nutrients required for every additional kg of grain produced. The conclusion was that for one kg of grain under irrigated condition and rainfed conditions required 10.5, 5.5 and 7.4 kg and 11.7, 6.3 and 6.5 kg of NPK respectively. Demony et al. (1973) noted contradictory results of crop response to direct application of potassium.

Kumaraswamy et al. (1975) reported that maize straw yield decreases with increased "P" level and the influence of added K on straw yield was not significant. The results of the investigation revealed further that it was not economical

to apply phosphatic and potassic fertilizers to maize crop, when the inherent availability of these nutrients were adequate. According to soil test classifications, Bajwa and Paul (1978) noted that maize variety Ganga-5 responded significantly to N and P but not to K.

Dev et al. (1980) reported that all the test crops except maize and "Sonalika" wheat showed curvilinear type of response to applied "N". For maize and for wheat varieties like "Kalyana sona" and "Sonalika" the response to applied K declined with increased soil test values.

Kapur et al. (1984) studied the response of maize and wheat to applied potassium on soils differing in K status. These crops responded to high dose of K in low and medium K soils and to a dose of $60 \text{ kg K}_2\text{O ha}^{-1}$ in soils high in K status.

2.1.2 Potassium uptake by maize

Hanway (1972) was also of the opinion that the fertility levels of soil influenced N, P and K uptake but there was no drastic change in the uptake of these elements by maize plants. But nitrogen and phosphorus were in higher quantities than potassium in plants.

Lutz (1974) studied the interaction of P and K on corn and observed that N, P and K treatments did not affect

nitrogen concentration of leaf. Concentration of P and K decreased when K was not applied.

Puntanker et al. (1975) observed influences of different levels of nitrogen on the uptake of nitrogen, phosphorus and potassium. Nitrogen content increased in the initial stages but later decreased. The amount of potassium was higher than nitrogen or phosphorus in shoot as compared to level in cob. Application of phosphorus and potassium did not show any significant increase in yields compared to nitrogen.

2.2.1 Soil sulphur and fractions of sulphur

Soil sulphur is present in two major forms viz., the organic and inorganic forms. Source for organic form is mainly from the organic matter and minerals like gypsum ($\text{CaSO}_4, 2\text{H}_2\text{O}$) and pyrite (Fe S_2) etc. form the inorganic forms of sulphur in soils.

According to Williams and Steinbergs (1959) the amount of available sulphur in Australian soils was lesser than 22 ppm which is considered very low.

While studying Australian soils, Williams and Steinberg (1959) found that most of the sulphur was present in organic forms which could be extracted by 0.1 N NaOH. On ignition, similar amounts were released as sulphates and others by

reduction method. Thus these three fractions were highly correlated with one another and also with total sulphur.

Kanwar and Takkar (1963 a) concluded that 75 per cent of groundnut soils of Samrala Tehsil of Ludhiana district of Punjab were deficient in sulphur. According to them 17.3 per cent of the soils might be considered satisfactory and 7.5 per cent rich. The limits for these categories being less than 10 ppm low, 10 to 15 ppm medium and 15 ppm above satisfactory.

In Punjab, Kanwar and Mohan (1964) found that the sulphate sulphur varied from 2 to 46 ppm. According to them the soils containing less than 10 ppm of sulphur were deficient and hence responsive to the application of sulphur.

According to Whitehead (1964), the total sulphur content of Scottish soils ranged from 200 to 1800 ppm. According to him the sulphate sulphur was significantly correlated with total sulphur.

Kanwar and Takkar (1964) stated that 74 per cent of tea soils of Kangra district were deficient in available sulphur.

Naik and Das (1964) found that a large number of laterite, red and alluvial soils collected from all over India contained less than 10 ppm of available sulphur. Jha

(1964) observed a wide range of variations in the available sulphur status of Delhi soils. In general, the surface soils contained much organic sulphur.

Chopra and Kanwar (1966 a) observed that ignition sulphur content of Ludhiana soils was comparatively higher than those of other forms of sulphur.

Ayyathurai (1969) reported that available sulphur content of Tamil Nadu soils was satisfactory. On an average maximum availability of sulphur was found in laterite soils but the proportion of total sulphur to available sulphur was maximum in alluvial soils.

Reddy and Mehta (1970) reported that loamy sand soils of Anand in Gujarat contained low amounts of available sulphur. They found that easily soluble sulphate content varied from 20 to 160 ppm. The loamy sand soil of Anand contained 22 ppm of heat soluble sulphur, 20 ppm of organic sulphur and 42 ppm of total sulphur. Available sulphur (NH_4OAc extractable) in Anand soil was reported to be around 5 ppm.

Palaniappan (1970) studied the influences of phosphorus and sulphur on the progressive changes in availability of soil nutrients during the growth of groundnut crop in different soil situations. In Pollachi soil, pre-sowing

stage had higher available sulphur. The available sulphur at the reproductive stage decreased significantly. In Tindivanam soil, the available sulphur was maximum in the vegetative stage.

Jones et al. (1972) noted that available sulphur was generally greater in soils of wet region than those of dry region and was highly correlated with the amount of soluble plus adsorbed sulphate originally present in the soil.

Patel and Sawarkar (1973) observed that available sulphur of Betul soils varied from 2.35 to 101.00 ppm (average 16.86 ppm), Chindwara soils from 1.19 to 71.40 ppm (average 18.44 ppm) and Narasingpur soils from 4.70 to 67.50 ppm (average 20.86 ppm). Based on critical level of 8 ppm, 24 per cent of Betul soils, 20 per cent of Narsingpur soils and 43.2 per cent of Chindwara soils were deficient in available sulphur.

Vijayakumar and Maharaj Singh (1974) noticed that the heat soluble sulphur content of surface soil samples varied from 5.7 to 105.6 ppm with an average of 24.0 ppm. It did not consistently increased with the fineness of texture but the highest content (30.1 ppm) was found in the Brown silt loam and the lowest (17.9 ppm) in loam.

2.2.2 Relationship between sulphur uptake and different fractions of S

Based on the results obtained by Williams and Steinberge (1959) sulphate sulphur, total water soluble sulphur and heat soluble sulphur were all correlated with the uptake of sulphur by the plants. They further suggested that any one of them might prove to be an index of available sulphur. But sulphur uptake was highly correlated with heat soluble sulphur. They also found that alkali soluble sulphur and ignition sulphur were not considered as index of available sulphur because they were very poorly correlated with sulphur uptake and yield.

Chopra and Kanwar (1966 a) confirmed the importance of heat soluble sulphur as an index of available sulphur. Williams and Steinbergs (1959) and Chopra and Kanwar (1966) found that atleast 8 to 10 ppm of heat soluble sulphur is required in the soil before plants can utilize sulphur from the soils.

Chopra and Kanwar (1966b) found that heat soluble sulphur was found to be best correlated with crop uptake as well as with the yield of groundnut and berseem. The correlation coefficient between the sulphur uptake and heat soluble sulphur was found to be 0.97 with groundnut and 0.96

with berseem. By extrapolating the curves depicting the relationship between heat soluble sulphur and sulphur uptake, a value of 10 ppm of heat soluble sulphur in a soil can be taken as the critical lower limit of available sulphur to groundnut and berseem.

Reddy and Mehta (1970) suggested that the heat soluble sulphur was strongly correlated with the sulphur uptake by plants. According to them at least 17 ppm of heat soluble sulphur was required in soil before plants could utilize sulphur from the soils.

Thakkar (1988) in his review stressed the significance of various forms of soil sulphur such as total, organic, non sulphate and available S in some soils of India and also in profile depths. He contended that non $\text{SO}_4\text{-S}$ form remains unextracted after removal of organic S (H_2O extractable) and $\text{SO}_4\text{-S}$ (0.15 % CaCl_2 soln.) because it forms insoluble S compounds of Ba and Ca occluded in and absorbed on carbonates of the soils and further suggested the suitability of various extractants for specific crops.

On fractionation of sulphur in Alfisols, next to total sulphur, organic-S formed the bulk followed by Morgan's reagent extractable S and least in total water soluble S in soils of University Farms at Bangalore, (Hebbal) Kathalgere

and Hiriyyur. Total water soluble S was highly correlated with plant uptake (Tippteswamy *et al.*, 1989).

2.2.3 Response of sulphur application to crops

Though oil seeds and pulses require comparatively more sulphur numerous other crop species such as maize, cotton, jute, tea, paddy, wheat, etc., also have been found to respond favourably to the application of sulphur under field conditions. The extent to which various crops respond to the sulphur application depends on the degree of sulphur deficiency in soil.

Attention to sulphur nutrition was drawn to the fact that plants having high protein content responded most to sulphur application and their protein content was increased.

Homes *et al.* (1965) observed that application of elemental sulphur had a beneficial effect on development, yield and nutrient utilization of maize crop. According to Roberts and Koehler (1965) when SO₂ was injected into silt loams at the rates of 2.5 to 500 ppm "S" the yield of wheat was nearly doubled.

Chopra and Kanwar (1966a) noticed significantly higher yields in groundnut by applying sulphur with NPK. They also

noticed increased methionine and cystine contents in the groundnut plants with application of sulphur.

Bockelee and Martin (1966) found an increased yield of 100 to 900 kg per ha by applying 10 kg sulphur per hectare. Dalal et al. (1963) reported 13 to 15 per cent higher yield of groundnut by the application of sulphur as gypsum.

Similarly Chesney and Diyaljee (1969) noticed an increased yield of groundnut by applying gypsum in sandy soils of Guyana. Gypsum increased the yield and total mineral contents as well as improved quality of peanuts in sandy soils.

Hill (1970) observed that the yields of groundnut were enhanced parabiologically to sulphur application. The response was solely due to increased nut size.

Herath and Ormrod (1971) indicated that when barley and rape plants were grown at "0" ppm "S" deficiency symptoms developed in about two weeks. The location of deficiency symptoms varied between species. Plant weight increased with increasing "S" levels, but the shoot had a greater growth response than did the root.

Khansal and Sekhon (1976) reported that inadequate supply of sulphur to maize appears to limit the plants

capacity to synthesize protein to a much greater extent than it inhibits the nitrogen uptake mechanism. Available Data indicate that added sulphur will increase yields of corn plants if their amido-N-level exceed 500 ppm. Amide-N concentration correlates with N/S ratios in plants.

With increased rates of applied sulphur, the concentrations of total N, total S, protein N, protein S and total soluble S in the plants increased but those of non-protein fractions like total soluble N, amino acid N, amide N and $\text{NO}_3\text{-N}$ decreased (Aulakh *et al.*, 1976).

The soil sulphur of coffee estates (Inceptisols) and Alfisols of Hebbal and GKVK were fractionated into total S, organic S, ignition - S, alkali soluble S, heat soluble S, sulphate S and total water soluble S and found high correlation between S concentration in leaf tissue of sunflower with heat soluble S, $\text{SO}_4\text{-S}$ and total water soluble S. Seed yield of sunflower showed high degree of correlation with heat soluble sulphate-S and total water soluble S in the Alfisols of Hebbal (Badiger and Jayaram, 1977).

The results of Dhillon and Dev (1978) on soybean showed that protein bound sulphur content in plants ranged from 0.13 to 0.25 per cent, whereas sulphate-sulphur ranged from 558 to 1000 ppm with the application of 20 ppm of sulphur. Non protein and organic sulphur did not vary much. Protein-

bound-sulphur and sulphate sulphur increased with dose of sulphur; protein-bound-sulphur content was the highest when compared to that of sulphate sulphur and non protein-bound-sulphur. This shows that the most of sulphur absorbed was metabolised in the plant body to proteins.

Requirements of sulphur for fodder crops are high and significant improvements in yield and qualities are well documented (Hazra, 1988). According to him the combined application of nitrogen and sulphur at 90 kg N and 50 kg S per ha. improved the dry matter yield from 32.7 to 75.9 Q/ha.

The magnitude of responses of maize to S application in different soils of India have been elucidated in a review by Dev and Sharma, 1988. On alluvial soil of northern Delhi and Punjab the percent increase in grain yield of maize varied from 9 to 56 in soils in which the available S status ranged from 5 to 10 ppm.

Mashi Mukul Rani et al. (1989) studied different forms of sulphur such as total, organic, sulphate, absorbed, easily soluble, cold water soluble and Bray's extractable-S in soils of Rajasthan. They found that all the forms of sulphur in plants, but SO_4 -S form was found highly correlated with plant uptake and was considered quite suitable index for sulphur supplying power of soils.

2.2.4 Effect of sulphur application on the availability of other nutrients

Sulphur when applied as elemental sulphur or in sulphate form to soil caused decrease in soil pH and exerted considerable influence on the availability of other nutrients.

Bertramson et al. (1954) suggested from their incubation studies that application of sulphur markedly reduced the pH and increased the availability of ammonium acetate-extractable manganese.

In pot experiments conducted by Grzesiuk (1955) application of sulphur as ammonium sulphate increased proteins as well as phosphorus content of the crops. Total nitrogen, potassium and sulphur uptakes were also increased.

Neller and Nartlatt (1959) showed that when sulphur was added at higher rates to rock phosphate, the availability of phosphorus in rock phosphate was significantly increased in 5 cm surface layer of the soil compared to the sub-surface soil.

Kanwar (1963) reported that application of gypsum to groundnut increased nitrogen, phosphorus, potassium, calcium and magnesium content of kernels.

Mehlich (1964) reported that when anion exchange complex was saturated with sulphate ions, the soils showed lower calcium sorption efficiency and higher lime requirement by lowering the pH value.

Shirshov and Paikava (1967) reported that by increasing the rate of application of sulphur, the nitrogen accumulation in lucerne plants were also increased.

Nicholadis and Cox (1969) noticed an increased nitrogen and sulphur contents in groundnut root and top portions with sulphur fertilization and the phosphorus content of groundnut decreased as the sulphur content.

Bharadwaj and Shukla (1970) studied the effect of sulphur and sulphur bearing compounds on the water soluble manganese content of a hill soil in Uttar Pradesh. They found that application of sulphur cause decrease in soil pH and increase in the amount of water soluble manganese in the following order:

ammonium sulphate	>	super phosphate	>
sulphuric acid	>	elemental sulphur	

According to Arora and Luthra (1971) application of sulphur alone or in combination with phosphorus and nitrogen, increased the contents of nitrogen, protein-nitrogen and total soluble nitrogen in beans.

Nanamate et al. (1973) noticed that the foliar application of sulphur of 0.012 per cent in the form of potassium sulphate increased the content of chlorophyll a and b and the total chlorophyll by 25, 16 and 21 per cent respectively. Activity of peroxidase enzyme increased by 33 and 36 per cent with application of sulphur at the rate of 0.15 mg per litre and 124 mg per litre respectively.

Pillai and Singh (1974) observed that application of elemental sulphur increased the pH of the leaf sap and (Ca + Mg) content and brought about a concomittant increase in N, K and Chlorophyll contents of rice all of which created a balanced nutritional environment, in calcareous rice soils.

Aulakh et al. (1977) observed sulphur, magnesium and potassium inter relationship. The interactions of S - Mg and K - Mg were significantly negative in suppressing the yield of grain, vegetative parts as well as concentration and uptake of sulphur in rape seeds.

2.2.5 Interaction of potassium and sulphur

Interaction has been defined "as mutual or reciprocal influence of one element upon another in relation to plant growth and its differential response to one element in combination with varying levels of a second element" (Olsen,

1972). One type of interaction increases plant growth by making a limiting nutrient more available from the medium. Interference also may be in the metabolic function of a nutrient present in normal concentration. Due to excessive level of another nutrient functional requirement of other nutrients may increase.

Kanwar and Takkar (1963 a) reported that application of gypsum to groundnut increased the size of the kernels.

In a pot culture experiment conducted by Grzesiuk (1965), it was revealed that application of sulphur as ammonium sulphate increased potassium and sulphur uptake.

Akhmodov and Vyvalko (1970) have stated that yield and starch content of potato were adversely affected by potassium chloride whereas potassium sulphate improved the attributes significantly.

Esteban et al. (1971) reported that application of SO_4^{2-} to a calcic brown soil increased the concentration of S and K in wheat plants in pot experiments. There was a significant positive N-S, N-K and S-K interactions.

Rehm and Sorensen (1974) reported that application of K and S had no significant influence on the yield and even on the tissue content of the respective nutrient.

Potassium and sulphur interaction had not been paid much attention mainly because they do not form complexes in soil. However, positive relationship of both has been observed in mustard by Kumar et al. (1980) which was attributed to increase in the yield by the application of these nutrients.

Ramanathan and Ramanathan (1980) found that sulphur application to groundnut did not show significant effect on the available potassium content of soils.

Pavanasaiyam and Axoey (1982) indicated that application of SO_4 to the stimulated soil solution had no effect on "K" absorption on barley crop. But the "S" absorption was reduced at the lowest levels of (1 ppm K) "K" in the nutrient solution.

Application of potassium at 5 ppm level increased the oil yield of groundnut significantly when combined either with sulphur or calcium (Badiger et al., 1982).

Vijayraj Kumar and Arun Sathe (1983) did not find any significant difference in the uptake of K due to application of S for groundnut.

In a study on yield, and quality of raddish seeds with levels of K, S and Zn, the interaction of K and S was significant on seed yield, 1000 - seed weight, concentration

significant on seed yield, 1000 - seed weight, concentration and uptake of sulphur and zinc but there was no effect on germination of seeds (Srinivas Gowda et al., 1989).

The influence of levels of K, S and Zn on the yield and uptake by carrot was studied on Alfisols. The significant positive interaction effects were observed on root yield, uptake of sulphur, (Basavaraj et al., 1989).

Based on the review of literature on aspects of potassium and sulphur on cereal crops, it may be stated that most of the studies were related to fertilizer potassium as muriate of potash (KCl) and hardly had any information on sulphate of potash (K_2SO_4). It may be probably due to its high cost.

Literature is scant on the roles of chlorides and sulphates, when used in conjunction with K or NH_4 forms on crop growth.

The fractionations of soil sulphur forms an integral part of testing soil for available sulphur. There is need to generate more information on these lines based on established soil series.

MATERIAL AND METHODS

CHAPTER III

MATERIALS AND METHODS

Field study comprised of testing response of fodder maize in two dominant soil series of Tyamagondlu and Vijayapura with graded levels of potassium and sulphur for growth, yield and composition and also to find out suitable K x S combinations to obtain maximum fodder production.

Characterisation of some soils belonging to soil series of Chikkaballapur, Hoskote and Tyamagondlu in Kolar and Tumkur districts with emphasis on different plant available soil sulphur fractions were also carried out.

3.1 Field Experiment

A field experiment was conducted at two locations each belonging to Tyamagondlu and Vijayapura soil series namely at Malangatihalli and Chagalhatti respectively in an effort to study the influence of graded levels of fertilizer potassium and sulphur on yield, chemical composition and uptake of potassium and sulphur by African hybrid fodder maize grown under protective irrigated conditions.

Experimental Site

The experiments were carried out on red sandy loam soils of Malangatihalli in Tyamagondlu soil series and at Chagalhatti in Vijayapura soil series.

3.1.1 Details Of Experiment

The design of the experiments adopted was Completely Randomised Block Design. Gross size of the plot was 5m x 4.2m and net plot size 2m x 2m. There were in all sixteen treatments which were replicated thrice. African tall hybrid fodder maize was used as test crop. The plan of field layout is presented in Fig. 1.

Levels Of Potassium And Sulphur

Potassium : 0, 30, 60 and 90 kg K₂O ha⁻¹

Sulphur : 0, 10, 20 and 30 kg S ha⁻¹

Treatment combinations

T₁ = K₀S₀

T₂ = K₀S₁₀

T₃ = K₀S₂₀

T₄ = K₀S₃₀

T₅ = K₃₀S₀

T₆ = K₃₀S₁₀

T7	=	K30S20
T8	=	K30S30
T9	=	K60S0
T10	=	K60S10
T11	=	K60S20
T12	=	K60S30
T13	=	K90S0
T14	=	K90S10
T15	=	K90S20
T16	=	K90S30

Recommended dose of nitrogen (N) and phosphorus (P_2O_5) at the rate of 150 and 100 kg ha⁻¹ respectively was applied uniformly before seeding in the form of urea and diammonium phosphate. Potassium and sulphur were applied as muriate of potash (KCl) and Factomphos (20:20:0:15). The P application was adjusted between Factomphos and DAP.

The crop remained healthy throughout the study. It was harvested 60 days after seeding. The green fodder was harvested plot wise and recorded the weight. It was further dried in shade and moisture content was determined for weight of dry matter.

T2R1	T6R1	T9R1	T4R1
T3R1	T13R3	T14R2	T15R2
T1R2	T4R2	T11R1	T2R3
T10R3	T2R2	T7R1	T6R3
T12R1	T8R1	T3R3	T14R3
T9R2	T10R2	T5R1	T8R3
T5R2	T3R2	T1R2	T12R3
T16R3	T6R2	T10R1	T11R3
T7R3	T11R2	T13R2	T9R3
T13R1	T16R1	T8R2	T15R1
T14R1	T1R3	T12R3	T5R3
T4R3	T15R1	T7R2	T16R3

Fig. 1 : PLAN OF FIELD LAYOUT AT EACH LOCATIONS

3.1.2 Soil Analysis

Before experimentation, representative surface soil samples upto 15 cm depth were collected from the experimental sites and transported to the soil science laboratory, GKVK Campus.

3.1.3 Preparation Of Soil Samples

The soil samples were dried in shade, powdered with wooden mallet, passed through a plastic 2 mm sieve and stored in clean polythene bags for analytical work. For estimation of organic carbon, the samples were further powdered in an agate pestle and mortar and were passed through 0.5mm sieve. The soil samples from experimental sites after the harvest of crop were also collected for analysis and were processed as stated earlier.

3.1.4 Analysis Of Soil Samples

Soil samples were analysed by following the standard procedures as given in Table 1.

3.1.4.1 ANALYSIS OF PLANT SAMPLES

TABLE 1. METHODOLOGY USED FOR SOIL ANALYSIS

Soil parameters	Method	References
1. Mechanical analysis	International pipette Method	Piper (1950)
2. pH	Soil:water (1:2:5) using pH meter	Jackson (1973)
3. Electrical Conductivity	Conductivity bridge	Jackson (1973)
4. Organic carbon	Walkley and Black's Wet oxidation Method	Jackson (1973)
5. Exchangeable calcium + Magnesium	Versenate method	Jackson (1973)
6. Cation exchange capacity	Neutral normal Ammonium acetate	Jackson (1973)
7. Total nitrogen	Kjeldahl's method	Black (1965)
8. Available phosphorus	Bray's extractant	Jackson (1973)
9. Available potassium	Neutral normal Ammonium acetate	Jackson (1973)
10. Available sulphur	Neutral normal Sodium acetate	Jackson (1973)
11. Available		
Zinc	DTPA extractant	Lindsay and Norwell (1978)
Iron		
Copper		
Manganese		

TABLE 2. PHYSICO-CHEMICAL PROPERTIES OF SOILS OF EXPERIMENTAL SITES

Mechanical composition	Location	
	Malanagatihalli	Chagalhatti
	Per cent	Per cent
Coarse sand	40.50	46.20
Fine sand	26.35	20.30
Silt	8.32	10.50
Clay	13.68	14.70
Loss on solution	11.15	8.30
Textural class	Sandy laom	Sandy loam
Texonomical classification(order)	Alfisol	Alfisol
<u>Chemical composition</u>		
pH (1:2.5)	6.3	6.8
EC (dSm ⁻¹ at 25°C)	0.17	0.20
Organic carbon (%)	0.33	0.48
Exchangeable calcium ₁ + Magnesium (C mol kg ⁻¹)	2.18	3.10
Cation exchange capacity (C Mol kg ⁻¹)	6.25	7.12
Total Nitrogen (%)	0.07	0.09
Available phosphorus (Kg P ₂ O ₅ ha ⁻¹)	16.4	20.8
Available potassium (Kg K ₂ O ha ⁻¹)	89.8	97.2
Available sulphur (Kg ha ⁻¹)	9.25	8.70
<u>DTPA extractable</u>		
Zinc (ppm)	0.48	0.51
Iron (ppm)	4.65	6.25
Copper (ppm)	2.18	2.85
Manganese (ppm)	2.50	2.78

Collection And Preparation Of Plant Samples

The plant samples were collected at random from the net plot area of each treatments during crop harvest. They were cleaned with cotton pad soaked with distilled water to remove possible contaminants. They were dried in shade, made into small pieces and then kept in hot air oven at 60^o C for eight hours. The samples were then powdered finely, in micro Willemill.

One gram test sample was treated with 15 ml HNO₃ and kept overnight. It was then heated on hot plate for a while and cooled. It was redigested on hot plate with 10 ml of diacid mixture containing nitric acid and per chloric acid (10 : 4) until gelatinous white residue was formed. It was cooled and made to a known volume with distilled water. This was used for determining phosphorus, potassium and sulphur.

Phosphorus

On a known aliquot, phosphorus was determined by Vanado molybdate method and the intensity of yellow colour was measured at 420 nm wavelength in spectrophotometer (Jackson, 1973).

Potassium

The method suggested by Black (1965) was adopted. On a suitable aliquot of digested material, potassium was determined flame photometrically fitted with appropriate filter as described by Jackson (1973).

Sulphur

A known amount of digested test sample was suitably diluted. On a known amount of aliquot, sulphur was determined turbidimetrically by BaCl_2 under acid condition as described by Jackson (1973).

Nitrogen

A known amount of test plant sample was digested in a Block digester with 15 ml H_2SO_4 to which added 5 gm digestion mixture containing CuSO_4 , K_2SO_4 and selenium powder until the material became colourless. It was cooled and the entire material was transferred to Kjeldahl unit for distillation. The ammonia thus released was collected in solution containing 4% boric acid and titrated against standard sulphuric acid.

Statistical Analysis

Data on yield and chemical compositions were analysed statistically for test of significance using standard procedures as outlined by Sundar Raj et al. (1972).

3.2 Collection Of Soil Samples From Typical Soil Series

Twenty soil samples each from three established series namely Chikkaballapur, Hoskote and Thamagondlu in Kolar and Tumkur Districts distributed in different villages were collected from 0-15 cm depth with the help of National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Regional Centre, Bangalore for purpose of assessing the status of different available fractions of sulphur and they were dried in shade and later in oven. The details of locations of soil samples collected from soil series are as under;

Chikkaballapur Soil Series	No. Of Soil Samples
1. Thogarighatta	5
2. Kanthankunte	"
3. Vaddarhalli	"
4. Thirumagonbianhalli	"

Hoskote Soil Series

1. Cholappanahalli	5
2. Malamakanpura	"
3. Chikkamallurahalli	"
4. Bimakanahalli	"

Tyamagondlu Soil Series

1. Minnapur	5
2. Hosur	"
3. T.Begur	"
4. Malanayakanahalli	"

3.2.1 Estimation Of Different Fractions Of S**3.2.2 Sodium Acetate Extractable S**

Soil sample was extracted with neutral N NH_4OAc solution (1:5). Sulphur in the supernatant was determined turbi-dimetrically by BaCl_2 forming BaSO_4 in acid medium as described by Black (1965).

3.2.3 Heat Soluble Sulphur

To 5 gm soil sample was added 25 ml of distilled water and evaporated to dryness on hot water bath and further heated to dryness on hot air oven at 102°C for an hour.

After cooling, the soil was transferred to centrifuge tubes and extracted with 33 ml of 1 % Sodium chloride solution. Sulphur was then determined on a suitable aliquot by turbidimetric procedure (Williams and Sterinberg, 1959).

3.2.4 Total Water Soluble Sulphur

Five gram soil sample was extracted with 33 ml of 1 % NaCl solution. After centrifuging a suitable aliquot was evaporated in a silica basin to dryness with 2 ml of 3% H_2O_2 and the basins were then kept in hot air oven in $102^{\circ}C$ for 60 min. to ensure the removal of excess peroxide. After cooling, the residue was taken up into 25ml of distilled water and centrifuged. The sulphur was then determined in a suitable aliquot (Williams and Steinbergs, 1959).

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The soils of Tyamagondlu and Vijayapura are known to be deficient in potassium and sulphur. Hence in the first part of the studies, the field experiments were conducted to know the responses to different levels of K and S on fodder maize.

The second part of the study consisted of characterisation of soil samples from three established soil series from Chikkaballapur and Kolar Districts, with special emphasis to available fractions of sulphur.

4. Field Experiments

Two field experiments were carried out at Chagalhatti (Vijayapura series) and Malanagatihalli (Tyamagondlu series) to study the response of different level of K and S on fodder maize as given under chapter II.

4.1 Field Experiment I

4.1.1 Dry matter yield of fodder maize as influenced by graded levels of potassium and sulphur at Malanagatihalli (Tyamagondlu series)

The data on the main effects of different levels of K and S on dry matter yields of fodder maize are given in

Table 3. Significant increase in dry matter yield was recorded with increase in levels of K up to 60 kg K₂O ha⁻¹ and also with 20 kg S ha⁻¹. Maximum yield of 4.68 t ha⁻¹ was recorded at 60 kg K₂O ha⁻¹ compared to 3.14 t ha⁻¹ without addition of potassium. Similarly the maximum yield of 4.88 t ha⁻¹ was observed by application of 20 kg S ha⁻¹ compared to 3.60 t ha⁻¹ without sulphur addition.

The interaction effects of K and S on dry matter yield of fodder maize were also significant. It was noted that maximum yield of 5.37 t ha⁻¹ was obtained with K₆₀ S₂₀ followed by 5.15 t ha⁻¹ with K₉₀ S₂₀ compared to 3.55 t ha⁻¹ with K₀ S₀. The yields steadily increased by applied K and S combinations upto K₆₀ S₂₀ beyond which yields were decreased.

4.1.2 Concentrations of potassium in fodder maize

Concentrations of potassium in fodder maize improved significantly by levels of K as well as of S (Table 4). The results showed to contain 0.99 % K at K₀, which gradually increased to 1.26 % at K₉₀. It was also seen that S levels were equally effective in enhancing K concentration in tissues from 1.05 at S₀ to 1.27 % K at S₃₀.

Potassium and sulphur interaction produced favourable and significant effects on concentration of K in dry matter

TABLE 3. DRY MATTER YIELD OF FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT MALANAGATIHALLI (TYAMAGONDLU SOIL SERIES).

K levels ₁ (kg K ₂ O ha ⁻¹)	Yield ₁ (t ha ⁻¹)	S levels ₁ (kg S ha ⁻¹)	Yield ₁ (t ha ⁻¹)
0	3.14	0	3.60
30	4.24	10	4.29
60	4.68	20	4.88
90	4.00	30	4.29
S.Em. \pm	0.14		0.14
C.D. @ 5%	0.40		0.40

Intercation of K x S on dry matter yield

K level (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10	20	30
	(tha ⁻¹)			
0	3.55	3.90	4.35	4.75
30	3.83	4.25	4.65	4.23
60	3.83	4.85	5.37	4.68
90	3.72	4.16	5.15	3.48
S.Em. \pm	0.28			
C.D. @ 5%	0.81			

TABLE 4. CONCENTRATION OF POTASSIUM IN DRY MATTER OF FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT MALANAGATHIHALI (TYAMAGONDLU SOIL SERIES)

K levels _{s₁} (kg K ₂ O ha ⁻¹)	Concentration of K (per cent)	S levels _{s₁} (kg S ha ⁻¹)	Concentration of K(per cent)
0	0.99	0	1.05
30	1.21	10	1.15
60	1.23	20	1.22
90	1.26	30	1.27

S.Em. \pm	0.01		0.01
C.D. @ 5%	0.03		0.03

Interaction of K x S

K levels _{s₁} (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10	20	30
	(per cent)			
0	0.79	0.90	0.10	1.18
30	1.10	1.20	1.24	1.28
60	1.14	1.22	1.26	1.30
90	1.18	1.26	1.28	1.32

S.Em. \pm	0.02			
C.D. @ 5%	0.04			

tissues of maize. There was gradual improvement in K concentration by additions of K and S in combinations. The concentration of 0.79 % at K₀ S₀ in dry matter was enhanced gradually with a maximum recorded concentration of 1.32 % at K₉₀ S₃₀ indicating the synergistic effects on fodder maize.

4.1.3 Uptake of potassium

As judged from the Table 5, each levels of K and S independantly enhanced the uptake of K significantly by fodder maize. The maximum uptake of K was with K₆₀ (56.53 kg K/ha) and with S₂₀ (57.43 kg K/ha) as against 40.76 and 37.93 kg K/ha in K₀ and S₀ levels, respectively.

The interaction effects of K X S levels enhanced the uptake to an extent of 65.73 kg K/ha at K₉₀ S₂₀ levels on fodder maize.

4.1.4 Concentration of sulphur in Fodder Maize

It is noted (Table 6) that maize plants accumulated more sulphur with graded levels of K and also S and the differences due to levels of each of K and S were statistically significant. Enhancement of concentration of S in plant tissues increased linerly either by graded levels of K or S. In case of K levels it increased from 0.174 per cent

TABLE 5. UPTAKE OF POTASSIUM BY FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT MALANAGATIHALLI (TYAMAGONDLU SOIL SERIES).

K levels ₁ (kg K ₂ O ha ⁻¹)	Uptake ₁ of K (kg ha ⁻¹)	S levels ₁ (kg S ha ⁻¹)	Uptake of K (kg ha ⁻¹)
0	40.76	0	37.93
30	51.27	10	49.42
60	56.53	20	57.43
90	50.48	30	54.25
S.Em. \pm	1.81		1.81
C.D. @ 5%	5.02		5.02

Interaction of K x S

K levels ₁ (kg K ₂ O ha ⁻¹)	S levels (kg S ha ⁻¹)			
	0	10 (kgha ⁻¹)	20	30
0	26.07	35.04	43.90	56.05
30	42.20	51.05	57.70	54.15
60	43.64	59.18	62.40	60.88
90	37.81	52.43	65.73	45.93
S.Em. \pm	3.62			
C.D. @ 5%	10.05			

TABLE 6. CONCENTRATION OF SULPHUR IN DRY MATTER OF FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT MALANAGATIHALLI (TYAMAGONDLU SOIL SERIES)

K levels ₁ (kg K ₂ O ha ⁻¹)	Concentration of S (per cent)	S levels ₁ (kg S ha ⁻¹)	Concentration of S(per cent)
0	0.174	0	0.16
30	0.185	10	0.18
60	0.197	20	0.20
90	0.207	30	0.22

S.Em. ±	0.006		0.006
C.D. @ 5%	0.017		0.017

Interaction of K x S

K levels ₁ (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10	20	30
	(per cent)			
0	0.15	0.17	0.18	0.21
30	0.16	0.18	0.19	0.21
60	0.16	0.19	0.21	0.23
90	0.17	0.19	0.23	0.24

S.Em. ±	0.012			
C.D. @ 5%	0.034			

with K_0 to 0.207 with K_{90} . In respect of levels of S it varied from 0.16 with S_0 to 0.22 per cent with S_{30} .

The interaction of K x S levels on the concentration of S in fodder maize tissue ranged from 0.15 at $K_0 S_0$ to 0.24 per cent at $K_{90} S_{30}$.

4.1.5 Uptake of Sulphur

Fodder maize responded favourably to graded levels of K and S to cause greater and significant uptake of sulphur (Table 7). It was observed that sulphur uptake improved significantly by each levels of K or S. In case of levels of K, it varied from 7.24 kg at K_0 to 9.16 kg ha^{-1} at K_{60} . Similarly for S levels, it enhanced from 5.75 at S_0 to 9.86 kg K ha^{-1} at S_{20} level.

The interaction of K x S levels on the uptake of S by fodder maize varied from 5.30 kg S at $K_0 S_0$ to 11.76 kgS ha^{-1} at $K_{90} S_{20}$ level.

4.2 Field Experiment II

4.2.1 Dry matter yield of fodder maize as influenced by levels of potassium and sulphur in Chagalhatti (Vijayapura series)

Significant effects of levels of K as well as of S on

TABLE 7. UPTAKE OF SULPHUR BY FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT MALANAGAHALLI (TYAMAGONDLU SOIL SERIES).

K levels ₁ (kg K ₂ O ha ⁻¹)	Uptake of S (kg S ha ⁻¹)	S levels ₁ (kg S ha ⁻¹)	Uptake of S (kg ha ⁻¹)
0	7.24	0	5.75
30	7.86	10	7.68
60	9.16	20	9.86
90	8.36	30	9.33
S.Em. ±	0.30		0.30
C.D. @ 5%	0.83		0.83

Interaction of K x S

K levels ₁ (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10 (kg ha ⁻¹)	20	30
0	5.30	5.39	7.60	9.47
30	6.02	7.69	8.82	8.90
60	6.13	8.55	11.25	10.71
90	5.54	7.89	11.76	8.23
S.Em. ±	0.60			
C.D. @ 5%	1.67			

the dry matter yield of fodder maize were noticed and the yield differences were statistically significant (Table 8).

Fodder maize yield increased from 2.69 t ha^{-1} at k_0 to a maximum of 4.44 t ha^{-1} at K_{90} . Similarly the yields of dry matter yield varied from 3.40 t ha^{-1} at S_0 to 4.41 t ha^{-1} S_{20} level.

The interaction of K x S levels on the yield of dry matter of maize were favourable to cause improvement in yields ranging from 2.5 t ha^{-1} at $K_0 S_0$ to 5.00 t ha^{-1} at $k_{30} S_{20}$ and also at $K_{60} S_{30}$ level (4.87).

4.2.2 Concentration of potassium in fodder maize

Application of potassium and sulphur significantly influenced the concentration of K in tissues of dry matter of maize (Table 9). The K concentration of tissues of fodder maize increased significantly at each graded levels of K. It varied from 0.91 per cent at K_0 to a maximum of 1.21 per cent K at K_{90} .

The effects of S levels on the concentration of K in fodder maize were also significant. At S_0 level, the concentration of K was 1.04 per cent which increased to 1.17 per cent of S_{30} level.

TABLE 8. DRY MATTER YIELD OF FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT CHAGALHATTI (VIJAYAPURA SOIL SERIES).

K levels ₁ (kg K ₂ O ha ⁻¹)	Fodder yield (t ha ⁻¹)	S levels ₂ (kg S ha ⁻¹)	Fodder yield (t ha ⁻¹)
0	2.69	0	3.40
30	4.32	10	4.11
60	4.35	20	4.41
90	4.44	30	4.08

S.Em. \pm	0.16		0.16
C.D. @ 5%	0.46		0.46

Interaction of K x S

K levels ₁ (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10 (t ha ⁻¹)	20	30
0	2.54	2.60	3.00	2.62
30	3.70	4.25	5.00	4.33
60	3.75	4.83	4.75	4.87
90	3.62	4.78	4.78	4.50

S.Em. \pm	0.33			
C.D. @ 5%	0.91			

TABLE 9. CONCENTRATION OF POTASSIUM IN DRY MATTER OF FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT CHAGALHATTI (VIJAYAPURA SOIL SERIES)

K levels _{s₁} (kg K ₂ O ha ⁻¹)	Concentration of K (per cent)	S levels _{s₁} (kg S ha ⁻¹)	Concentration of K(per cent)
0	0.91	0	1.04
30	1.14	10	1.10
60	1.17	20	1.14
90	1.21	30	1.17

S.Em. ±	0.01		0.01
C.D. @ 5%	0.03		0.03

Interaction of K x S

K levels _{s₁} (kg K ₂ O ha ⁻¹)	S levels (kgS ,ha ⁻¹)			
	0	10	20	30
	(per cent)			
0	0.82	0.91	0.94	0.98
30	1.08	1.11	1.18	1.21
60	1.10	1.16	1.20	1.23
90	1.16	1.21	1.24	1.26

S.Em. ±	0.02			
C.D. @ 5%	0.06			

Interaction of K x S levels on the concentration of K yielded similar results. The concentration of 0.82 per cent K at $K_0 S_0$ level increased to maximum of 1.26 per cent K at $K_{90} S_{30}$ level.

4.2.3 Uptake of potassium

Fertilizer potassium and sulphur applied to fodder maize at graded levels from 0 to 90 kg K_2O ha^{-1} and 0 to 30 kg S ha^{-1} each produced significant influence on the uptake of potassium (Table 10).

Potassium levels increased K uptake significantly from 36.56 kg K ha^{-1} at K_0 level to 58.23 kg K ha^{-1} at K_{60} level. Sulphur levels also caused similar effects on the uptake of K from 39.95 at S_0 to 54.12 kg K ha^{-1} at S_{20} levels.

Interaction of K x S in fodder maize registered K uptake from 20.82 kg K at $K_0 S_0$ to 69.0 kg K/ha at $K_{60} S_{20}$. It was also observed that levels of K and S added beyond 60 and 20 kg each were ineffective on the uptake of potassium.

4.2.4 Concentration of sulphur in fodder maize

It was noticed that sulphur concentration increased significantly in fodder maize tissues by applying fertilizer K or S in increasing order (Table 11). Potassium levels from

TABLE 10. UPTAKE OF POTASSIUM BY FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR IN CHAGALAHATTI (VIJAYAPURA SOIL SERIES).

K levels _s (kg K ₂ O ha ⁻¹)	Uptake _s of K (kg ha ⁻¹)	S levels _s (kg S ha ⁻¹)	Uptake of K (kg ha ⁻¹)
0	36.56	0	39.95
30	49.56	10	47.38
60	58.23	20	54.12
90	54.26	30	49.33
S.Em. ±	1.30		1.30
C.D. @ 5%	4.18		4.18

Interaction of K x S

K levels _s (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10 (kg ha ⁻¹)	20	30
0	20.82	23.83	28.23	26.09
30	39.97	47.15	58.77	52.36
60	41.19	58.10	69.03	64.60
90	42.01	57.82	60.45	56.75
S.Em. ±	3.48			
C.D. @ 5%	9.12			

TABLE 11. CONCENTRATION OF SULPHUR IN DRY MATTER OF FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT CHAGALHATTI (VIJAYAPURA SOIL SERIES)

K levels ₋₁ (kg K ₂ O ha ⁻¹)	Concentration of S (per cent)	S levels ₋₁ (kg S ha ⁻¹)	Concentration of S(per cent)
0	0.197	0	0.185
30	0.217	10	0.207
60	0.215	20	0.222
90	0.218	30	0.233
S.Em. \pm	0.050		0.050
C.D. @ 5%	0.013		0.013

Interaction of K x S

K levels ₋₁ (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10	20	30
0	0.17	0.20	0.21	0.21
30	0.19	0.21	0.23	0.24
60	0.19	0.21	0.22	0.24
90	0.19	0.21	0.23	0.24
S.Em. \pm	0.009			
C.D. @ 5%	0.026			

0 to 90 kg K_2O ha^{-1} enhanced the concentration of K from 0.197 to 0.218 per cent whose differences were statistically significant. The steady and gradual increase in S concentration of tissues of dry matter was significant which varied from 0.185 at S_0 to 0.233 per cent S at S_{30} level.

Though the effects of K x S levels on the concentration showed increasing trend only at S_{30} level with all the levels of applied K showed significant increase in S concentration.

4.2.5 Uptake of Sulphur

Marked significant effects of added levels of fertilizer K and S each to fodder maize on sulphur uptake was noticed (Table 12). Greater uptake of S by fodder maize was noted at K_{60} level recording 10.35 kg S ha^{-1} compared to 5.30 kg S ha^{-1} at K_0 level.

Regarding addition of fertilizer sulphur, the trend was similar recording values of 6.31 kg S at S_0 to 10.27 kg S ha^{-1} at S_{20} level whose differences at each levels were statistically significant.

Interactions of K x S levels on the uptake of S showed improved trend in concentrations varying from 4.30 kg S ha^{-1} at $K_0 S_0$ to 12.63 kg S ha^{-1} at $K_{60} S_{20}$ levels.

TABLE 12. UPTAKE OF SULPHUR BY FODDER MAIZE AS INFLUENCED BY LEVELS OF POTASSIUM AND SULPHUR AT CHAGALHATTI (VIJAYAPURA SOIL SERIES).

K levels ₁ (kg K ₂ O ha ⁻¹)	Uptake ₁ of S (kg ha ⁻¹)	S levels ₁ (kg S ha ⁻¹)	Uptake of S ₁ (kg ha ⁻¹)
0	5.30	0	6.31
30	9.46	10	8.56
60	10.35	20	10.27
90	9.70	30	9.67

S.Em. ±	0.26		0.26
C.D. @ 5%	0.73		0.73

Interaction of K x S

K levels ₁ (kg K ₂ O ha ⁻¹)	S levels (kgS ha ⁻¹)			
	0	10 (kg ha ⁻¹)	20	30
0	4.30	5.17	6.23	5.50
30	7.03	8.93	11.49	10.41
60	7.09	10.13	12.63	11.53
90	6.82	10.00	10.72	11.25

S.Em. ±	0.53			
C.D. @ 5%	1.46			

4.3.1 Chemical Composition of Soil at Malanagatihalli (Tyamagondlu series) After Harvest of Fodder Maize

The data on chemical composition of soil after harvest of fodder maize at Malanagatihalli (Tyamagondlu series) are given in Table 13 a and 13 b.

Though there found to be a slight decrease in pH after the application of treatments from the original pH (6.3), there was no significant variations among the treatments. Similarly, treatments had no significant effect on EC. The original organic carbon content of the soil was 0.33% (Table 1) which slightly increased to 0.4 - 0.5 due to the treatments. Varying levels of S at a given level of K showed significant influence on organic carbon content in most of the cases. Organic carbon increased with increase in the level of sulphur application at a given K level. However, K x S interaction had no significant influence in the status of total nitrogen. But available P_2O_5 showed a general decrease with higher S levels with all levels of K. When sulphur was applied at the rate of 20 and 30 kg ha⁻¹ available P_2O_5 in the soil was significantly reduced. Available potassium status increased with K application. There was no significant variation on Ca + Mg with respect to different treatments. There was significant variation in zinc content

Table 13 (a). CHEMICAL COMPOSITION OF SOIL AT MALANAGATHIHALLI (TYAMAGONDLU SERIES) AFTER HARVEST OF FODDER MAIZE

Treatment	pH	EC ⁻¹ (dSm ⁻¹)	Organic carbon (per cent)	Total N (per cent)	Available P ₂ O ₅ kg ha ⁻¹	Available K ₂ O kg ha ⁻¹
K0 S0	6.02	0.17	0.40	0.08	36.2	62.2
K0 S10	6.01	0.17	0.44	0.09	32.8	59.0
K0 S20	6.01	0.18	0.43	0.09	30.2	56.3
K0 S30	6.02	0.18	0.40	0.08	30.0	55.8
CD @ 5%	NS	NS	0.03	NS	2.0	3.6
K30 S0	6.03	0.17	0.42	0.07	34.8	52.5
K30 S10	6.01	0.18	0.46	0.07	31.6	70.0
K30 S20	6.06	0.18	0.50	0.06	28.5	65.8
K30 S30	6.06	0.18	0.48	0.05	28.5	64.8
CD @ 5%	NS	NS	0.02	NS	2.8	4.2

Contd..... Table 13 (a)

Treatment	pH	EC ₁ ⁻¹ (dSm ⁻¹)	Organic carbon (per cent)	Total N (per cent)	Available P ₂ O ₅ Kg ha ⁻¹	Available K ₂ O kg ha ⁻¹
K60 S0	6.03	0.17	0.42	0.06	31.2	108.5
K60 S10	6.02	0.18	0.44	0.07	28.2	94.2
K60 S20	6.01	0.19	0.47	0.07	25.3	80.0
K60 S30	6.00	0.19	0.51	0.07	24.6	65.8
CD @ 5%	NS	NS	0.03	NS	1.98	8.5
K90 S0	6.03	0.18	0.43	0.08	30.0	132.5
K90 S10	6.01	0.19	0.44	0.06	26.2	116.4
K90 S20	6.00	0.20	0.47	0.06	25.8	108.5
K90 S30	6.00	0.20	0.49	0.05	23.4	114.2
CD @ 5%	NS	NS	0.02	NS	2.2	6.8

Table 13 (b). CHEMICAL COMPOSITION OF SOIL AT MALANAGATIHALLI (TYAMAGONDLU SERIES) AFTER HARVEST OF FODDER MAIZE

Treatment	Available S (Kg S ha ⁻¹)	Ca + Mg (C mol kg ⁻¹)	Zinc (ppm)	Copper (ppm)	Manganese (ppm)	Iron (ppm)
K0 S0	11.8	2.12	0.44	2.00	2.10	4.02
K0 S10	20.0	2.10	0.48	1.80	1.90	4.50
K0 S20	23.3	2.08	0.52	1.60	1.85	4.55
K0 S30	23.0	2.09	0.49	1.50	1.70	4.20
CD @ 5%	2.8	NS	0.05	NS	NS	0.10
K30 S0	10.0	2.10	0.42	1.89	2.40	4.38
K30 S10	23.2	2.10	0.46	1.79	2.18	4.48
K30 S20	26.0	2.06	0.49	1.30	2.08	4.50
K30 S30	25.8	2.06	0.47	1.10	2.10	4.30
CD @ 5%	2.4	NS	0.03	NS	NS	NS

Contd..... Table 13 (b)

Treatment	Available S (Kg S ha ⁻¹)	Ca + Mg (C mol kg ⁻¹)	Zinc (ppm)	Copper (ppm)	Manganese (ppm)	Iron (ppm)
K60 S0	9.8	2.10	0.40	1.85	2.13	4.25
K60 S10	22.8	2.08	0.45	1.68	1.85	4.00
K60 S20	27.6	2.06	0.48	1.60	1.70	4.10
K60 S30	25.9	2.06	0.49	1.62	1.65	4.10
CD @ 5%	NS	2.08	0.06	NS	NS	NS
K90 S0	9.02	2.00	0.39	1.06	2.08	3.98
K90 S10	23.2	2.06	0.43	1.63	1.85	4.25
K90 S20	26.8	2.06	0.46	1.42	1.60	4.55
K90 S30	27.2	2.05	0.48	1.38	1.55	4.40
CD @ 5%	3.2	NS	0.09	NS	NS	0.09

among the treatments though no general trend was noticed. The changes in micronutrients like, copper and iron were not significant.

In regard to available status of micronutrients, there was gradual depletion in their contents from the original status. The DTPA extractable Cu, Fe and Mn decreased from 2.18, 4.65 and 2.5 (original concentration) to 1.60, 4.10 and 1.70 ppm respectively with $K_{60} S_{20}$. There was no change in the Zn concentration.

4.3.2 Chemical Composition of Soils of Chagalhatti (Vijayapura Series) After Harvest of Fodder Maize

The soil pH was not significantly affected by different treatments although the pH showed slight decrease, from the original value (6.8) (Table 14a and 14b). The treatments did not differ significantly with respect to EC. However significant differences were noticed for organic carbon values due to the treatments. In general organic carbon varied from 0.38 for $K_0 S_0$ to 0.49 with $K_{30} S_{20}$. Different treatments did not influence the total nitrogen but higher levels of sulphur decreased available P as in the case of soils at Malanagatihalli. Application of sulphur at 20 and 30 $kg\ ha^{-1}$ increased available sulphur status but decreased available P significantly. When potassium was applied at the rate of 90 $kg\ K_2O$, the available K in the soil after harvest of

Table 14 (a). CHEMICAL COMPOSITION OF SOIL AT CHAGALAHATTI (VIJAYAPURA SERIES)
AFTER HARVEST OF FODDER MAIZE

Treatment	pH	EC ⁻¹ (dSm ⁻¹)	Organic carbon (per cent)	Total N (per cent)	Available P ₂ O ₅ kg ha ⁻¹	Available K ₂ O kg ha ⁻¹
K0 S0	6.7	0.17	0.38	0.09	31.5	58.5
K0 S10	6.6	0.17	0.40	0.09	30.2	49.8
K0 S20	6.4	0.18	0.43	0.08	30.0	46.3
K0 S30	6.4	0.17	0.42	0.08	29.2	42.3
CD @ 5%	NS	NS	0.03	NS	0.10	2.5
K30 S0	6.8	0.17	0.43	0.09	30.5	70.2
K30 S10	6.6	0.18	0.46	0.08	28.5	62.5
K30 S20	6.3	0.18	0.49	0.08	25.0	60.2
K30 S30	6.3	0.19	0.48	0.07	24.8	60.0
CD @ 5%	NS	NS	0.02	NS	2.8	2.4

Contd..... Table 14 (a)

Treatment	pH	EC ₋₁ (dSm ⁻¹)	Organic carbon (per cent)	Total N (per cent)	Available P ₂ O ₅ Kg ha ⁻¹	Available K ₂ O kg ha ⁻¹
K60 S0	6.8	0.17	0.43	0.08	29.2	100.2
K60 S10	6.5	6.19	0.47	0.07	26.8	88.2
K60 S20	6.3	6.19	0.45	0.06	25.2	80.5
K60 S30	6.2	0.19	0.44	0.06	23.5	82.4
CD @ 5%	NS	NS	0.03	NS	1.98	2.1
K90 S0	6.7	0.17	0.44	0.08	30.0	128.5
K90 S10	6.5	0.18	0.48	0.06	25.9	110.2
K90 S20	6.2	0.19	0.46	0.06	24.0	100.8
K90 S30	6.3	0.20	0.45	0.06	24.2	122.5
CD @ 5%	NS	NS	0.02	NS	1.50	10.2

Table 14 (b). CHEMICAL COMPOSITION OF SOIL AT CHAGALHATII (VIJAYAPURA SERIES) AFTER HARVEST OF FODDER MAIZE

Treatment	Available S (Kg S ha ⁻¹)	Ca + Mg (C mol kg ⁻¹)	Zinc (ppm)	Copper (ppm)	Manganese (ppm)	Iron (ppm)
K0 S0	10.2	2.82	0.48	2.0	2.6	5.4
K0 S10	18.2	2.68	0.38	1.7	2.5	4.5
K0 S20	22.5	2.68	0.36	1.5	2.3	4.2
K0 S30	25.2	2.67	0.34	1.6	2.1	4.2
CD @ 5%	2.4	NS	0.08	NS	NS	0.10
K30 S0	9.0	2.50	0.40	1.9	2.5	5.0
K30 S10	16.8	2.59	0.38	1.6	2.5	4.4
K30 S20	20.6	2.55	0.32	1.4	2.1	4.2
K30 S30	23.5	2.52	0.29	4.3	1.5	4.3
CD @ 5%	3.8	NS	0.10	NS	NS	0.20

Contd..... Table 14 (b)

Treatment	Available S (Kg S ha ⁻¹)	Ca + Mg (C mol kg ⁻¹)	Zinc (ppm)	Copper (ppm)	Manganese (ppm)	Iron (ppm)
K60 S0	8.2	2.78	0.34	1.7	2.4	4.8
K60 S10	14.2	2.50	0.30	1.6	2.3	4.3
K60 S20	18.5	2.45	0.28	1.4	2.1	4.0
K60 S30	24.5	2.42	0.29	1.5	2.2	4.1
CD @ 5%	4.2	NS	NS	NS	NS	0.20
K90 S0	8.0	2.75	0.28	1.7	2.3	4.5
K90 S10	12.0	2.52	0.26	1.6	2.3	4.2
K90 S20	17.8	2.48	0.25	1.4	2.2	4.1
K90 S30	27.8	2.40	0.26	1.8	2.2	4.3
CD @ 5%	8.9	NS	NS	NS	NS	0.15

the crop ranged from 100.8 - 128.5 K₂O/ha. It was also observed in Table 14b that the status of exchangeable Ca + Mg decreased due to effects of treatment from 2.82 to 2.40 C mol kg⁻¹. Copper and manganese content did not alter significantly among treatments, whereas with no sulphur application, there was significantly higher iron content. As a consequence of growing fodder maize with fertilizers N, P, K and S, there was alteration in the status of available micronutrients.

DTPA extractable Zn, Cu, Fe and Mn decreased from 0.51, 2.85, 6.25 and 2.78 ppm (original concentration) to 0.38, 1.6, 4.4 and 2.5 ppm, respectively with K₃₀ S₂₀ which was the optimum level for economic yield in this soil.

4.4 Characterisation of soil samples from some typical soil series

4.4.1 Tyamagondlu soil series

Twenty samples from four villages, namely Minnapura, Hosur, T.Begur and Manayakanahalli, were analysed for some soil parameters (Table 15). Results indicated that the soils of Minnapura and Hosur were slightly acidic but four soils out of five in Begur and two soils out of five in Malanayakanahalli were alkaline. The soil samples were low in soluble salts and organic carbon. Among the fraction of sulphur, sodium acetate extractable sulphur status varied

Table 15. CHARACTERISATION OF SOILS FROM SOME TYPICAL SERIES FOR THEIR CHEMICAL PROPERTIES WITH EMPHASIS ON SOIL SULPHUR STATUS

Sl. No.	pH	EC (dSm ⁻¹)	Organic Carbon %	Heat Sol.-S (Kg ha ⁻¹)	Total Water Sol.-S (kg ha ⁻¹)	Sodium acetate extractable-S (kg ha ⁻¹)
Tyamagondlu soil series						
Village - Minnapura						
1.	6.5	0.12	0.42	31.2	11.0	13.8
2.	6.2	0.11	0.40	38.5	14.5	19.0
3.	6.3	0.17	0.32	30.4	10.5	17.6
4.	6.2	0.28	0.36	26.8	12.6	20.8
5.	6.3	0.12	0.42	37.4	14.2	17.2
Village - Hosur						
6.	6.2	0.18	0.42	22.8	8.4	12.8
7.	6.4	0.20	0.25	30.2	10.2	16.4
8.	6.3	0.17	0.36	36.2	12.5	17.2
9.	6.9	0.19	0.32	29.2	11.2	16.4
10.	6.2	0.18	0.28	24.6	6.8	12.4
Village - T.Begur						
11.	7.5	0.12	0.40	24.2	8.8	12.8
12.	7.3	0.20	0.36	23.8	12.5	17.6
13.	5.8	0.18	0.30	28.9	10.0	14.4
14.	7.2	0.21	0.45	24.0	9.6	15.6
15.	7.3	0.20	0.38	28.0	14.8	15.2
Village - Manayakanahalli						
16.	7.1	0.17	0.30	31.5	12.2	23.2
17.	5.4	0.14	0.14	26.5	13.6	18.4
18.	7.1	0.15	0.41	30.2	12.0	15.8
19.	5.6	0.16	0.13	20.3	9.6	15.0
20.	6.8	0.15	0.20	20.2	8.2	12.8

from 12.8 to 27.2 ppm. Heat soluble form of S was dominant over total water soluble-S and Sodium acetate extracted sulphur, heat soluble-S ranged from 20.2 to 28.5 ppm. Total water soluble-S ranged from 6.08 - 14.8 ppm.

Hoskote soil series

There were twenty samples collected five each from villages Cholappanahalli, Malamkanapura, Chikkanallurhalli and Bimakanhalli (Table 16). Most of them were acidic in reaction. Five soils out of twenty registered pH more than 7, the soils were low in soluble salts and organic carbon content ranged from 0.28 to 0.64 %. The sodium acetate extracted-S varied from 12.0 to 18.6 and heat soluble-S ranged from 21.3 to 30.2 ppm and the least was total water soluble fraction (6.8 - 13.5 ppm).

Chikkaballapur series

Unlike soils belonging to Hoskote and Tyamagondlu soil series, these soils tended to be acidic to a greater extent. Only three soil samples recorded pH more than 7 (Table 17). The soil pH varied from 5.5 to 7.5. But they were quite low in organic carbon. The heat soluble-S content varied from 20.5 to 36.8 ppm. Total water soluble-S ranged from 5.5 to 14.2 ppm. The sodium acetate extractable S varied from 9.0 to 20.4 kg ha⁻¹.

Table 16. CHARACTERISATION OF SOILS FROM SOME TYPICAL SERIES FOR THEIR CHEMICAL PROPERTIES WITH EMPHASIS ON FORMS OF SULPHUR

Sl. No.	pH	EC (dSm ⁻¹)	Organic Carbon %	Heat Sol.-S (Kg ha ⁻¹)	Total Water Sol.-S (kg ha ⁻¹)	Sodium acetate extractable-S (kg ha ⁻¹)
Hoskote series						
Village - Cholappanahalli						
21.	5.5	0.12	0.28	24.6	10.2	13.6
22.	6.0	0.08	0.43	21.3	8.5	13.0
23.	6.1	0.11	0.31	22.0	10.2	12.4
24.	6.5	0.10	0.32	23.6	9.5	12.8
25.	6.7	0.13	0.42	28.5	10.4	14.4
Village - Cholankapura						
26.	6.3	0.50	0.36	25.6	10.5	13.8
27.	7.4	0.31	0.63	23.2	8.5	15.0
28.	7.0	0.14	0.56	20.4	10.2	12.8
29.	6.4	0.14	0.46	29.6	10.4	18.4
30.	5.9	0.11	0.64	26.5	11.0	15.6
Village - Chikkanallurhalli						
31.	8.1	0.30	0.49	23.8	8.2	12.4
32.	6.0	0.16	0.40	26.5	9.8	14.6
33.	6.3	0.11	0.42	30.2	11.5	16.4
34.	6.4	0.12	0.53	28.5	8.8	13.8
35.	7.3	0.14	0.47	24.6	6.8	12.0
Village - Bimakanahalli						
36.	5.4	0.07	0.36	24.6	8.2	12.8
37.	6.3	0.12	0.36	26.8	10.5	15.6
38.	6.9	0.16	0.61	30.2	13.5	18.6
39.	6.4	0.19	0.42	21.2	8.2	14.4
40.	7.7	0.17	0.54	27.6	11.5	17.6

Table 17. CHARACTERISATION OF SOILS FROM SOME TYPICAL SERIES FOR THEIR CHEMICAL PROPERTIES WITH EMPHASIS ON FORMS OF SULPHUR

Sl. No.	pH	EC (dSm^{-1})	Organic Carbon %	Heat Sol.-S (Kg ha^{-1})	Total Water Sol.-S (kg ha^{-1})	Sodium acetate extract- able-S (kg ha^{-1})
Chikkaballapur series						
Village - Thogrihatti						
41.	5.2	0.16	0.40	35.8	14.2	20.4
42.	5.7	0.21	0.30	28.6	8.6	12.6
43.	5.6	0.17	0.28	36.8	7.8	12.8
44.	5.5	0.19	0.24	20.5	7.5	13.0
45.	5.5	0.13	0.29	22.8	9.6	12.6
Village - Kanthanakunte						
46.	5.5	0.16	0.43	28.0	12.0	16.8
47.	5.6	0.36	0.41	20.5	6.8	15.0
48.	7.5	0.37	0.41	20.8	9.2	16.4
49.	7.3	0.11	0.30	28.5	6.2	10.4
50.	6.8	0.17	0.62	22.5	8.5	17.6
Village - Kanthankunte						
51.	6.1	0.16	0.30	35.2	6.5	12.8
52.	7.0	0.36	0.33	36.2	8.2	11.0
53.	5.7	0.37	0.36	25.8	9.2	17.0
54.	6.8	0.08	0.33	22.6	7.2	13.8
55.	6.3	0.19	0.29	26.5	8.6	12.6
Village - Thirumagonbianhalli						
56.	6.4	0.12	0.36	28.5	10.2	18.4
57.	7.1	0.23	0.28	30.2	8.4	12.4
58.	6.9	0.11	0.26	32.5	7.6	11.6
59.	6.2	0.17	0.26	30.4	5.5	9.0
60.	6.7	0.18	0.35	29.5	8.2	12.6

DISCUSSION

CHAPTER V

DISCUSSION

There is growing concern towards declining trend in crop yields in the present day system of farming. In spite of the best cultural and farm practices, the yield of crops could not be stepped up. It has been contended that lack of balanced nutrition might be one of the contributory factor for downward trend in crop yields. Among the plant nutrients, the potassium supply and its fractions to plants are not well understood as responses to added potassium result in even in soils known to be quite adequate is available potassium status. Of late, sulphur is becoming a limiting nutrient in most of the soils for crop production. With this in view the field studies were carried out to know the effects of graded levels of potassium and sulphur on soils known to be deficient in potassium and sulphur (Tyamagondlu and Vijayapura series) by using fodder maize as a test crop. Studies were also carried out to characterise the status of available sulphur through soil sulphur fraction in soils of some soil series in Bangalore and Kolar Districts.

Vijayapura and Tyamagondlu series are well established soil series distributed in Bangalore and Kolar district of Karnataka. They are known to be very low in available K and

available S. The field experiment I was conducted at Malanagatihalli village, soils in this village belong to Tyamagondlu series. This soil recorded 89.8 kg available K_2O ha^{-1} and available S registered was only 9.25 kg ha^{-1} which were quite low for sustainance of crop production.

The second field experiment was conducted at Chagalhatti village belonging to Vijayapura series. The available K_2O was only 97.2 kg ha^{-1} and available S was 8.7 kg ha^{-1} (Table 1).

Fodder maize is a major crop in this area where cattle rearing is an important component in farming system of many marginal farmers. The yield level of the crop in this areas is very low mainly because of non practice of recommended agronomic packages.

Usually farmers apply nitrogen and to some extend phosphorus but application of K and S neglected though they are very deficient in these soils. In order to find a suitable K and S combinations, field experiments were conducted in Malanagatihalli (Tyamagondlu series) and Chagalhatti (Vijayapura series) using fodder maize as the test crop. The treatment combination are as described under chapter III.

5.1 Field Experiment I

5.1.1 Dry matter yield of fodder maize

Malanagatihalli (Tyamagondlu Series)

There was significant increase in dry matter yield with the increase in level of K application along with graded levels of sulphur. When K was supplied at the rate of 60 kg K_2O ha^{-1} there was more than 49 per cent increase in yield as compared to that of K_0 level. When effect of sulphur levels was monitored over K levels, significant response was obtained up to S_{20} level. There found to be 35.5 per cent increase in fodder yield over S_0 level when 20 kg S was supplied ha^{-1} . When K x S interaction were compared significant increase in fodder yield was noticed by combined application of K x S. The yield recorded with $K_{60} S_{10}$ was 4.85 against 3.55 t ha^{-1} with $K_0 S_0$ which is 36.6 % increase in yield. This was illustrated in Fig. 1. Further, when S level is increased to 20 kg S ha^{-1} a further increase in dry matter yield by another 10.7 % over $K_{60} S_{10}$ was noticed. This clearly indicate that the utilization of K is more when sulphur in optimum level was supplied with K. The data emphasises the importance of sulphur nutrition in this soil more than that of K. Sulphur fertilization on S deficient soils is necessary for getting optimum yield (Aulakh and

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LEVELS (Kg. K₂O ha⁻¹)

K₀

K₃₀

K₆₀

K₉₀

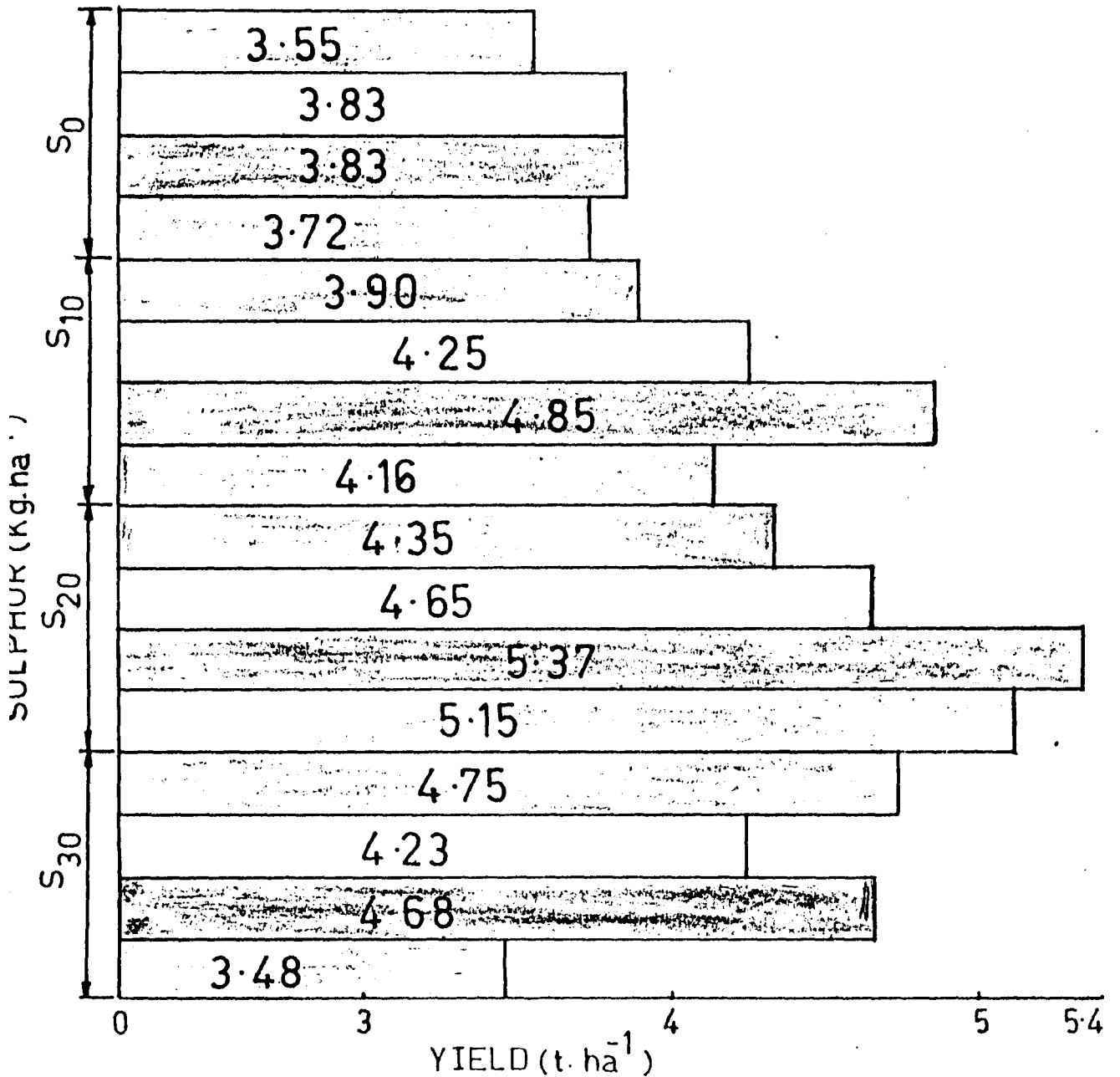


FIG.1: DRY MATTER YIELD OF FODDER MAIZE AS INFLUENCED BY 'K' AND 'S' LEVELS AT MALANAGATIHALLI

Pasricha, 1978). Sulphur has been reported as one of the nutrient limiting crop production in India by many previous workers (Dev and Sharma, 1988 and Bansal, 1992). Removal of sulphur depends upon the crops and the cropping systems. Though oil seeds and legumes require more sulphur as they remove up to 41.5 kg S/t of dry matter, many other species including cereals may remove S to the extent of 2-3 kg S/t of dry matter (Takkar, 1988). Since the soil in which the field experiment was conducted was low in sulphur (9.25 kg ha^{-1}) response to sulphur is highly pronounced. In the present study also similar trend of S uptake was noticed. When S was applied to the crop, the uptake also increased as given in Table 7. This increased uptake was reflected on the yield increase. With S_0 level the sulphur uptake per tonne was found to be 1.59 kg which increased to 2.02 kg at S_{20} level (Table 7). When K was supplied along with sulphur at the rate of $K_{60} S_{20}$ the sulphur uptake increased to 2.09 kg S/t. This explains the requirement of sulphur to the crop along with optimum level of K. Joshi and Seth (1975) found that in sulphur deficient soils for optimum production of wheat, sulphur requirement may be even upto 50 kg S ha^{-1} . Since the soil registered 9.25 kg ha^{-1} available sulphur which is very low compared to the arbitrary optimum level of 10 ppm, the fodder maize is showing significant response to applied S. It is well known that crops need greater amount of K than P

for nourishment and sulphur requirement is almost matching with that of P. The interaction effects of K x S on such deficient soils are synergistic with graded levels of each of K x S resulting in higher crop yield as well as uptake. The critical level for S in this soil needs to be worked out.

The need of applying sulphur along with optimum level of K was also reported by Srinivasa Gowda et al. (1989) in sandy loam soils of Bangalore. According to them when soils are deficient in K and S combined application of optimum levels of K and S positively influenced the germination per cent and also crop growth of radish. The results of the present study reiterated the findings of the above study.

5.1.2 Concentration and uptake of K and S

The concentration of K in fodder maize tissue was lowest in K_0S_0 treatment.

The K concentration increased not only with K application but also with sulphur application indicating the complementary effect of sulphur application on crop growth and thereby increasing nutrient uptake. The maximum K concentration was noticed with $K_{90} S_{30}$ (1.32 %), whereas with $K_{90} S_0$, the K concentration was only 1.18 %. Similar observation was reported by Kumar et al. (1980) for mustard.

The uptake of K increased from 40.76 kg ha⁻¹ with K₀ to 56.53 with K₆₀ recording increase in uptake by 38.6 % Potassium uptake has registered significant increase with sulphur level upto S₂₀.

In regard to interaction effect, it was noticed that K₉₀ S₂₀ registered maximum uptake of K (65.73 kg ha⁻¹). With this treatment, the K removal by the crop works out to 12.76 kg K t⁻¹ where as with K₆₀ S₂₀, the K uptake is 11.62 kg K t⁻¹ of fodder maize. This was applied in Fig. 2. The uptake of K beyond K₆₀ level may be just a luxury consumption, since the yield level was maximum at K₆₀ level and further increase in K additions did not cause any increase in dry matter production. This also illustrated the influence of sulphur on uptake of potassium by the fodder maize. This could be attributed to enhanced crop growth by application of K and S which were deficient. The effect of one nutrient on the other was also noticed when concentration of sulphur was monitored in maize tissue from treatment which received different levels of K and S.

With no S application, when K levels were increased there found to be no significant increase in S concentration. But with increasing levels of sulphur applications even at K₀ level, the concentration of sulphur significantly increased upto S₃₀ level. Sulphur requirement of many crops are

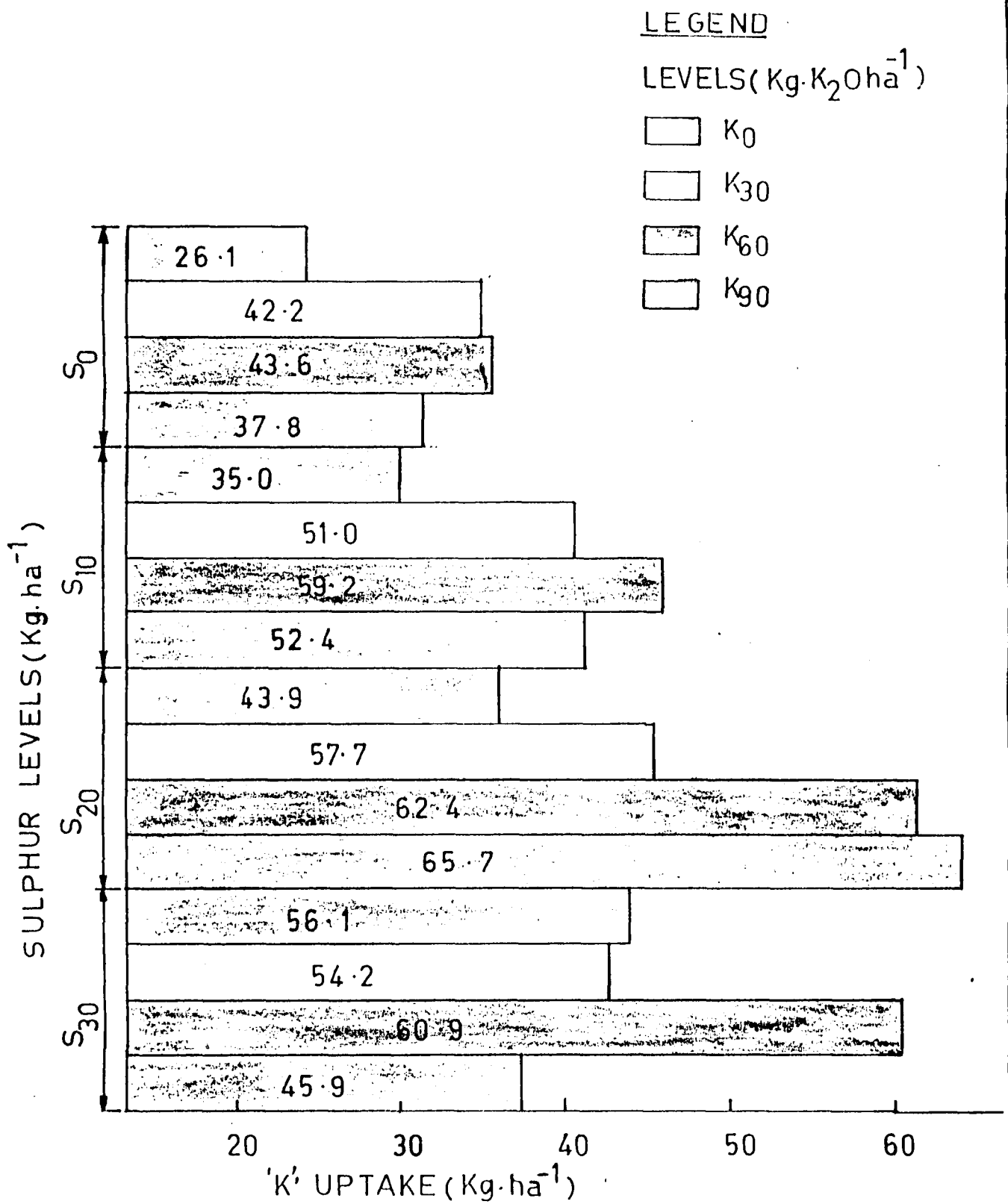


FIG 2: UPTAKE OF 'K' BY FODDER MAIZE AS INFLUENCED BY LEVELS OF FERTILISER 'K' AND 'S' AT MALANAGATIHALLI

comparable to those of phosphorus. The critical level of sulphur for maize was reported to be 14 ppm by Takkar (1988). This suggested that the Malanagatihalli soils belonging to Tyamagondlu soil series is deficient in sulphur to support maize crop. There is need to work out the critical levels for sulphur for different crop in this soils series. However, when K is also deficient, a suitable K and S ratio could increase the yield as found in the present study. Significant uptake of sulphur was noticed with potassium at 60 kg K₂O ha⁻¹ over no K. However sulphur levels resulted in very high increase in S uptake upto S₂₀. In Combination, of K₆₀ S₂₀ recorded 11.25 kg S ha⁻¹ which is equivalent to crop removal of 2.09 kg S/t of dry matter. To sum up, application of 60 kg K₂O ha⁻¹ and 20 kg S ha⁻¹ is the best combination along with 150 kg of N and 100 kg of P₂O₅ ha⁻¹ for fodder maize in this soil. This is depicted in Fig. 3.

5.2 Field Experiment No. II

5.2.1 Dry matter yield of fodder maize

Chagalhatti (Vijayapura series)

From the data given in Table 8 it could be seen that yield response to maize was significant only up to K₃₀ level. This was true even when sulphur was applied along with

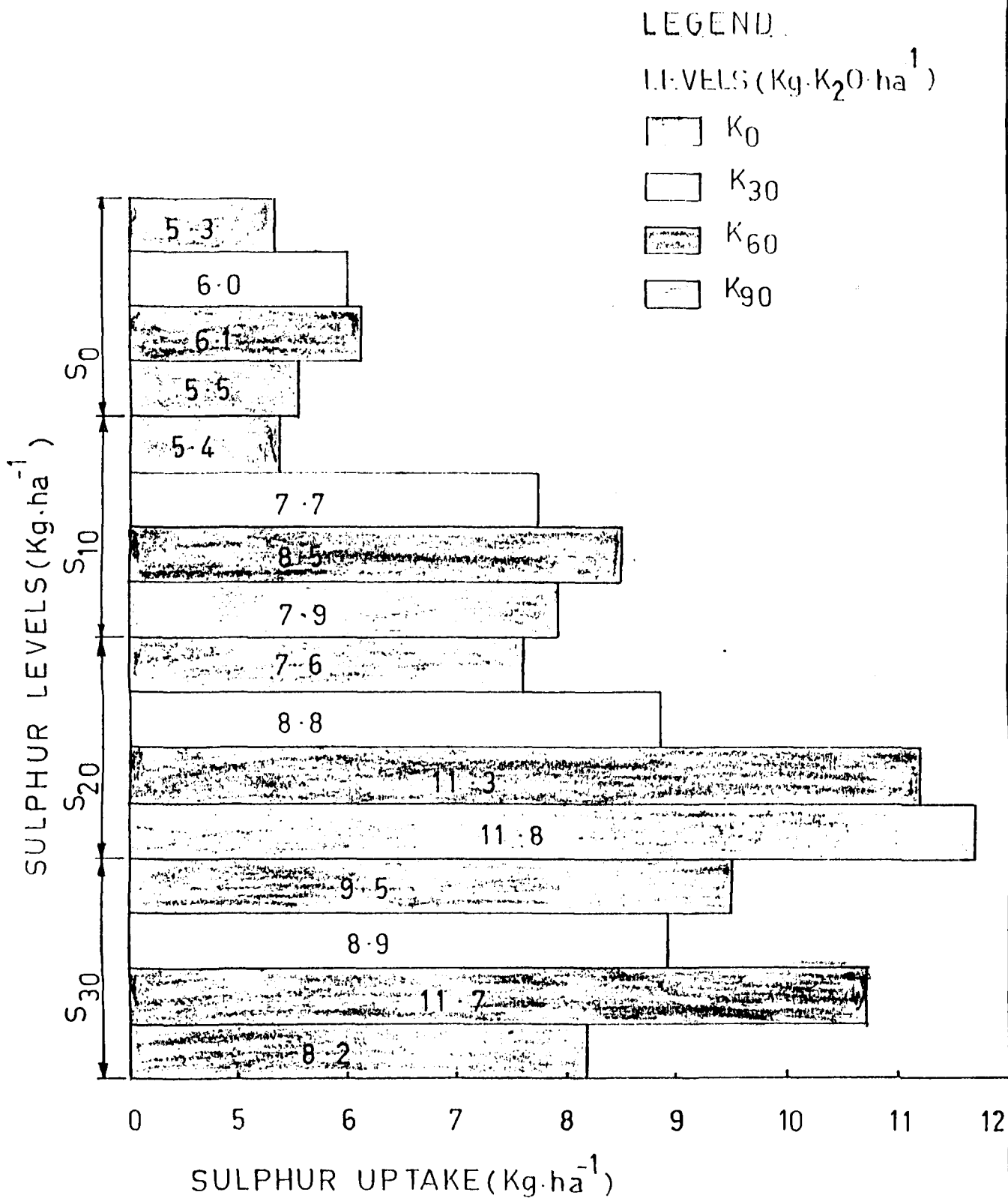


FIG 3: UPTAKE OF SULPHUR BY FODDER MAIZE AS INFLUENCED BY LEVELS OF 'K' AND 'S' AT MALANAGATIHALI

potassium. Hence K₃₀ S₂₀ level was found to be optimum for fodder maize in this soil which is self explanatory as shown in Fig. 4. When sulphur effects were separately considered, there was no significant difference between S₁₀ and S₂₀ levels. But when applied along with K, sulphur addition upto the level of 20 kg ha⁻¹ was found to be beneficial. The soil of Chagalhatti belonging to Vijayapura series are basically low in sulphur (8.7 kg ha⁻¹) and K (97.2 kg K₂O ha⁻¹). However there was no advantage of adding potassium more than 30 kg K₂O ha⁻¹ even in combination with sulphur. The finding of the study lends credence to those of Prithvi Raj et al. (1971) and Kapur (1984).

5.2.2 Concentration and uptake of potassium and sulphur

There was significant and gradual increase in dry matter of fodder maize due to graded levels of potassium and sulphur since the crops were fertilized with uniform levels of N and P. Concentration of K increased with increase in the level of K application. It was interesting to note that K concentration was also influenced due to application of sulphur to a lesser extent as in the case of field experiment I. Similar observations were also reported by Aulakh and Pasricha (1978). Uptake of potassium by maize increased significantly upto K₆₀ S₂₀ level. Application of K beyond 60 kg K₂O ha⁻¹ and application of sulphur beyond 20 kg sulphur

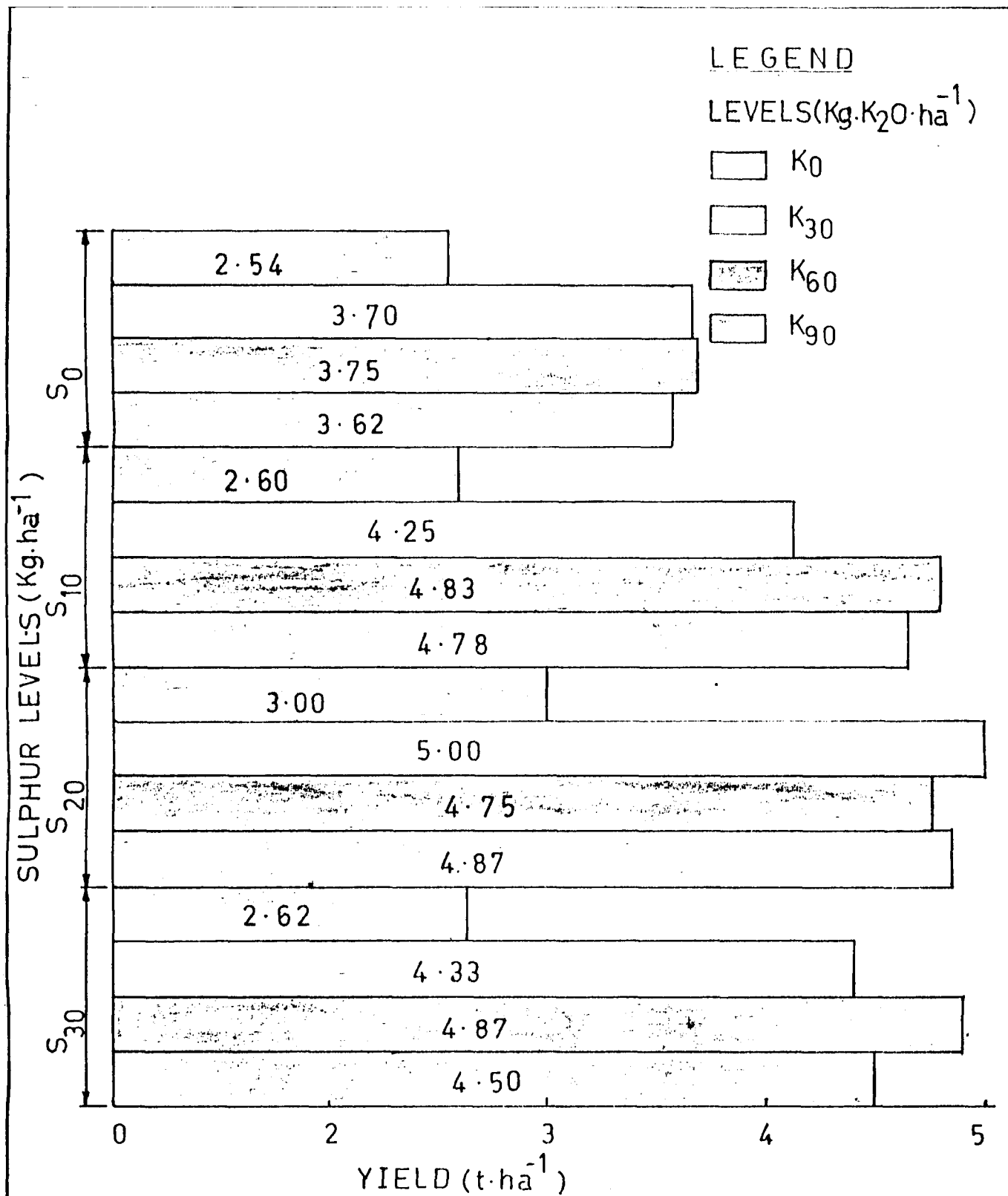


FIG 4: DRY MATTER YIELD OF FODDER MAIZE AS INFLUENCED BY LEVELS OF 'K' AND 'S' AT CHAGALAHATTI

ha^{-1} had no positive effect on K uptake as shown in Fig.5. With $\text{K}_{30} \text{S}_{20}$ level the dry matter production was maximum (5.00 t ha^{-1}), and the uptake of K worked out to 11.75 K t^{-1} . However, for the production of 4.75 t ha^{-1} of dry matter, the uptake recorded was 14.5 kg K t^{-1} . This increase in level of K removal is not reflected in increased production. It is quite possible to predict that the crop growth may be limited due to imbalanced fertilization with NPK (Aulakh and Pasricha, 1978).

The increase in uptake of K with graded levels of K and S fertilizers on other crops like potato were reported by Shukla and Prasad (1979). The findings of the present study reiterate that potassium uptake will be increased by applying other nutrients like N, P and S at optimum levels to the crops.

Concentration and uptake of sulphur with graded levels of K and S showed that S uptake increased upto S_{20} level. But maximum uptake of S was recorded at $\text{K}_{60} \text{S}_{20}$ level showing a positive and synergistic effect of one nutrient on other.

There was no significant increase in S uptake by further increase in K and S levels beyond $\text{K}_{60} \text{S}_{20}$ level as shown in Fig. 6. The study demonstrated that fertilization of crops with nutrients deficient in soils would increase the

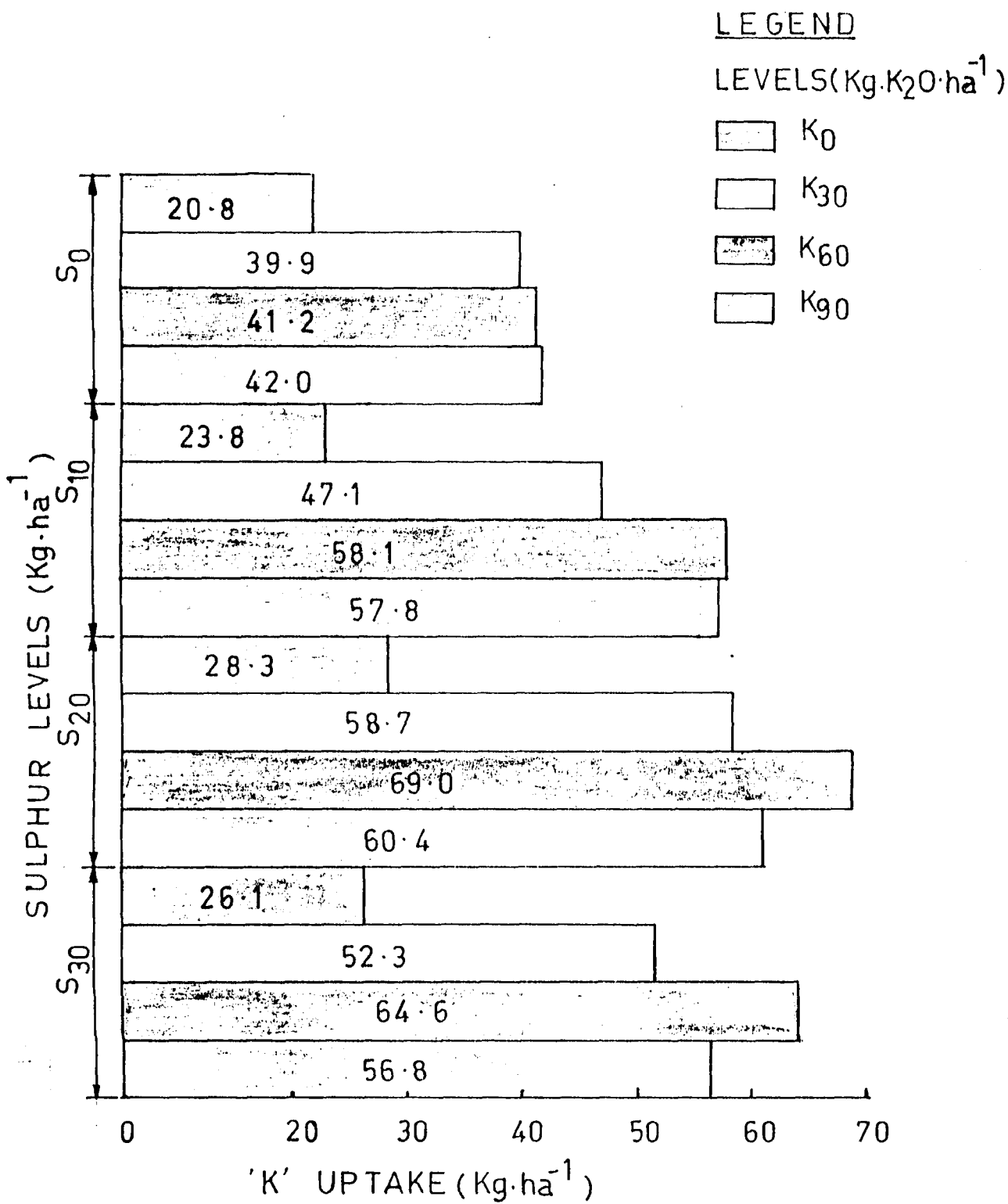


FIG 5: UPTAKE OF 'K' BY FODDER MAIZE AS INFLUENCED BY LEVELS OF 'K' AND 'S' AT CHAGALAHATTI

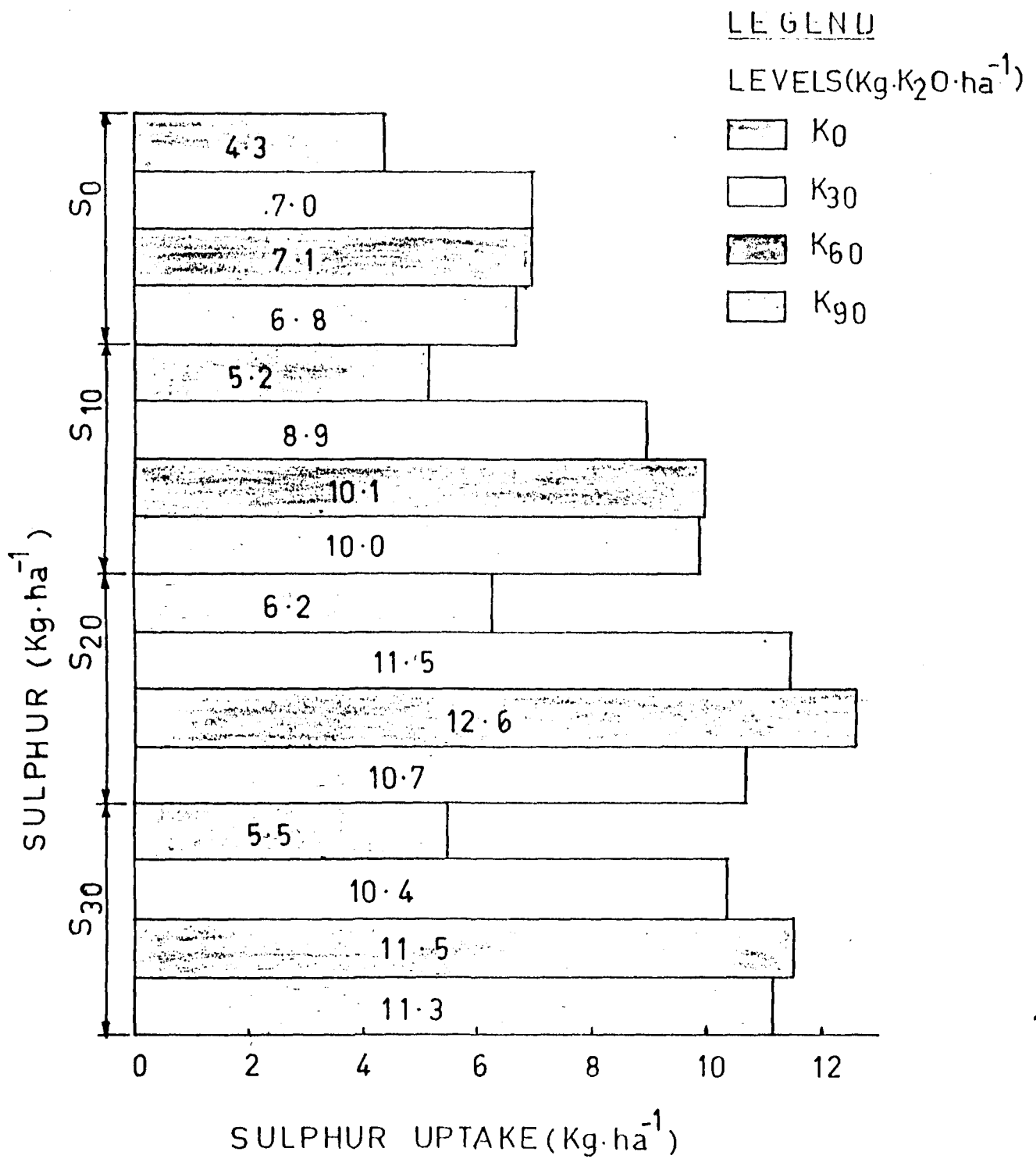


FIG 6: UPTAKE OF SULPHUR BY FODDER MAIZE AS INFLUENCED BY LEVELS OF 'K' AND 'S' AT CHAGALAHATTI

uptake as well as the crop yields. According to Umesh Gupta and Clipman (1975) the beneficial effect of sulphur could be obtained in terms of yield and nutritional utilization by maize, when S is applied to S-deficient soils. Further the significance of S supply on plant growth and uptake was also stressed by Shukla and Prasad (1979). The findings of the present study are in agreement with those reported by these workers.

5.3 Chemical Analysis of Soils at Malanagatihalli in Tyamagondlu Soil Series After Harvest of Fodder Maize

As a consequence of fertilizer application with N and P along with graded levels of K and S to soils, there was considerable removal of plant nutrients from soil matrix causing perceptible changes in the available status of several nutrients.

By and large there was no perceptible changes due to nutrient removal by crop on the status of soil pH, soluble salts and total nitrogen. The increase in organic carbon content was obvious. But the increase in the available status of phosphorus, potassium and sulphur occurred due to their applications. On the other hand, there has been gradual decline in the available status of Ca, Mg, Zn and Fe. Among the nutrients, there was no significant reduction in the

status of Cu but it was not in case of zinc because of its marginal status at the beginning of the study.

Based on the yield and uptake pattern of K and S by maize, it was observed that there appeared to be reduction in the status of native calcium, magnesium and micronutrients especially of zinc. Maize is known to have high requirements of plant nutrients in general and is sensitive to zinc nutrition.

5.4 Chemical Composition of Soils of Chagalhatti Belonging to Vijayapura Soil Series After Harvest of Fodder Maize

The treatment effects of K and S added in graded levels along with uniform application of N and P caused differential removal of plant nutrients by fodder maize. However, treatments imposed therein did not alter the soil pH, EC and total nitrogen status. This might be attributed to the fact that the added fertilizers could hardly bring about significant influence on these parameters. But it was obvious that available status of phosphorus, potassium and sulphur improved indicating that the crop could not be able to utilize all added nutrients. Further in the process, the mineralisation of several nutrients in soil would enable crops to nourish well. Since the yield and uptake pattern showed greater influence of treatments with graded levels,

the concurrent status of available nutrients was related to levels of K and S added. As a result the transformation of nutrients were substantial which was mainly attributed to synergistic effects of K and S.

5.5 Characterization of Soils From Some Typical Soil Series For Available Sulphur Fractions

For this study three soil series were selected namely, Tyamagondlu, Hoskote and Chikkaballapur series. These soil series are distributed in Tumkur, Bangalore and Kolar districts. From each soil series twenty soil samples were collected from four different villages as given under Chapter III.

5.5.1 Tyamagondlu series

Out of twenty samples studied only six samples registered pH more than 7, but all other soils recorded pH between 5.4 to 6.9 and EC range from 0.11 to 0.28 dSm^{-1} .

Soils were very low in organic carbon content which ranged from 0.13 to 0.45 %. Total water soluble sulphur recorded ranged from 6.8 kg ha^{-1} to 14.5 kg ha^{-1} . The distribution of total water soluble sulphur was more uniform in Minnapura village compared to soils from other villages. Morgan extractant extracted higher amount of S but the values

were more uniform. With respect to fractions, heat-soluble sulphur was almost three times greater than water soluble sulphur and almost two times more than sodium acetate extractable sulphur.

5.5.2 Hoskote series

The soils belonging to Hoskote series in Bangalore district were mostly acidic with one soil from Chikkanallur halli indicating pH 8.1 and four soils from Bimakanahalli. Chikkanallurhalli and Cholankanpur registered pH more than 7. All other soils had pH ranging from 5.4 to 6.9 EC values ranged from 0.07 to 0.5 dSm⁻¹, organic carbon ranged from 0.28 to 0.63 %.

The status of different fractions of available sulphur are narrow in Hoskote series as compared to Tyamagondlu series. However the relations among the three fractions remained almost same. Lowest values are registered for total water soluble sulphur ranging from 6.8 to 13.5 kg ha⁻¹, sodium acetate extractable S ranged from 12.0 to 18.6 and heat soluble sulphur ranged from 20.4 to 30.2 kg ha⁻¹.

5.5.3 Chikkaballapur series

Only four soils out of 20 soils belonging to

Chikkaballapur series showed pH greater than 7 and the remaining 16 samples, registered pH between 5.2 to 6.9 and the EC value ranged from 0.08 to 0.37 and organic carbon per cent varied from 0.2 to 0.62 per cent. The soils of Chikkaballapur series had comparatively lower total water soluble sulphur content as compared with other two series. Sodium acetate extractable sulphur was almost two times more than that of total water soluble sulphur, whereas heat soluble sulphur was around three time more than total water soluble sulphur. The range of values for total water soluble, sodium acetate extractable and heat soluble sulphur were 5.5 to 14.2, 9.0 to 20.4 and 20.5 to 36.8 kg ha⁻¹, respectively.

According to Williams and Steinbergs (1959), sulphate sulphur, total water sulphur and heat soluble sulphur were all correlated with the amount of sulphur taken up by the plant. According to them any one of this might provide a suitable index of available sulphur.

White (1958) reported that plants prefer soil sulphur in the form of sulphate ions and suggested that the sulphate-sulphur may prove to be a suitable index in evaluating sulphur content of the soils. While studying different fraction of soil sulphur of G.K.V.K. soils of Bangalore.

Thippeswamy et al. (1988) found that the various fractions of S in the soil in the following order.

Total sulphur > Organic Sulphur > Available sulphur >
Total water soluble sulphur

In the present study also the available sulphur (sodium acetate extractable) was found to be more than total water soluble sulphur. However the heat soluble sulphur recorded the highest values which according to Williams and Steinberges (1959) provide the most suitable index of sulphur availability.

Many reports suggest that organic sulphur is a major fraction of soil sulphur (Thippeswamy, 1988; Mukul Rani Moshi, 1989). A fraction of organic sulphur becomes soluble in water and hence it is possible to hydrolize a fraction of this organic sulphur and the fraction of organic sulphur is also included in heat soluble sulphur. This is the reason for getting higher value for heat soluble sulphur compared to sodium acetate extractable sulphur.

One per cent sodium chloride solution is sometimes used and recommended for extracting sulphate sulphur (Williams and Steinberg, 1959). The sodium chloride extracts a little organic sulphur fraction also and hence hydrogen peroxide treatment was given for sodium chloride extract. The sulphur

in this extract is designated as total water soluble sulphur. From the data it could be seen that total water soluble sulphur represents only a part of sodium acetate extractable sulphur but heat soluble sulphur probably extracts sulphate sulphur and easily oxidisable organic sulphur thereby giving a higher value than sodium acetate extractable sulphur.

The possibility of using any one of these fractions as an index of available S in these soil series are to be tested as a future line of work.

Practical utility of the study

From the present study, the following findings emerge:

1. For optimum production of fodder maize in soils of Vijayapura and Tyamagondlu series a minimum of 30-60 kg K_2O in combination with 20 kg S ha^{-1} is necessary with recommended level of N and P.
2. The three major available S fraction namely total water soluble, sodium acetate extractable and heat soluble sulphur are quantitatively related in 1:2:3 proportions in three major soil series of Bangalore and Kolar districts of Karnataka.

SUMMARY

CHAPTER VI

SUMMARY

The soils of Vijayapura and Tyamagondlu series are known to be very deficient in K and also sulphur. Heavy feeder crops like vegetables and fodder crops are largely cultivated in these soils further depleting the soil nutrients. Farmers practice of fertilization takes care of N needs and to some extent P, but K and S applications are usually neglected. With this view, two field experiments, one in each soil series were conducted with graded levels of K and S.

Field Experiment I

Field experiment - I was conducted in Malanagathihalli in Thyamagondlu soil series. The findings are summarised below:

1. The fodder maize recorded significant response to fertilizer K and S in terms of dry matter production.
2. Almost 36.6 % increase in dry matter yield was registered with K₆₀ S₁₀ over K₀ S₀.
3. When S level was increased to S₂₀ to get a combination of K₆₀ S₂₀, a further increase in dry matter yield by another 10.7 % over K₆₀ S₁₀ was noticed.

4. At this level of $K_{60} S_{20}$, the K uptake was 11.62 kg t^{-1} whereas S uptake was 2.09 kg S t^{-1} .

Field Experiment - II

Field experiment - II was carried out at Chagalhatti village coming under Vijayapura soil series. The findings are summarised below;

1. The optimum combination of K and S for fodder maize in this soil was found to be $k_{30} S_{20}$. At this level the dry matter yield recorded was 5.00 t ha^{-1} , almost 100% more than that recorded with $K_0 S_0$ (2.54 t ha^{-1}).
2. With $K_{30} S_{20}$, the uptake of K recorded was $11.75 \text{ kg K t}^{-1}$ and uptake of S was 1.76 kg S t^{-1} of dry matter of fodder maize.

Characterisation of soils for available S fractions

Sixty soil samples from three soil series namely, Thyamagondlu, Hoskote and Chikkaballapur series were analysed for three soil S fractions.

In all these soils Heat soluble S > Sodium acetate extractable S > Total water soluble S.

In general, the water soluble S; Sodium acetate extractable S; Heat soluble S was approximately 1:2:3 in all the soils.

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CHAPTER VII

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