EFFECT OF APPLICATION OF SULPHUR AND POTASSIUM ON THE YIELD AND QUALITY OF RADISH (*Raphanus sativus*, L.,) AND CARROT (*Daucus carota*, L.,)

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To

Dear Parents

Department of Chemistry and Soils
UNIVERSITY OF AGRICULTURAL SCIENCES
Bangalore

CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF SULPHUR AND POTASSIUM APPLICATION ON THE YIELD AND QUALITY OF RADISH (*Raphanus sativus* L.) AND CARROT (*Daucus carota* L.)" submitted by Sri R. CHANDRASEKHARAN for the degree of MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE of the University of Agricultural Sciences, Bangalore, is a record of the research work done by him during the period of his study, in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

More and more lands are being brought under cultivation. Added to the poor fertility status of soils, deficiency of the major and secondary elements usually occurs in many areas. In the past, large quantities of sulphur were applied to the soil through sulphur containing fertilisers like ammonium sulphate, superphosphate and potassium sulphate. In recent times manufacture and usage of high analysis fertilizers like liquid ammonia, urea, triple superphosphate, diammonium phosphate as well as complexes and so on has resulted in the replacement of sulphur carrying fertilizers. Added to this, the cultivation of highly fertilizer responsive, high yielding varieties of crops have accelerated the depletion of sulphur and have accentuated the imbalances in the supply of nitrogen and sulphur in the soils.

Next in importance to nitrogen and phosphorus potassium is the other major nutrient element that takes part in plant metabolism. It plays an important role in photosynthesis and protein formation. It is also associated with cell division and is indirectly involved in chlorophyll formation. It also contributes to the disease resistance in plants. Rai (1965) and Deosthale <u>et al</u>. (1969) found that potassium treatment alone raised the protein content of sorghum by 1.04 per cent over control, while potassium in combination with nitrogen enhanced the protein content of sorghum over control by 1.74 per cent.

A number of crops have shown response to N.P.K. applications and have shown better yields and to some extent the quality also. It is also found that cruciferous crops, onion and the like, have shown improvement in the yield and quality of the crops, through application of sulphur.

Though some sporadic work has been done on the response to application of sulphur and sulphur with nitrogen and phosphorus, not much work has been done on the response of crops to sulphur with potassium.

In Karnataka especially, information on the response to application of sulphur alone or in combination with the major elements on vegetable crops is not adequately found.

Hence, in view of paucity of information a study on the effect of sulphur and potassium on carrot and radish crops was taken up.

The objectives of the study planned were:

1. To assess the optimum level of sulphur and potassium application for getting maximum yields of radish and carrot crops.

2. To determine the quality parameters as affected by applied fertilizers to radish and carrot crops.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.01. Importance of Vegetable Crops

Hunger and Malnutrition are the inseperable problems facing most of the developing countries. Unless these enemies are fought on a warfooting, the suffering millions, that are and to be, become a threat to the very existence of the nation.

Balanced nutrition is the most critical factor that influences the physical and mental growth, abilities, outlook and behavioral patterns of a person especially during the growing years - Childhood days.

Balanced diet includes the food ingredients like proteins, vitamins, minerals, carbohydrates and the like, Vegetables are a rich source of these next only to fruits and animal products, but more easily available.

2.02. Importance of Radish and Carrot Crops

Radish (*Raphanus sativus* - cruciferae) and Carrot (*Daucus carota* - Umbelliferae) are popular among the root crops in the vegetable world.

Purewal (1957) states that radish has a cooling effect. It prevents constipation and increases appetite. It is more wholesome when cooked together with leaves. It is considered good for patients suffering from piles, liver trouble, enlarged spleen and jaundice (Yawalkar, 1969).

Chauhan (1968) states that carrot has beneficial effect on the kidneys and as a preventive for the brick dust sediments found in urine. According to Nadkarni (1927) carrot seeds are used for producing abortion, fruits are recommended for preventing chronic diarrhoea. Decoction of carrot is a sure remedy for jaundice in Europe. It is considered as a source of sugar and a substitute for coffee. Its scraping is a good stimulating poultice. Ointment of rasped carrot made with lard is useful in curing burns and scalds. They are exceptionally rich in iron and is said to beautify complexion. Its Kanji is a good appetiser. Jain and Mukherjee (1966) have stated that carrot is rich in beta Carotene (β-Carotene). They have also explained processing it for usage.

2.03. Importance of using fertilizers with special reference to sulphur and potassium

It is a well known fact that all crops respond to fertilizer application. In order to get higher yields of crops, the application of nutrients in the form of fertilizers and manures is necessary, particularly in soils which do not have inherent fertility to meet the needs of the crops for certain nutrients (Swaminathan, 1976).

Much of our concern for fertiliser use has been restricted to use of nitrogen, phosphorus and potassium, the three primary nutrients required by crops in large quantities. Due to intensive cropping, some of the secondary and micronutrients are becoming deficient in soils. Hence, attention to the three primary nutrients should be continued and attention should also be given to the secondary and micronutrients. Sulphur is one of the secondary nutrients. Sulphur is an essential element for plant growth and ranks in importance with nitrogen and phosphorus in the formation of plant proteins.

Naik and Das (1964) stated that in the case of a number of laterite, red and alluvial soils deficiency of available sulphur was observed.

Kanwar and Randhawa (1974) stated that in countries like India, vitally concerned with increasing their food production, sulphur is one element that must not be overlooked.

2.04. <u>Sulphur in plant nutrition</u>

A large number of crop species have been found to respond to applications of sulphur under field conditions and pot culture experiments (Tisdale and Nelson, 1966). Some of these are clover, lucerne, pasture grasses, cotton, maize, rice, jute, banana, sweet potato, potato cruciferous crops, berseem, oats, soyabean, groundnut, bulb crops like onion and garlick, coffee, tea and many others.

Sulphur is important in crop production because certain plant functions require sulphur for:

1) The synthesis of amino acids like cystine, cysteine methionine and in turn the formation of proteins.

2) The activation of certain proteolitic enzymes such as papainases, in the synthesis of certain vitamins, glutathiones and of coenzyme 'A'.

3) The formation of certain disulphide linkages that have been associated with the structural characteristics of protoplasm etc.

4) In some species the concentration of sulphydryl (-SH) group in the plant tissues has also been found to be related to increased cold resistance (Coleman, 1966).

2.05. Sulphur metabolism

In general plants form reduced sulphur compounds from sulphates. Methionine and Cysteine (or Cystine-conversion of Cysteine to cystine proceeds rapidly, hence no distinction between cysteine or cystine) are the primary products of sulphur metabolism in plants. In most plants, methionine and cysteine accounts for 90 per cent of the total sulphur. Nearly all the methionine and cysteine are present in proteins (Young and Maw, 1958).

2.06. Importance of Potassium

Potassium is one of the major nutrient elements in plant growth. It plays an important role in photosynthesis and the formation of proteins. It is known to activate forty two different enzyme systems. It is also associated with cell division and is indirectly involved in chlorophyll formation. It contributes to the disease resistance in plants. Muhr et al. (1965) stated that soils can be classified as low, medium or high in potassium depending on available K_2O in the soil. They are low in potassium if they contain less than 140 kg/ha. They are medium upto 336 kg/ha and high if more than 336 kg/ha.

Svenson (1964) while investigating the effect of ammonium sulphate and potassium sulphate on the yield of table potatoes, reported that dressing of 250 kg/ha of potassium sulphate (54 kg sulphur/ha) consistently increased the yield but the response to higher rates of sulphur varied according to variety, when ammonium-sulphate was applied. However, potassium sulphate gave consistent increase in the yield irrespective of the variety. Similarly increase in yield of soyabeans has been reported by Allen (1943), Miyasaka et al.

(1962), Mascarenhas *et al*. (1969), purely because of application of potassium fertilizers. Rao and Pathak (1972) have observed not only an increase in the yield but also an increase in the protein content of soyabeans, by using potassium fertilizers.

2.07. Sources of sulphur to plants

Crop deficiencies can be corrected by the application of numerous sulphur compounds or elemental sulphur. These may be applied separately or included with fertilizers. It may perhaps be more economical to include the sulphur compounds with the fertilizers as the field can be traversed only once.

Elemental sulphur can be safely included with triple superphosphate, ammonium phosphate, urea and anhydrous ammonia (Coleman, 1966). Urea sulphur and sulphur anhydrous ammonia are produced and sold in the U.S. The former is a prilled material containing 40 per cent nitrogen and 10 per cent sulphur while the latter contains 75 per cent nitrogen and 10 per cent sulphur.

Elemental sulphur has been successfully introduced in to the complete N-P-K granular materials. These products have been successfully tested in agronomic experiments (Factamphos contains 16 per cent nitrogen, 20 per cent phosphoric acid and 15 per cent sulphur). High analysis solid materials can also be combined with such sulphur containing fertilizers such as simple super phosphate, ammonium sulphate, potassium sulphate or calcium sulphate to supply the required sulphur. Elemental sulphur however seems to have the advantage of containing the greatest amount of plant nutrient sulphur for the least bulk of any of the fertilizer sources of this element.

Polysulphides, thiosulphates and bisulphites are used either separately or with other liquid fertilizers. Ammonium polysulphide for example contains 20 per cent nitrogen and 45 per cent sulphur and is frequently applied with anhydrous or liquid ammonia in western countries. Ammonium thiosulphate also seems to be an excellent source of sulphur, the commercial product containing 12 per cent nitrogen and 26 per cent sulphur.

However the form to be selected will be, normally determined by the farmers' applied cost. The various sources of sulphur are generally equally effective in promoting plant growth. The extent to which crops respond to sulphur fertilization depends upon the degree ff of sulphur deficiency and type of soil (Jordan and Reisenauer, 1957; Thompson and Neller, 1963; and Jordan, 1964).

Based on the results obtained by Williams and Steinberger (1958), sulphate sulphur, total water soluble sulphur and heat soluble sulphur were all correlated with the uptake of sulphur by plants. They further suggested that only one of them might prove to be an index of available sulphur. But sulphur uptake by plants was highly correlated with heat soluble sulphur.

Sanford and Lancaster (1961) found that sulphur uptake by the crop and sulphate sulphur content in the soil were highly correlated.

Harward et al. (1962) from their studies noted that total uptake of sulphur, of Oregon soils ranged from 88 to 115 mg per pot. There was a close relationship between sulphur uptake and the yield of dry matter.

On application of elemental sulphur to maize, Homes et al. (1965) found beneficial effect on its yield and nutrition, when compared to sulphate application.

Bocklee and Martin (1966) found that though all forms of sulphur were efficient, the sulphate forms were found to be most readily available.

Chopra and Kanwar (1966) and Reddy and Mehta (1970) suggested that heat soluble sulphur was strongly correlated with the sulphur uptake by plants and further noticed that 17 ppm of heat soluble sulphur was required before plants could utilise sulphur from soils.

Sittson Sylvesters (1967) noted that mineralisation of organic sulphur was enhanced by the application of nitrogen and uptake of sulphur was increased in the case of wheat.

Mann (1955) and Little (1958) indicated that continuous application of sulphur containing fertilizers had no influence in increasing the total sulphur content of soils. Jenson (1962) also observed that the increased sulphur content of soil to plough depth was not possible by mere application of sulphur containing fertilizers but was possible through application of organic matter.

According to Roberts and Koehler (1965) growth responses of wheat to sulphur and potassium sulphate at 10 ppm sulphur were almost identical.

2.08. Sources of Potassium to Plants

Potassium is an important nutrient element required for plant growth. It is present in excess quantities in many soils. In soils it exists in the form of potash bearing minerals like feldspars, augite, and mica, in the primary mineral suite. Crop responses to application of nitrogen and phosphorus are positive as against responses to potassium which is soil and crop specific. Among the three major nutrients potassium is the only nutrient taken by plants in the Cationic form. Non-exchangeable, Exchangeable and Soluble forms of potassium influence crop nutrition and the three forms are in a state of dynamic equilibrium in a given soil-crop environment. The complex behaviour of potassium in soils and plants has been succinctly epitomised by Albresht (1947). Fertile loam soils commonly contain 1 to 2 per cent of total potassium. The amount present in most cases is greater than that of any of the major nutrient elements obtained by plants (Attoe and Truog, 1945).

2.09. Effect of sulphur applications on soil properties

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.

Kamprath *et al.* (1956) concluded after their experiments that soils containing a relatively large amount of 1:1 type clay minerals adsorbed more sulphates than soils containing predominantly 2:1 clay minerals. Increasing phosphate concentration decreased the adsorption of sulphates.

Kanwar (1963) stated that soils containing sulphur less than 15 ppm are deficient, up to 15 ppm medium and above 15 ppm are good.

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

Menary and Hughes (1967) noticed that the elemental sulphur and sodium sulphate apparently increased the utilization of fertilizer phosphorous by decreasing the rate of phosphorus fixation.

Kacar and Angul (1967) concluded after their experiment that sulphur increased the availability of soil phosphorous in alkaline calcareous soils.

Bharadwaj and Shukla (1970) studied the effect of sulphur and sulphur bearing compounds on the watersoluble manganese content of a hilly soil in U.P. They found that all the materials were found effective to cause a decrease in soil pH and the amount of water soluble manganese.

Bharathsingh and Mahendrasingh (1975) reported that sulphur availability increased with increased levels of sulphur irrespective of the source of sulphur, but decreased with increased soil phosphorus concentration.

2.10. Effect of sulphur application on the nutrient uptake and yield attributes of crops

Grzesiuk (1965) observed in pot culture experiments that application of sulphur and ammonium sulphate increased protein content of spring rape and also increased uptake of phosphorous, nitrogen, potassium and sulphur.

Pumphrey (1967) found that the sulphur fertilization to deficient soils raised the sulphur content of the forage crops to an extent of 0.22 per cent. It was found that forage crops containing 0.23 per cent sulphur did not respond to sulphur fertilization. Pathak and Bharadwaj (1968) noticed higher contents of sulphur phosphorous, calcium and magnesium in berseem plants with sulphur treatment.

Reisenauer (1963) reported that the uptake of soil and fertilizer molybdenum was markedly reduced by the application of sulphate fertilizer in peas. Application of sulphur prevented chlorosis and increased the yields of peas (Singh, 1970), Dube and Misra (1969) reported that sulphur deficiency reduced the growth of the plants, yield, quality and protein content of the seeds in Peas, blackgram and groundnut. In gram and groundnut small size seeds, small size fruits and fruits without seeds were noticed.

Verma et al. (1973) observed that application of sulphur irrespective of the source, in combination with nitrogen, phosphorous and potash markedly increased the shelling percentage and the oil and protein contents of groundnut Kernels.

Laurence and Gibbons (1976) reported that in addition to yield improvement, total protein content of groundnut Kernels was raised and the oil to protein ratio generally lowered by the application of sulphur alone in sulphur deficient soils.

Dungerwal *et al*. (1974) also oberved that soil application of sulphur or spraying with 0.1 per cent sulphuric acid were effective in increasing groundnut yields. The treatments increased the leaf sulphur content decreased leaf iron content but did not affect nitrogen, phosphorous, and potash contents.

Aulakh *et al*. (1976) worked on the effect of sulphur applications on alfalfa. With increased rates of applied sulphur, the concentrations of total nitrogen, total sulphur, protein nitrogen, protein sulphur and total soluble sulphur in the plants increased but those of non-protein fractions like total soluble nitrogen, amino-acid nitrogen, amide nitrogen and nitrate nitrogen decreased. Aulakh *et al*. (1977) observed in potato that sulphur application increased the yield of potato tubers, content of protein sulphur, total soluble sulphur, total nitrogen and total sulphur. Sulphur fertilization significantly increased potassium and zinc contents but consistantly decreased phosphorus contents.

Dhillon and Dev (1978) reported that sulphur uptake by soyabean was increased with increasing levels of sulphur. The utilization of applied sulphur decreased when the dose was raised to 20 ppm of sulphur.

2.11. 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. According to Dube and Misra (1969) the nitrogen and proteins of peas and groundnut crops were increased by sulphur application. Nicholaides and Cox (1969) noticed an increased nitrogen and sulphur content in groundnut root and top portions with increase in sulphur fertilization and the phosphorous content of groundnut decreased as the sulphur content increased.

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

Pillai and Singh (1974) observed that application of elemental sulphur increased the pH of the leaf sap and calcium and magnesium content and brought about a concommittant increase in nitrogen, potassium and chlorophyll contents of rice, all of which created a balanced nutritional environment, This in turn prevented the occurrence of chlorosis due to low supply of sulphur.

2.12. Response of crops to sulphur and potassium application

Numerous crop species such as maize, cotton, jute, tea, coffee, cruciferous crops, legume crops like alfalfa, soybean, groundnut, bulb crops like onion and garlic, root crops like radish and others have been found to respond favourably to the application of sulphur under field conditions. The extent to which various crops respond to sulphur application depends on the degree of sulphur deficiency in soils.

Attention to sulphur nutrition was drawn by Hart and Peterson (1911). Miller (1919), noticed that plants having high protein content responded most to sulphur fertilization and their protein content was increased.

Younge (1941) stated that there was a significant reduction in yield of cotton where sulphur was not a applied. Sulphur deficiency showed a marked decrease in the number of bolls formed. John (1950) and Conrod (1950) showed that application of sulphur resulted in more than double the yield of some legumes. The yield of succeeding nonlegume crops, was thereby substantially increased.

Sheldon et al. (1951) found twice as much methionine in vegetative material of soybean grown in nutrient solution containing 96 ppm sulphur as compared to the one containing 16 ppm. In non-legumes sulphates may increase considerably with increased sulphur applications (Ergle and Eaton, 1951; Andrew et al., 1952). In leguminous crops much of the increase in total sulphur is synthesised in to proteins (Andrew et al., 1952; Needham and Hauge, 1952). Application of sulphur makes the soil more acidic and this releases enough manganese for normal plant growth (Thomson and Kelly, 1957). Kuhn and Mengel (1963) found that sulphate in superphosphate increases the yield of onion in sulphur deficient soils.

Misra and Keshavaprasad (1966) have tried the effect of sulphur on growth, yield and storage quality of Poona red onion and have noted that 100 pounds of sulphur per hectare has increased the yield of onion by 8.5 per cent and its content of allyl-propyl-disulphide in presence of nitrogen, phosphorus and potash. In addition they have stated that sulphur fertilization has improved the storage quality of onion by decreasing the percentage of rotting during storage. Chopra and Kanwar (1966) noticed that by applying sulphur with nitrogen, phosphorus and potash, significant higher yields of groundnut are obtained. They also noticed increased methionine and cystine contents in groundnut with increased sulphur application.

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

Nanaksingh _et al._ (1970) observed that the yields of groundnut and mustard increased significantly irrespective of the form of sulphur applied and gypsum was found to be a very good source of sulphur especially for oilseed crops.

Aulakh _et al_. (1977) observed that the application of sulphur at the rate of 25 kg per hectare seems to be optimum for both yield and for improving the quality of potatoes.

Somasekhar (1980) studied the growth, yield and quality attributes of knolkhol as influenced by nitrogen and sulphur. Increasing levels of nitrogen and sulphur had favourable and significant influence on all vegetative growth parameters studied. The highest level of nitrogen (225 kg per hectare) and sulphur (25 kg per hectare) resulted in maximum increase in plant height, number of leaves, leaf area index, dry weight of plant, percentage dry matter and yield per hectare. Quality parameters of stem tuber such as ascorbic acid, crude protein crude fibre, ash content and nitrogen content of leaves were most favourably influenced by the highest level of nitrogen and sulphur, that is 225 kg per hectare and 25 kg per hectare respectively.

Next to nitrogen and phosphorus, potassium is another major nutrient element that takes part in plant metabolism. It plays an important role in photosynthesis and protein formation. It is associated with cell division, involved in chlorophyll formation and contributes to disease resistance in plants.

Morgan (1939) found that potato tubers grown with complete fertilizers with adequate amount of potassium have kept better in storage than those grown without the addition of fertilizers without enough potassium. Allen (1943) studied the behaviour of 2 soyabean cultivars at different fertilizer levels noticing difference in response to potassium but less marked differences in response to nitrogen and phosphorous. Lushechkin and Lempitskaya (1958) reported that application of 0.15 kg potassium sulphate per kg of soil increased potato yield compared to potassium chloride. Gerald, E.Wilcox (1961) observed that potato yields were increased by the addition of potassium fertilizer. Miyasaka et al. (1962) also observed an increase in the yield of soyabeans by ten per cent by application of potassium fertilizers. Mascarenhas et al. (1969) observed that, in an acid soil, potassium increased the yield of soyabeans upto 18 per cent by applied potassium.

Akhmodov and Vyvalko (1970) have stated that phosphorous and potassium fertilizers increased the yield and starch content of potatoes but varied with the forms of potassium used. Potassium chloride adversely affected the yield and starch content. Yields improved significantly with potassium sulphate. Muthuswamy and Muthukrishnan (1971) studied the growth responses of radish to treatments of farm yard manure and nitrogen, phosphorous and potassium and observed that fresh root weight responded only to phosphorous and potassium interactions and that each nutrient was effective only in the absence of the other and the response was marked in the presence of nitrogen. Roy and Seth (1972) studied the comparative efficiency of soil and foliar application of nitrogen, phosphorøus and potassium with regard to growth and yield of radish and found that the growth and yield of radish increased significantly in response to applications of nitrogen at 60 and 120 kg per hectare, phosphorøus at 30 and 60 kg per hectare and potash at 30 kg per hectare. Potash at 60 kg per hectare depressed the growth. For equal doses of fertilizers, soil application of whole dose was less effective than split dose of 50 per cent by soil application and the remainder by foliar spray. Haq and Khan (1972) studied the effects of different doses of nitrogen in the form of ammonium sulphate, phosphorøus in the form of superphosphate on the yield of fresh root and seed of radish and found that fresh root weight was greatest in response to 60 pounds nitrogen and 30 pounds phosphorøus per acre, where as seed yield was maximum for the application of 30 pounds of nitrogen only. Rao and Pathak (1972) observed the effect of potassium fertilizers on the yield and protein content of soyabeans. Protein percentage increased with increase in potassium levels and highest dose of 320 kg potash per hectare produced 3 per cent more protein than control. Pirovski and Dyankova (1973) observed that all treatments used in the 3 year factorial trials gave increased yields compared to control. The highest total and marketable crops being produced by nitrogen, phosphorøus and potash with mineral fertilizers.

Kulikova (1975) studied the characteristics and chemical composition of radish grown in the arctics and found that the Chinese and European radish varieties grown outdoors in the arctic cold, dry-weather promoted ascorbic acid and leucoanthocyanin accumulations and higher temperature aided in the accumulation of dry matter, sugars, crude proteins, anthocyanins, potassium and phosphorus. Application of 150 kg per hectare of potassium for sweet potato crop in red oxisol soils of Tanzania increased the yield of potato tubers. But phosphorus application with potassium at this rate reduced the yield (Urio and Kasseba, 1975).

Bible and Chong (1975a) also observed that in 2 cultivars of radishes grown hydroponically in modified Hoaglands solution in 2 concentrations and sulphate at 3 levels, the thiocyanate content in the root and foliage of both cultivars grown in 1/2 x solution contained more thiocyanate, than in tissues grown in 2 x solution. Although the thiocyanate content in Burpee white roots increased linearly with sulphate level in 1/2 x solution, the thiocyanate content in corresponding French breakfast roots and in roots of both cultivars grown in 2 x solution was not significantly affected by sulphur nutrition.

Bible and Chong (1975b) concluded that the thiocyanate content of radish-goiterogen was higher in crops in organic soil and increased under cooler conditions. It was positively correlated with accumulated cold units (degree day accumulation 18°C) and negatively correlated with mean daily air temperature only in organic soil and positively correlated with rainfall accumulation only in loam soil.

Kulikova (1975) assessing the nutritional value of Chinese and European radish cultivars concluded that the cultivars grown in the arctic, cold dry weather promoted ascorbic acid and leuco-anthocyanin accumulations and higher temperature aided the accumulation of dry matter, sugars, crude protein, anthocyanins, potassium and phosphorous. Luzzati et al. (1975) studied the interactions between organic and mineral manuring in vegetable growing (carrot) using nitrogen, phosphorous and potash mineral fertilizers (perphosphate, calcium nitrate, Ammonium nitrate and potassium sulphate) and an organic preparation of fermented popular bark in pot and field experiments. He concluded that bark did not increase root yields but improved the mineral contents of the roots. Yields were highest when nitrogen, phosphorous and potash were applied but phosphorous and potash only increased the mineral content when applied with bark and inorganic nitrogen lowered the mineral content. Mills et al. (1975) studied the nitrate accumulation in radish as affected by nitrapyrin. They concluded that plant nitrate concentration was less with ammonium sulphate than with potassium nitrate and accumulation in both roots and shoots was virtually eliminated by nitrapyrin at concentrations of 5 mg per pot or greater. Total shoot nitrogen was greater with ammonical nitrogen than with nitrate nitrogen but total root nitrogen differed little between the 2 nitrogen sources. Shoot growth was greater with ammonical nitrogen and root growth was greater with nitrate nitrogen. Nitrapyrin had little effect on plant growth.

Burdine and Hall (1976) studied the carrot responses to fertilizer levels on everglade organic x soils. He noticed that response to phosphorøus was quadratic with optimum yield at 88 pounds per acre. Response to potassium was not significant. In a similar experiment where residual soil phosphorous was higher, nitrogen, phosphorøus and potash at 3 levels each was applied. There was no significant response to nitrogen or phosphorus but with higher potash levels there were fewer small roots. In a third experiment with the same residual phosphorøus but with higher residual potash, nitrogen phosphorus and potash at 3 levels each was applied. A linear response to nitrogen may have been caused by a 3.2 inches rainfall, 2.5 weeks before harvest which probably leached most of the available nitrate nitrogen, from the soil. The quadratic response to phosphorus and linear response to potash were mostly due to increase in the number of large sized roots.

In the second experiment the percentage root sucrose and alcohol insoluble solids increased linearly with potassium. In the third experiment nitrogen-phosphorus, nitrogen-potash and nitrogen phosphorus potash interactions were significant for percentage sucrose. Root colour was unaffected by treatments. Pankov (1976) studied the effect of potassium on the chemical composition and productivity of carrots and observed that in container and field trials good plant growth and high yields were obtained only from plants with more than 1.7 percent leaf potash content. Potassium deficiency which decreased leaf potash content,increased calcium, magnesium and phosphorus contents. A close correlation was observed between leaf potash concentration and plant productivity. Kitamura (1977) studied the relationship between yield of Japanese radish and the weather. Multiple regression analysis was used to predict yields. The growing period was divided in to 3 parts and the independent variables were the mean maximum and minimum temperature, precipitation and sunshine hours for these periods. Yield predictions were made for all regions of Japan. They increased moving northward and were higher in eastern Hokkaido.

Hipp (1978) studied the response by carrot to nitrogen and assessment of nitrogen status by plant analysis. He observed that under the subtropical conditions of south texas, carrot grown for more than 128 days showed a yield response to applications of 56 and 112 kg nitrogen per hectare. An application of 168 kg nitrogen per hectare did not improve yields over the 112 kg per hectare level. The optimal nitrogen level in carrot tops was 2.8 and 4.0 per cent of dry weight, sampled 96 and 49 days after emergence respectively.

D'Yachenko and Kurumli (1978) found that in trials in Moscow region phosphorus and potash fertilizer increased carrot yield, carrot quality and resistance to storage rot (unspecified). Storage losses over 6.5 months were 6.3 per cent. However, nitrogen, potash fertilizers doubled storage losses and lowered carrot resistance to rots. Farm Yard Manure at 30 tons per hectare had a similar adverse effect.

Badiger *et al*. (1982) reported that significant response was observed in groundnut crop to application of potassium at 5.00 ppm level with or without sulphur (0 and 10 ppm) and calcium (5 and 10 ppm). The response was significant on Kernel and haulm yield, shelling percentage, crude protein, Cysteine and Methionine. Potassium at 5 ppm level also increased oil yield significantly when combined either with calcium or sulphur.

2.13. Effect of sulphur application on the ascorbic acid, amino acid, and protein content of plants

Ascorbic acid is one of the most important measures of the nutritive quality of vegetables. The content of ascorbic acid present in potato for example varies from 13 mg to 40 mg per 100 gm of fresh weight. Immature tubers contain more ascorbic acid than mature ones. There are varietal differences in Vitamin C content. This vitamin is independent of the size and weight of potato tubers but is present in appreciable amounts in freshly dug potato tubers. Considerable losses of this vitamin occur during storage especially when the storage temperatures are high. The same thing holds good in the case of other vegetables also, since it is a water soluble vitamin, losses during cooking and other processing operations also occurs.

Apart from these losses, complete absence of a nutrient during the growth period might decrease the ascorbic acid content. However, these nutrients are to be supplemented during the growth period of the plant so that the quality is improved.

Dmitrenko and Grotovaschuk (1963) in an experiment to study the effect of different types of mineral fertilizers on the content of starch, and ascorbic acid in potato tubers, noted that application of ammonium chloride lowered the starch and ascorbic acid content but ammonium chloride with basic slag increased the contents of starch and ascorbic acid. This increase they attributed to the basic slag (in combination with ammonium chloride) a good source of phosphorous and sulphur proving advantageous for potato crop.

In green manure experiments with potatoes grown on grey podsolised soils , ʋuk (1972) reported that application of nitrogen, phosphorus and potash resulted in tuber yields of 425 to 460 g per plant, compared with 195 g per plant which received no fertilizers at all. Tuber contents of starch, ascorbic acid, cystine, methionine and protein were increased by increasing the rates of sulphur containing fertilizers. Many researchers including Somoilenko (1971) reported increased average tuber yields due to the application of 80 kg nitrogen, 120 kg phosphorøus and 60 kg potash per hectare when compared to plots which have not received any fertilizers. Application of nitrogen and phosphorus increased ascorbic acid and starch contents in the tubers. Sharma et al. (1976) while reporting the effect of potassic fertilizers on the yield and composition of potatoes reported that sulphate of potash increased the ascorbic acid content, by 2.7 mg per 100 g of fresh weight of tubers. They further noted that sulphate carrying fertilizers were usually better for improving both quality and quantity of potato tubers. Tisdale et al. (1950) observed that alfalfa when grown with different concentrations of sulphur showed a considerable difference in the synthesis of aminoacids with a given amount of sulphur. The percentage of methionine and cystine increased with increase in concentration of sulphur.

Bardsley and Jordan (1957) also concluded that cystine and protein content of clover increased with sulphur applications. Chopra and Kanwar (1966) noted that methionine and cystine contents of groundnut were dependent on sulphur applications. Arora and Luthra (1971) observed a close correlation between sulphur content of leaf at various stages of growth and sulphur containing amino acids like methionine, cystine and cysteine. Beaton et al. (1971) studied crop responses to sulphur application in North America and adduced that sulphur fertilisation increased the protein content of plants.

2.14. Summary of Review

It is evident from the studies conducted by several workers that sulphur and potassium individually increases the yield of many crops.

It was observed from the findings cited above, that most of the studies have been carried out mostly on various crops other than vegetables and the work on vegetable crops in general and that on Radish and carrot in particular was almost meagre. Even the work turned out was mostly on the major nutrient elements and sulphur alone. Work on the combination of sulphur and potassium, and their impact on the yield and quality of vegetables in general and those of Radish and Carrot in particular has not been observed. Hence this study was taken up.

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

A field experiment was conducted during the kharif season 1978, at the District Horticultural Farm, Tumkur, to study the effect of application of sulphur and potassium on the yield and quality of Radish (*Raphanus sativus* L.) and carrot (*Daucus carota* L.) crops.

3.01. Details of experiment

The experiment was laid out in the field with the under mentioned treatments.

Treatment	Sulphur level (ppm)	Potassium level (kg/ha)
T_1	0	37.50
T_2	0	56.25
T_3	0	75.00
T_4	5	37.50
T_5	5	56.25
T_6	5	75.00
T_7	10	37.50
T_8	10	56.25
T_9	10	75.00

Sulphur was applied in the form of factamphos* in the above mentioned doses. Potassium was applied in the form of muriate of potash in the above mentioned doses. A common

* Composition given in page 9.

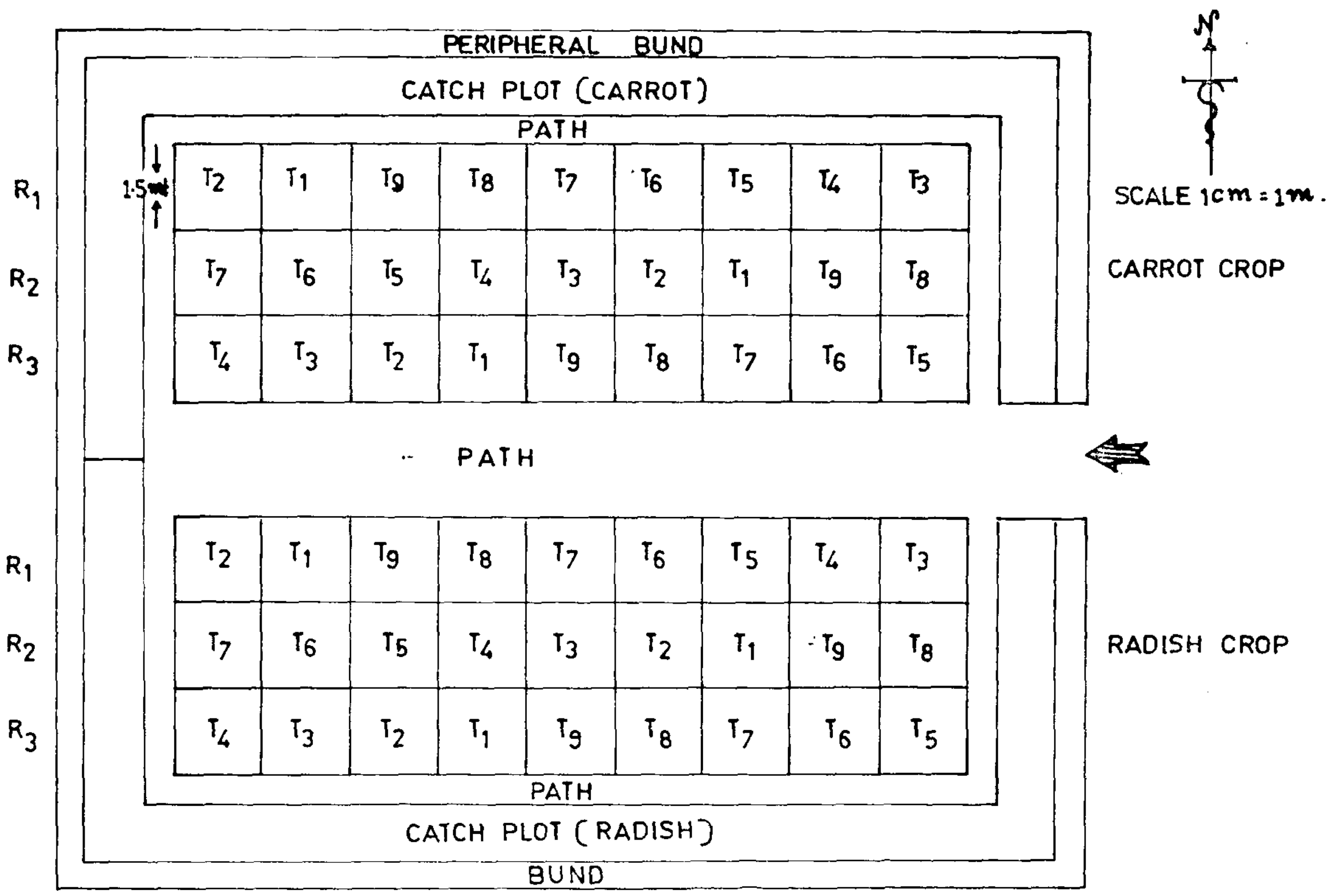

FIG: 1. LAYOUT PLAN OF THE EXPERIMENT.

dose of nitrogen and phosphorous, as per the Package of Practices was applied. That was nitrogen at 75 kg/ha both for radish and carrot crops and phosphorous at 37.5 kg/ha for radish and 62.5 kg/ha for carrot crop was applied. Phosphorus was applied in the form of factamphos and diammonium phosphate. Nitrogen was applied in the form of factamphos and diamophos (to suit the doses of sulphur and phosphorus and the rest of the requirement in the form of urea.

Each treatment was replicated 3 times by randomisation. The plan of layout is given in Fig.1.

3.02. Sowing of radish seeds

White icicle variety of radish seeds was obtained through the Agro Seeds Corporation, Lalbagh, Bangalore. They were sown in beds 30 cm apart between rows and 10 cm apart within rows. All interculture operations including plant protection work, were followed. The crop was harvested after 45 days. Immediately after harvest fresh weight was recorded.

3.03. Sowing to carrot seeds

Similar to and next to the radish plots, an experiment was laid out for the carrot crop also. Early nantes variety of carrot seeds was obtained from Agroseeds Corporation, Lalbagh, Bangalore. They were sown in beds 22.5 cm apart between rows and 10 cm apart within rows. All interculture operations including plant protection work were followed. The crop was harvested after 100 days. Immediately after harvest fresh weight was recorded.

3.04. Collection and preparation of Soil samples

Initial soil samples were also collected from the experimental area before treatments were imposed. Representative soil samples from each plot were collected from the entire experimental area, after the harvest of the crop.

The soil samples were air dried and ground taking care not to break the primary particles and passed through a 2 mm sieve. The sieved samples were mixed, packetted and labelled for further laboratory analysis.

3.05. Analysis of soil samples

The representative soil samples were analysed for the following properties. Mechanical analysis was also done in the case of initial soil samples.

i) Mechanical analysis: The international pipette method was followed using sodium hexametaphosphate as the dispersing agent (Piper, 1966).

ii) Soil reaction: The pH of the soil samples was determined in 1:2.5, soil:water suspension using a pH meter (Jackson, 1973).

iii) Electrical conductivity: It was determined from 1:2.5 - soil : water suspension using the conductivity bridge (Jackson, 1973).

iv) Cation Exchange Capacity: Cation exchange capacity of soil samples was determined by leaching the soil several times with 1.0 N neutral ammonium acetate and washing with alcohol to remove excess of electrolyte. The adsorbed NH_4^+ was displaced by K^+ by leaching the soil with potassium chloride. In the leachate NH_4^+ was estimated by distilling with excess sodium hydroxide and ammonia distilled was collected in 4 per cent boric acid containing Bromocresol green-Methyl red mixed indicator and titrated against standard acid. From this data C.E.C. of soil samples was calculated (Jackson, 1973).

v) Organic carbon: Organic carbon was determined by the Walkley and Black's (1934) rapid titration method as described by Jackson (1973). A known weight of soil sample was passed through a 0.5 mm sieve and was digested with standard potassium dichromate solution and concentrated sulphuric acid and the excess of dichromate solution was back titrated against standard ferrous ammonium sulphate solution using diphenylamine indicator.

vi) Available nitrogen: It was determined by alkaline permanganate method of Subbaiah and Asija (1956).

vii) Available phosphorus: It was determined by molybdate blue colour method using Bray's extractant. The intensity of blue colour developed was measured in Klett sumerson photo-electric colorimetre (Perur, et al., 1973).

viii) Available potassium: It was determined flame phtometrically from the extract using neutral 1 N ammonium acetate with 1:5 soil extractant ratio (Perur, et al., 1973).

ix) Exchangeable calcium: Exchangeable calcium was extracted by neutral normal ammonium acetate solution and the calcium content in the extract was determined by titrating an aliquot of the extract against standard versenate solution using muroxide indicator, as described by Jackson (1973).

x) Exchangeable magnesium: Using an aliquot of the above soil extract, calcium + magnesium were determined by titrating against standard versenate solution, using eriochrome black -T as indicator. From the difference in concentration between (Ca^{++} + Mg^{++}) and Ca^{++} alone, the exchangeable magnesium in milliequivalent per 100 g was calculated Jackson, 1973).

xi) Available sulphur or sulphate sulphur: Twenty grams of air dried soil was taken in a 250 ml conical flask and 50 ml of ammonium acetate was added. The flask was shaken for one hour on a mechanical shaker. The contents of the flask were then filtere through Whatman No1 42 filter paper. Twenty ml of the aliquot was transferred to a 25 ml volumetric flask and 1 g of barium chloride was added, shaken for one minute and one ml of 0.25 per cent gum acacia was added and again shaken for a minute. The turbidity of the solution was measured to estimate sulphate sulphur in the sample (Black, 1965).

3.06. Analysis of plant samples

a) Preparation of root and leaf samples

After recording the fresh weight of the samples, representative root and leaf samples were taken. A part of the samples was grated, oven dried, powdered and bottled and labelled for further chemical analysis. Another part was preserved in a refrigerator for analysis of Vitamin C, pungency and "Beta Carotene" (β-Carotene).

b) Analysis of dried samples

i) Total Nitrogen: Nitrogen in plant samples was estimated by following microkjedahl method as outlined by Jackson (1973). 0.5 g of plant sample was digested to a clear solution using 0.5 g of digestion mixture (100 parts of potassium sulphate and 20 parts of copper sulphate +0.05 parts of selenium) and 6.0 ml of conc.sulphuric acid. The digested sample was transferred to microdistillation set and made alkaline. Steam distillation liberates ammonia which was collected in 4 per cent solution of boric acid and estimated by titration with standard sulphuric acid.

Digestion of plant samples with di-acid mixture

To 1 g sample, 10 ml of dia-acid mixture (nitric acid and perichloric acid in the ratio of 10:4) was added and the samples were digested on a hot plate till solution turned clear and then were made to 50 ml volume.

ii) Phosphorus: In the diacid digest of the plant samples phosphorus was estimated by following the Vanadomolybdic yellow colour method as described by Jackson (1973).

iii) Potassium: In the diacid digest of the plant samples potassium was estimated by using narrow band interference filter, flame-photometrically.

iv) & v) Calcium and Magnesium: Calcium and magnesium were estimated in a known aliquot of the diacid extract by following the procedure as described by Jackson (1973).

vi) Sulphur: This was determined by taking 20 ml diacid extract in a 25 ml conical flask to which 1 g of barium chloride and 1 ml of 0.25 per cent gum acacia were added. Then the contents were shaken and the intensity of turbidity was estimated using the spectrophotometre at 420 nm. The percentage of sulphur was calculated using a standard curve (Black, 1965).

vii) Protein: Protein content of the sample was calculated by multiplying the nitrogen percentage with the factor 6.25.

viii) Crude fibre: Crude fibre was estimated by treating the sample with dilute acid and alkali and the undissolved portion excluding mineral matter is considered as crude fibre.

3.06. c) Analysis of fresh samples

i) Vitamin-'C' (ascorbic acid). The ascorbic acid of the samples was extracted, as described in A.O.A.C. (1965) by using metaphosphoric acid, acetic acid mixture.

Five grams of fresh sample was washed thoroughly and macerated well, using the extractant mixture and made to 50 ml and centrifuged at 500 revolutions for 5 minutes. From this an aliquot was taken and titrated against dichlorophenol indophenol dye. A standard solution of 1 mg ascorbic acid per ml of acid extractant served as reference standard.

ii) Pungency in radish roots: Pungency in radish roots was estimated as per procedure detailed in the book "The chemical analysis of foods and food products" by Morris B. Jacobs and D.Van (1951).

Five gram of sample was macerated for 2 hours using 100 ml water and to this 20 ml of ethyl alcohol was added. Sixty ml of this was distilled into a 100 ml volumetric flask containing 10 ml of 1:2 ammonium hydroxide. Twenty ml of 0.1 N Ag No_3 solution was added and set aside overnight. Heated to boiling on a waterbath to agglomerate silver sulphide. Cooled and made up to 100 ml with water and filtered. Fifty ml of this was acidified with 5 ml nitric acid and titrated with 0.1 N ammonium thiocyanate, using 5 ml of 10 per cent ferric ammonium sulphate solution as indicator. Using the formula 1 ml 0.1 N $AgNO_3$ ≡ 0.004956 g Allylisothiocyanate, the pungency was calculated, in terms of allylisothiocyanate.

iii) <u>β-Carotene in Carrots</u>: β Carotene in carrots was estimated by following the procedure described in the book "Methods of Vitamin Assay" (Anon, 1951)

Five g of the sample was taken. The sample was macerated using small amounts of 85 per cent acetone. Filtered through Buchner funnel, washed with 85 per cent acetone. Homogenisation was repeated till filtrate and washings were colourless. The washings and the filtrate was then made up in a volumetric flask to 100 ml. This was refluxed for 30 minutes with 2 g barium hydroxide and filtered, into a separating funnel and washed with 85 per cent acetone. Swirled with 50 ml petroleum ether. After separation of phases acetone layer was run off and washed with 10 ml portions of petroleum ether. The washings were mixed with the original ether phase. Ether was washed with 20 ml portions of water. Washings were discarded.

Extracted with 30 ml portions of 90 per cent methanol until the extracts were colourless. Extracts retained. Washed the combined methanol extract with 10 ml petroleum of ether and added the washings to original phase. Washed the ether phase with water and discarded the washings. Filtered through anhydrous sodium sulphate to dry. Washed with petroleum ether and diluted to 100 ml. Titrated against potassium dichromate. β - Carotene was calculated using the formula - 1 ml dichromate = 0.00158 g of β -Carotene.

3.07. Climate during the period of the crop

Meteorological data during the crop period was obtained from the meterological observatory and has been presented in the Appendix IV.

3.08. Statistical procedure

Statistical analysis has been carried out using Duncan's Multiple Range (DMR). Test as given by Steel and Torrie (1960) for mean separation, after test for analysis of variance was performed. DMR test was carried out for observations on yield and quality parameters at 5 per cent probability level, wherever significant differences were noticed through ANOVA.

RESULTS

CHAPTER IV

RESULTS

With the objective of assessing - (i, the optimum level of application of sulphur and potassium for maximum yield of radish (white icicle) and carrot (Early nantes); (ii) to determine the effect of these nutrients on the quality parameters of the crops, and (iii) to study the effect of these nutrients on the properties of Tumkur Red Soils (Aquic ustifluvent-Lakkanapalya series), experiments were conducted at the District Horticultural Farm, Tumkur. The results are presented in the following tables.

4.01. Characteristics of the soil

The physical and chemical properties of the representative soil samples collected at two depths from the experimental site, before starting the experiment are represented in Table 1. The data revealed that the soil is red, clayey with more than 40 per cent clay, at both the depths. It is acidic in reaction and the soluble salt content of the soil is negligible (0.2 mmhos/cm at 25°C) as revealed by the low electrical conductivity of the soil suspension. The cation exchange capacity of the soil is moderate with moderate to poor nutrient status (Appendix I). The soil contained low amounts of exchangeable calcium and magnesium. The soil is poor in available phosphorous content and medium in available

Table 1: Physical and Chemical properties of the soil before the experiment

		0 to 22.5 cms	22.5 to 45 cms
I. Physical Properties			
i) Mechanical Analysis:			
a) Coarse sand	(%)	26.00	22.95
b) Fine sand	(%)	29.00	28.87
c) Silt	(%)	0.90	3.00
d) Clay	(%)	44.10	46.00
Textural Class		Clayey	Clayey
II. Physico Chemical Properties			
a) pH (1:2.5)		6.2	6.1
b) EC (m.mhos/cm at 25°C)		0.200	0.200
c) CEC (meq.per 100 g)		14.85	17.22
III. Chemical Properties			
a) Available nitrogen	(Kg/ha)	321.10	321.10
b) Available phosphorus	"	19.60	8.40
c) Available potassium	"	320.00	160.00
d) Organic carbon	(%)	0.70	0.68
e) Exch. Calcium	(me/100 g)	6.80	6.20
f) Exch. Magnesium	"	0.40	0.40
g) Available sulphur	(%)	0.0042 (or)(105 kg/ha)	0.0035 (or)(87 kg/ha)

nitrogen and Potassium contents. The available sulphur content of the soil was 0.0042 per cent (105 kg/ha) at 0 to 22.5 cm depth and 0.0035 per cent (87 kg/ha) at 22.5 to 45 cm depth.

3.02. Effect of sulphur and Potassium on the yield of radish and carrot

i) Yield of radish: The effect of sulphur and potassium application on the per plot and per hectare yield of radish is presented in Table 2. Significant increase in yield due to increase in application of sulphur and potassium is observed. The yield values ranged from 4.0 kg per plot to 5.35 kg per plot. Highest yield was recorded in T_9 treatment (S_2K_3) and lowest yield in T_1 treatment (S_0K_1). The DMR test revealed that the increasing difference between T_3 and T_4, T_6 and T_7 and T_8 and T_9 were not significant. Significant increase was observed in other treatments. T_9 was found to be superior compared to treatments T_1 to T_7. The yield obtained per hectare (17,770 kg/ha in T_1 to 23,770 kg/ha in T_9) was comparitively higher to values mentioned in Package of Practices (10,000 to 20,000 kg/ha) published by UAS.

As per ANOVA test, no significant difference in the yield of radish due to interaction between sulphur and potassium levels, was observed but both potassium and sulphur application individually showed significant increase in the yield of radish.

ii) Yield of Carrots: The per plot yield and per hectare yield of carrot as affected by sulphur and potassium application

Table 2: Effect of sulphur and Potassium application on the root yield of radish and carrot

Treatments	Radish		Carrot	
	Yield in kg/plot	Yield in M.tons/ha	Yield in Kg/plot	Yield in M.tons/ha
T_1 S_0K_1	4.00a	17.77	3.46a	15.35
T_2 S_0 K_2	4.25b	18.88	3.49a	15.51
T_3 S_0 K_3	4.45 c	19.77	3.52a	15.65
T_4 S_1 K_1	4.50c	20.07	3.54a	15.73
T_5 S_1 K_2	4.75d	21.11	3.62ab	16.06
T_6 S_1 K_3	4.95e	21.99	3.70bc	16.44
T_7 S_2 K_1	5.08ef	22.58	3.75cd	16.66
T_8 S_2 K_2	5.25fg	23.32	3.84de	17.07
T_9 S_2 K_3	5.35g	23.77	3.92e	17.43
F.test	**	**	**	**

Note: Notations indicate the significant differences in this case increase in yield, due to treatments
The principle involvedin giving notations is tx clearly explained in Appendix II

is presented in Table 2. An increase in the yield of carrot was obtained with increase in the quantum of sulphur and potassium applied as in the case of radish. Highest yield was recorded in T_9 treatment (3.92 kg/plot) and lowest in T_1 treatment (3.46 kg/plot). Significant increase in the yield of carrot due to treatments has been observed, through ANOVA. As per DMR test, it has been found that there was no significant difference between T_1, T_2, T_3 and T_4 treatments but all other treatments (T_5 to T_9) were significantly different from T_1 to T_4 treatments. There was no significant increase among T_2, T_3 and T_4 treatments and between T_4 and T_5, T_5 and T_6, T_6 and T_7, and T_7 and T_8 and T_8 and T_9 treatments. T_9 was the only treatment which was significantly different compared to all other treatments except T_8 treatment. The per hectare yield (15,350 kg in T_1 treatment to 17,430 kg/ha in T_9 treatment) obtained in the experiment was well within the values mentioned in the package of practices published by UAS (20,000 kg/ha). As in the case of radish, significant difference in the yield of carrot was obtained due to sulphur and potassium application but there was no significant difference due to interaction effect.

4.03. Effect of sulphur and potassium application on the quality parameters of radish (root)

A. Nutrient content

The effect of sulphur and potassium application on the nutrient content of radish roots is presented in Table 3.

Table 3: Effect of Sulphur and Potassium application on the nutrient content of radish roots

Treatments		Nitrogen %	Phosphorus %	Potassium %	Calcium %	Magnesium %	Sulphur %
T_1	S_0 K_1	0.17a	0.30a	0.25	0.36a	0.14	0.37a
T_2	S_0 K_2	0.18ab	0.30a	0.26	0.36a	0.14	0.37a
T_3	S_0 K_3	0.19abc	0.31b	0.27	0.37b	0.15	0.37a
T_4	S_1 K_1	0.18ab	0.31b	0.27	0.37b	0.15	0.38b
T_5	S_1 K_2	0.19abc	0.31b	0.28	0.38c	0.15	0.38b
T_6	S_1 K_3	0.20c	0.32c	0.28	0.38c	0.16	0.38b
T_7	S_2 K_1	0.19abc	0.32c	0.29	0.38c	0.16	0.39c
T_8	S_2 K_2	0.20c	0.32c	0.29	0.39d	0.16	0.39c
T_9	S_2 K_3	0.21d	0.32c	0.30	0.39d	0.16	0.39c
F. test		**	**	NS	**	NS	**

Note: Same principle as explained in appendix II is followed in giving notations

a) Nitrogen: In case of radish roots, there was significant difference between treatments, the values were ranging from 0.17 per cent to 0.21 per cent, with lowest value in T_1 treatment and highest value in T_9 treatment. T_6 and T_8 treatments have shown higher nitrogen content (0.20%) than others except T_9 where the nitrggen content observed was 0.21 per cent. DMR test revealed further that there was an increasing trend of difference between T_1 and all other treatments. There was no significant difference between T_2 and T_4; T_3, T_5 and T_7; T_5 and T_7 ; T_6 and T_8 treatments. There was significant difference between T_4 and T_3, T_7 and T_6 , and T_8, and T_9 treatments. T_9 treatment was found to be superior to all other treatments.

b) Phosphorous: The phosphorus content of radish root (Table 3) also differed significantly wih the values ranging from 0.30 to 0.32 per cent with highest value in T_6, T_7, T_8 and T_9 treatments and lowest value in T_1 and T_2 treatments. An increase in the phosphorus content of radish was observed with increase in the quantity of sulphur and potassium applied. The DMR test indicated that there was no significant differences between T_1 and T_2; T_3, T_4 and T_5 and T_4 and T_5 treatments. T_6, T_7, T_8 and T_9 have significantly increased due to treatments and found significantly superior compared to T_1 to T_5 treatments.

c) Potassium: There was no significant difference in the potassium content of radish root (Table 3). The values ranged from 0.25 to 0.30 per cent with lowest value in case of T_1 treatment and highest value in T_9 treatment.

d) Calcium: The calcium content of radish roots differed significantly due to treatments. The values ranged from 0.36 to 0.39 per cent, with highest value in T_8 and T_9 treatments and lowest value in T_1 and T_2 treatments. The DMR test indicated that only T_8 and T_9 treatments differed significantly compared to other treatments. There was no significant difference between T_1 and T_2; T_2, T_3 and T_4; T_3, T_4 and T_5, and T_6 and T_7 treatments. Even between themselves T_8 and T_9 did not differ significantly.

e) Magnesium: There was no significant difference in the magnesium content of radish root. The values ranged from 0.14 to 0.16 per cent with lowest value in T_1 and T_2 treatments and highest value in T_6, T_7, T_8 and T_9 treatments.

f) Sulphur: Significant difference in the sulphur content of radish root, due to treatment was observed. Highest value (0.39 per cent) was obtained in T_7, T_8 and T_9 treatments and lowest value (0.37 per cent) in T_1, T_2 and T_3 treatments. From DMR test it is clear that only T_8 and T_9 treatments were significantly different compared to all other treatments. There was no significant difference between T_1, T_2 and T_3; T_2, T_3 and T_4; T_3, T_4 and T_5, and between T_4, T_5, T_6 and T_7 treatments.

B) <u>Quality Parameters</u>

The changes in the quality parameters of radish roots due to sulphur and potassium applications have been presented in Table 4.

a) <u>Protein</u>: There was a significant difference in the protein content of radish due to treatments. The values ranged from 1.07 to 1.31 per cent. The higest value recorded was in T_9 treatment and lowest in T_1 treatment. Protein content of radish increased with increase in the quantity of S and K applied. *From DMR test it was clear that only T_9 was significantly* superior compared to T_1 , T_2, T_4, T_5 and T_7 treatments. There was no significant difference between T_1, T_2, T_4, T_5 and T_7; T_2, T_4, T_5, T_7 and T_3; T_4, T_5, T_7 and T_3; T_5, T_7, T_3, T_6, and T_8; T_7, T_3, T_6 and T_8, T_3, T_6, T_8 and T_9; T_6, and T_9 and T_8 and T_9 treatments. The protein content of radish roots differed significantly due to the application of sulphur alone. There was significant difference due to interaction effect of these two nutrients. As per ANOVA test there was no effect due to potassium application.

b) <u>Crude fibre</u>: There was no significant difference in the crude fibre content of radish roots due to treatments. The values ranged from 0.71 to 0.83 per cent with highest value in T_9 treatment and lowest value in T_1 treatment.

Table 4: Effect of sulphur and potassium application on the quality parameters of radish root

Treatments			Protein %	Crude fibre %	Vitamin 'C' mg/ 100 g	Pungency %
T_1	S_0	K_1	1.07a	0.71	20.70a	0,18a
T_2	S_0	K_2	1.12ab	0.75	20.70a	0.20ab
T_3	S_0	K_3	1.21bcd	0.75	22.50b	0.22b
T_4	S_1	K_1	1.13ab	0.77	25.65c	0.64c
T_5	S_1	K_2	1.18abc	0.77	26.25c	0.71d
T_6	S_1	K_3	1.25 cd	0.78	26.90c	0.76e
T_7	S_2	K_1	1.18abc	0.78	29.40d	0.92f
T_8	S_2	K_2	1.25cd	0.78	29.40d	1.04g
T_9	S_2	K_3	1.31d	0.83	30.00d	1.13h
F.test			**	NS	**	**

Note: Same principle as explained in Appendix II is followed in giving notations

c) <u>Vitamin 'C'</u>: The Vitamin 'C' content of radish roots differed significantly due to treatments, values ranged from 20.70 mg/100 g in T_1 and T_2 to 30.00 mg/100 g in T_9 treatment. An increase in the Vitamin C content of radish was observed with increase in the quantity of sulphur and potassium applied. Subjected to DMR test it was found that there was no significant difference between T_1 and T_2 and T_5 and T_6 treatments. Significant differences were observed between. T_2 and T_3 and T_3 T_4 treatments. T_7, T_8 and T_9 treatments were found to be significantly superior compared to all other treatments. The Vitamin C content of radish roots differed significantly due to the application of sulphur but not due to potassium indicating the importance of sulphur. Difference due to interaction was not observed.

d) <u>Pungency</u>: Significant differences in the pungency due to allylisothiocyanate content of radish root, due to treatments was observed. Highest content (1.13 per cent) of Allyl-isothiocyanate (the pungency factor in radish) was recorded by T_9 treatment and the lowest value (0.18 per cent) by T_1 treatment. T_7, T_8 and T_9 treatments were found to be significantly superior compared to all other treatments. As per the DMR test, there were no significant differences between T_1 and T_2; T_2 and T_3 treatments. As per ANOVA test significant difference in the pungency percentage of radish was observed due to potassium and sulphur individually and also due to interaction indicating the effect of these two nutrient elements on the pungency of radish.

4.04. Effect of application of sulphur and Potassium on the quality parameters of radish leaves

A) Nutrient Content

The changes in the nutrient content of radish leaves due to sulphur and potassium applications is presented in Table 5.

a) Nitrogen: Significant difference in the nitrogen content of radish leaves due to treatments was observed, with values ranging from 0.62 per cent to 0.66 per cent. Highest value was recorded in T_8 and T_9 treatments and lowest value in T_1 and T_2 treatments. The DMR test indicated that only T_8 and T_9 treatments were significantly different from all other treatments. There was no difference between T_1 and T_2; T_3 and T_4; T_5 and T_6; and T_6 and T_7 treatments.

b) Phosphorus: The phosphorus content of radish leaves differed significantly due to treatments and the values ranged from 0.06 to 0.08 per cent with x highest values in T_7, T_8 and 9 treatments and lowest value in T_1, T_2, T_3 and T_4 treatments. From DMR test it was clear that T_7, T_8 and T_9 treatments were significantly superior to all other treatments. There was no significant difference between T_1, T_2, T_3 and T_4; T_5 and T_6 and T_7, T_8 and T_9 treatments. T_7, T_8 and T_9 treatments were found to be superior compared to T_1 to T_6 treatments.

Table 5: Effect of sulphur and potassium application on the nutrient contents and quality parameters of radish leaves

Treatments	Nutrient contents						Quality parameters	
	Nitrogen %	Phosphorus %	Potassium %	Calcium %	Magnesium %	Sulphur %	Proteins %	Vitamin C Mg/100 g
T_1 S_0 K_1	0.62a	0.06a	0.05	0.30	0.20	0.35a	3.87a	10.05
T_2 S_0 K_2	0.62a	0.06a	0.05	0.30	0.20	0.35a	3.89a	11.25
T_3 S_0 K_3	0.63b	0.06a	0.05	0.31	0.20	0.35a	3.93ab	11.85
T_4 S_1 K_1	0.63b	0.06a	0.05	0.31	0.20	0.36b	3.95ab	11.85
T_5 S_1 K_2	0.64c	0.07b	0.06	0.32	0.21	0.36b	4.00bc	16.20
T_6 S_1 K_3	0.64c	0.07b	0.06	0.32	0.21	0.36b	4.02bc	18.90
T_7 S_2 K_1	0.65d	0.08c	0.06	0.32	0.21	0.37c	4.06cd	18.90
T_8 S_2 K_2	0.66d	0.08c	0.06	0.33	0.21	0.37c	4.14d	22.52
T_9 S_2 K_3	0.66d	0.08c	0.06	0.33	0.21	0.37c	4.14d	26.87
F.test	**	**	NS	NS	NS	**	**	NS

Note: Same principle, as explained in Appendix II is followed in giving notations

c) Potassium: There was no significant difference in potassium content of radish leaves due to treatments. The values ranged from 0.05 to 0.06 per cent with the lower value recorded in T_1 to T_4 treatments and the higher value by other treatments.

d) Calcium: Sulphur and potassium application did not produce any significant difference, due to treatments, in the calcium content of radish leaves. The values ranged from 0.30 to 0.33 per cent, with highest value recorded by T_8 and T_9 treatments and lowest by T_1 and T_2 treatments.

d) Magnesium: The magnesium content of radish leaves also did not differ significantly due to treatments. Here also as in potassium T_1, T_2, T_3 and T_4 have recorded 0.20 per cent value and T_5, T_6, T_7, T_8 and T_9 have recorded 0.21 per-cent value.

f) Sulphur: Significant difference in the sulphur content of radish leaves due to treatments was observed. Highest value (0.37 per cent) was recorded by T_7, T_8 and T_9 treatments and lowest value (0.35 per cent) by T_1, T_2 and T_3 treatments. An increase in the concentration of sulphur was observed with an increase in the quantity of sulphur applied. The DMR test indicated that T_7, T_8 and T_9 treatments were significantly different from all other treatments. There was no significant difference between T_1, T_2 and T_3; T_2 and T_3; T_4, T_5 and T_6 and T_5 and T_6 treatments.

B) Quality Parameters

a) Protein: The protein content of radish leaves also differed significantly due to treatments, with values ranging from 3.87 to 4.14 per cent, the lowest value was recorded in T_1 and highest value by T_8 and T_9 treatments. From the DMR test, it is clear that only T_8 and T_9 treatments were significantly different from all other treatments. There was no significant difference between T_1, T_2, T_3 and T_4; T_2, T_3 and T_4; T_3, T_4, T_5 and T_6; T_5 and T_6 and T_6 and T_7 treatments.

b) Vitamin 'C': There was no significant difference in the Vitamin 'C' content of radish leaves. The values ranged from 10.05 mg/100 g in T_1 treatment to 26.87 mg/100 g in T_9 treatment. There was a progressive increase in the Vitamin C content of leaves due to sulphur and potassium applications.

4.05. Effect of application of sulphur and potassium on the nutrient contents and quality parameters of carrot

A) Nutrient Content of Carrot

The effect of sulphur and potassium application on the nutrient content of carrot is presented in Table 6.

a) Nitrogen: Significant differences in nitrogen content of carrot, as a result of treatments was observed. The highest value (0.21 per cent) was obtained in T_9 and lowest value (0.17 per cent) in T_1 treatments. Only T_9 treatment was

Table 6: Effect of sulphur and potassium application on the nutrient content of carrot

Treatments	Nitrogen %	Phosphorus %	Potassium %	Calcium %	Magnesium %	Sulphur %
T_1 S_0 K_1	0.17a	0.37	0.30	0.38a	0.20	0.21a
T_2 S_0 K_2	0.18b	0.37	0.31	0.38a	0.20	0.21a
T_3 S_0 K_3	0.19c	0.37	0.32	0.39b	0.21	0.21a
T_4 S_1 K_1	0.18b	0.37	0.32	0.39b	0.21	0.22b
T_5 S_1 K_2	0.19c	0.37	0.33	0.40c	0.21	0.22b
T_6 S_1 K_3	0.20d	0.38	0.33	0.40c	0.22	0.22b
T_7 S_2 K_1	0.19c	0.38	0.34	0.40c	0.22	0.23c
T_8 S_2 K_2	0.20d	0.38	0.35	0.41d	0.22	0.23c
T_9 S_2 K_3	0.21e	0.39	0.35	0.41d	0.22	0.23c
F.test	**	NS	NS	**	NS	**

Note: Same principle, as explained in Appendix II is followed in giving notations.

found to be significantly different from all other treatments. Compared to T_1 all other treatments are found to be significantly different. Compared to T_2 and T_4 the treatment effects found to be significantly different are T_3, T_5,T_7, T_6, T_8 and T_9. Compared to T_3, T_5 and T_7 treatments T_6, T_8 and T_9 are found to be significantly different. T_9 alone is significantly superior compared to T_6 and T_8 treatments.

b) Phosphorus: The phosphorus content of carrot does not show a significant difference due to treatments. The highest value of 0.39 per cent is found in T_9 and lowest value of 0.37 per cent is found in treatments T_1 to T_5. Treatments T_6, T_7 and 8 recorded the same phosphorus percentage of 0.38.

c) Potassium: In case of potassium content also the difference due to treatments was not significant. The values ranged from 0.30 to 0.35 per cent with the lowest value recorded by T_1 and the highest by T_8 and T_9 treatments.

d) Calcium: The calcium content of carrot differed significantly due to treatments. The values ranged from 0.38 to 0.41 per cent with highest value in T_8 and T_9 and lowest value in T_1 and T_2 treatments. The DMR test indicated that only T_9 treatment was significantly different from all other treatments. There was no significant difference between T_1 and T_2, T_2, T_3 and T_4; T_3, T_4 and T_5 and T_5, T_6, T_7 and T_8 treatments.

e) Magnesium: There was no significant difference in the magnesium content of carrot due to treatments. 0.20 per cent magnesium was recorded in T_1 and T_2, 0.21 per cent in T_3, T_4 and T_5 treatments and a slightly higher value of 0.22 per cent by T_6, T_7, T_8 and T_9 treatments.

f) Sulphur Significant difference in the sulphur content of carrot due to treatments was observed. The values ranged from 0.21 per cent to 0.23 per cent with highest value in T_7, T_8 and T_9 treatments and lowest in T_1, T_2 and T_3 treatments. From the DMR test it was quite clear that T_7, T_8 and T_9 treatments are significantly different from all other treatments. There was no significant difference between T_1, T_2 and T_3 ; T_2 and T_3; T_4, T_5 and T_6 , and T_5 and T_6 treatments.

B) Quality Parameters

The changes in the quality parameters of carrot due to sulphur and potassium application are presented in Table 7.

a) Protein: The protein content of carrot differed significantly due to treatments, with the values ranging from 1.07 to 1.31 per cent. Lowest value was recorded in T_1 treatment and highest value in T_9 treatment. The DMR test has indicated that only T_9 treatment was found to be significantly superior to T_1, T_2, T_4, T_5 and T_7 treatments. There was no significant difference among T_1, T_2, T_4, T_5 and T_7; T_2, T_4, T_5, T_7 and T_3;

Table 7: Effect of sulphur and potassium application on the quality parameters of Carrot

Treatments			Proteins %	Vitamin 'C' mg/ 100 g	Crude-fibre %	β Carotene mg/100 g
T_1	S_0	K_1	1.07a	1.88a	0.99	3.26a
T_2	S_0	K_2	1.12ab	2.10b	1.00	4.41b
T_3	S_0	K_3	1.21bcd	2.40 c	1.02	5.56c
T_4	S_1	K_1	1.13ab	2.43c	1.03	5.65d
T_5	S_1	K_2	1.18abc	2.47cd	1.03	5.98e
T_6	S_1	K_3	1.25cd	2.52cd	1.03	6.97f
T_7	S_2	K_1	1.18abc	2.60cd	1.03	7.24g
T_8	S_2	K_2	1.25cd	2.62cd	1.03	7.94h
T_9	S_2	K_3	1.31d	2.70d	1.07	8.61i
F.test			**	**	NS	**

Note: Same principle as explained in Appendix II is followed in giving notsations.

T_5, T_7, T_3, T_6 and T_8 ; T_7, T_3, T_6 and T_8; T_3, T_6 and T_8 and T_8 and T_9 treatments. As per ANOVA test significant difference in the protein content of carrot roots was obtained due to the application of sulphur and also due to interaction between these two nutrient elements. There was no effect by potassium alone.

b) Vitamin C: There was significant difference in the ascorbic content of carrot, and the values ranged from 1.88 mg/ 100 g to 2.70 mg/100 g with highest value in T_9 treatment and lowest value in T_1 treatment. TheDMR test indicated that there was a significantly increasing difference between T_1 treatment and all other treatments and T_2 and other treatments. Significantly increasing difference between T_3 and T_9 and T_4 and T_9 treatments was observed. The other treatments did not differ significantly. Thus T_9 can be said to be superior to T_1, T_2, T_3 and T_4.

Subjected to ANOVA test, it is observed that application of sulphur and potassium individually and significantly increased the Vitamin 'C' content of carrot. Significant differences in the Vitamin 'C' content of carrot due to interaction effect also was observed.

c) Crude fibre: No significant difference in the crude fibre content of carrot was observed. The highest value (1.07 per cent) was recorded by T_9 treatment and lowest value

(0.99 per cent) was recorded by T_1 treatment.

d) 'β' Carotene. Significant difference in the β-Carotene content of carrot due to treatments was observed. The values ranged from 3.26 mg/100 g in T_1 to 8.61 mg/100 g in T_9. The β-Carotene content of carrot increased with increase in the quantity of S and K applied. From DMR test it is clear that only T_9 treatment was found to be significantly superior to all other treatments. As per ANOVA test β-Carotene content of carrot roots differed significantly due to both sulphur and ~~also~~ potassium application. Significant difference was obtained due to interaction effect also.

4.06. Effect of sulphur and Potassium application on the soil properties

A) Radish Plot

The changes in the physical and chemical properties of soil of radish plot due to treatments is presented in Table 8.

a) pH

i) Soil samples from 0 to 22.5cms depth: Significant difference in the pH values of soil due to treatments was observed, with values ranging from 6.0 in T_7, T_8 and T_9 treatment plots to 6.2 in T_1, T_2 and T_3 treatment plots. The DMR test indicated that T_7, T_8 and T_9 treatments significantly differed from the rest. It also indicated that treatments T_4, T_5 and T_6 significantly differed from T_1, T_2

Table 8: Effect of Sulphur and Potassium application on the Physical and Chemical Properties of the Soil from Radish Plot

Treatments	pH		Electrical conductivity mmhos/cm at 25°C		Organic carbon %		Nitrogen kg/ha		Phosphorus kg/ha		Potassium kg/ha		Calcium me/100 g soil		Magnesium me/100 g soil		Sulphur %	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
T_1 S_0 K_1	6.2	6.10	0.20	0.20	0.70	0.69	321.80	321.80	19.65	8.47	319.5	159.8	6.8	6.2	0.40	0.40	0.0039	0.0034
T_2 S_0 K_2	6.2	6.10	0.20	0.20	0.71	0.68	321.75	321.75	19.65	8.47	320.7	160.4	6.8	6.2	0.40	0.40	0.0040	0.0035
T_3 S_0 K_3	6.2	6.10	0.20	0.20	0.71	0.69	321.70	321.70	19.67	8.47	321.3	160.7	6.8	6.2	0.40	0.40	0.0040	0.0035
T_4 S_1 K_1	6.1	6.10	0.19	0.20	0.71	0.68	320.70	320.70	19.67	8.49	320.7	160.0	6.8	6.2	0.41	0.40	0.0041	0.0035
T_5 S_1 K_2	6.1	6.10	0.19	0.19	0.70	0.69	320.65	320.65	19.68	8.49	321.3	160.7	6.8	6.2	0.41	0.40	0.0041	0.0036
T_6 S_1 K_3	6.1	6.10	0.19	0.19	0.71	0.68	320.60	320.60	19.69	8.49	321.5	160.9	6.8	6.2	0.41	0.40	0.0042	0.0036
T_7 S_2 K_1	6.0	6.10	0.18	0.19	0.71	0.68	319.50	319.50	19.66	8.49	320.7	160.3	6.8	6.2	0.42	0.40	0.0043	0.0036
T_8 S_2 K_2	6.0	6.03	0.18	0.19	0.70	0.69	319.00	319.00	19.66	8.49	321.5	160.8	6.8	6.2	0.42	0.40	0.0043	0.0036
T_9 S_2 K_3	6.0	6.07	0.17	0.18	0.71	0.68	318.50	318.50	19.69	8.49	321.7	160.9	6.8	6.2	0.42	0.40	0.0044	0.0036
F.Test	*	NS	NS	*	NS	NS	*	*	NS	*	*	*	NS	NS	NS	NS	NS	NS

Note: A = 0 to 22.5 cm; B = 22.5 to 45 cm and T_3 treatments. There was no significant difference among T_1, T_2 and T_3 ; T_4, T_5 and T_6; and T_7, T_8 and T_9 treatments.

ii) <u>Soil depth 22.5 to 45.0 cms:</u> There was no significant difference between treatments due to sulphur and potassium applications. The values recorded shows that pH was 6.03 in T_8, 6.07 in T_9 and in all other plots it was 6.1.

b) <u>Electrical conductivity</u>

i) <u>Soil depth 0 to 22.5 cms</u>: There was no significant difference due to treatments. T_9 plot recorded 0.17 m.mhos/cm; T_7 and T_8 plots have recorded0.18 m.mhos/cm; T_4; T_5 and T_6 plots have recorded 0.19 m.mhos/cm and T_1, T_2 and T_3 plots have recorded 0.20 m.mhos/cm.

ii) <u>Soil depth 22.5 to 45.0 cms:</u> Significant difference in E.C. values was observed with values ranging from 0.20 mmhos/cm in T_1, T_2 and T_3 plots; 0.19 mmhos/cm in T_4, T_5, T_6, T_7 and T_8 plots and 0.18 mmhos/cm in only T_9 plot. DMR test has revealed that T_1, T_2 and T_3 are same and the rest of the treatments are significantly different. Significantly lower value was observed in treatment T_9 compared to all other treatments.

c) <u>Organic carbon</u>

i) <u>Soil depth 0 to 22.5 cms</u>: There was no significant difference in the organic carbon content of soil due to treatments. Higher value of 0.71 per cent was recorded in T_2, T_3 ,

T_4, T_6, T_7 and T_9 plots and lower value of 0.70 per cent was recorded in T_1, T_5 and T_8 plots.

ii) Soil depth 22.5 to 45 cms: There was no significant differences in organic carbon content at this depth also due to treatments. 0.68 per cent O.C. was recorded in T_2, T_4, T_6, T_7 and T_9 treatment plots and rest of the plots recorded 0.69 per cent.

d) Nitrogen

i) Soil depth 0 to 22.5 cm: There was significant difference in the nitrogen content of soil and the values ranged from 318.50 kg/ha in T_9 plot to 321.80 kg/ha in T_1 plot. A decrease in the nitrogen content of the soil with increase in sulphur and potash application was observed. The DMR test indicated that only T_9 was significantly lower than all other treatments. There was no significant difference between T_1 and T_2; T_2 and T_3; T_4 and T_5; T_5 and T_6 and among T_6, T_7 and T_8 treatments.

ii) Soil depth 22.5 to 45 cm: Here also significant difference due to treatments was observed and followed a similar trend like that of 0 to 22.5 cm depth soil. The same values were recorded here also.

e) Phosphorus

i) Soil depth 0 to 22.5 cm: There was no significant difference in the phosphorus content of soil due to treatments.

The values ranged from 19.65 to 19.69 kg/ha in T_1 and T_9 treatments respectively.

ii) <u>Soil depth 22.5 to 45 cms:</u> At this depth a significant difference in the phosphorus content of soil was observed with values ranging from 8.47 kg/ha in T_1 treatment to 8.49 kg/ha in T_9 treatment. From DMR test it is quite clear that except T_1, T_2 and T_3 treatments in all other treatments significantly higher values are recorded.

f) <u>Potassium</u>

i) <u>Soil depth 0 to 22.5 cm:</u> Significant difference in the potassium content of the soil due to the treatments was observed. The values ranged from 319.5 kg/ha in T_1 treatment to 321.7 kg/ha in T_9 treatment. The DMR test indicated that all other treatments were significantly higher compared to T_1 treatment only.

ii) <u>Soil depth 22.5 to 45 cm:</u> Here also there was significant difference in the potassium content of the soil. The values ranged from 159.8 kg/ha in T_1 treatment to 160.9 kg/ha in T_9 treament. From DMR test it is clear that T_6 and T_9 treatments were significantly higher than all other treatments. There was no significant difference between T_1, T_4 and T_7 treatments; T_7 and T_2 treatments and among T_2, T_3, T_5 and T_8 treatments.

g) Exchangeable calcium

i) Soil depth 0 to 22.5 cm: There was no significant difference between treatments. All the treatments have recorded the same value of 6.8 me/100 g soil.

ii) Soil depth 22.5 to 45 cm: Here also there was no significant difference due to treatments. All treatments have recorded the same value (6.2 me/100 g soil) and was slightly less than in 0 to 22.5 cm depth.

h) Exchangeable Magnesium

i) Soil depth 0 to 22.5 cm: The exchangeable magnesium content of soil did not differ significantly due to treatments. The values ranged from 0.40 meq/100 g soil in T_1, T_2 and T_3 treatments to 0.42 meq/100 g soil in treatments T_7, T_8 and T_9. Treatments T_4, T_5 and T_6 have recorded 0.41 meq/100 g soil.

ii) Soil depth 22.5 to 45 cm: Here also there was no significant difference between treatments. All treatments have recorded the same value (0.40 meq/100 g soil).

i) Available sulphur

i) Soil depth 0 to 22.5 cm: There was no significant difference in the available sulphur content of soil due to treatments. The lowest value of 0.0039 per cent was recorded by T_1 and highest value of 0.0044 per cent by T_9 treatments.

ii) Soil depth 22.5 to 45 cm: Here also there was no significant difference between treatments. T_1 treatment recorded 0.0034 per cent and T_9 treatment recorded 0.0036 per cent.

4.07. B) Effect of sulphur and Potassium application on the physical and chemical properties of soil pertaining to Carrot plot are presented in Table 9.

a) pH

i) Soil depth 0 to 22.5 cm: The pH of the soil differed significantly due to treatments.The values ranged from 6.0 in T_7, T_8 and T_9 treatments to 6.2 in T_1, T_2 and T_3 treatments. The DMR test revealed that treatments T_7, T_8 and T_9 were significantly lower than all other treatments. Treatments T_4 to T_9 were significantly lower compared T_1, T_2 and T_3 . Treatments T_7 to T_9 were significantly lower than other treatments.

ii) Soil depth 22.5 to 45 cms: There was no significant difference in pH values of soil at this depth, due to treatments. pH value of 6.03 was recorded in T_8 6.07 in T_9 and 6.1 in all other treatments.

b) Electrical conductivity

The electrical conductivity of the soil in 0 to 22.5 cm depth did not differ significantly due to treatments. The values ranged from 0.17 m.mhos/cm in T_9 to 0.20 m.mhos/cm in T_1, T_2 and T_3 treatments.

Table 9: Effect of sulphur and Potassium application on the Physical and Chemical Properties of the Soil from Carrot Plot

Treatments	pH		Electrical conductivity mmhos/cm at 25°C		Organic carbon %		Nitrogen kg/ha		Phosphorus kg/ha		Potassium kg/ha		Calcium me/100 g soil		Magnesium me/100 g soil		Sulphur %	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
T_1 S_0 K_1	6.2	6.1	0.20	0.20	0.71	0.68	321.67	321.70	19.59	8.48	319.5	159.8	6.8	6.2	0.40	0.40	0.0039	0.0034
T_2 S_0 K_2	6.2	6.1	0.20	0.20	0.71	0.68	321.62	321.62	19.61	8.49	320.7	160.4	6.8	6.2	0.40	0.40	0.0040	0.0035
T_3 S_0 K_3	6.2	6.1	0.20	0.20	0.71	0.68	321.60	321.60	19.62	8.50	321.3	160.7	6.8	6.2	0.40	0.40	0.0040	0.0035
T_4 S_1 K_1	6.1	6.1	0.19	0.19	0.71	0.68	321.50	321.55	19.60	8.50	321.0	160.0	6.8	6.2	0.41	0.40	0.0041	0.0035
T_5 S_1 K_2	6.1	6.1	0.19	0.19	0.70	0.68	321.48	321.50	19.61	8.52	321.3	160.7	6.8	6.2	0.41	0.40	0.0041	0.0036
T_6 S_1 K_3	6.1	6.1	0.19	0.19	0.71	0.68	321.47	321.47	19.62	8.53	321.5	160.9	6.8	6.2	0.41	0.40	0.0042	0.0036
T_7 S_2 K_1	6.0	6.1	0.18	0.19	0.70	0.68	321.35	321.37	19.61	8.51	320.7	160.3	6.8	6.2	0.42	0.40	0.0043	0.0036
T_8 S_2 K_2	6.0	6.03	0.18	0.19	0.71	0.68	321.32	321.33	19.62	8.52	321.5	160.8	6.8	6.2	0.42	0.40	0.0043	0.0036
T_9 S_2 K_3	6.0	6.07	0.17	0.18	0.71	0.68	321.30	321.30	19.63	8.53	321.7	160.9	6.8	6.2	0.42	0.40	0.0044	0.0036
F.Test	*	NS	NS	*	NS	NS	*	*	NS	*	*	*	NS	NS	NS	NS	NS	NS

Note : A = 0 to 22.5 cm; B = 22.5 to 45 cm

In the soil depth of 22.5 to 45 cm the electrical conductivity has shown a significant difference due to treatments. The values recorded ranged from 0.18 mmhos/cm in T_9 treatment to 0.20 mmhos/cm in T_1, T_2 and T_3 treatments. All other treatments have recorded 0.19 mmhos/cm. DMR test has indicated that only T_9 treatment was significantly lower than ~~from~~ all other treatments.

c) Organic Carbon

i) At 0 to 22.5 cm depth there was no significant difference due to treatment. The values ranged from 0.70 per cent in T_5 and T_7 to 0.71 per cent in all other treatments.

ii) At 22.5 to 45 cm depth also there was no significant difference due to treatments. In this case all treatments have recorded the same organic carbon content of 0.68 per cent.

d) Available nitrogen

i) At 0 to 22.5 cm depth significant difference in the available nitrogen content of the soil, due to treatments, was observed. The values ranged from 321.30 kg/ha in T_9 to 321.67 kg/ha in T_1 treatment. In this case also the nitrogen content of the soil decreased with increase in sulphur and potassium applications. The DMR test indicated that only T_8 and T_9 were significantly lower than all other treatments. There was no difference among T_1, T_2 and T_3 ; T_2 , T_3, T_4, and T_5; T_3, T_4, T_5 and T_6 treatments and between T_6 and T_7 treatments.

ii) At 22.5 to 45 cm depth also, significant difference due to treatments was observed. The values recorded ranged from 321.30 kg/ha in T_9 to 321.70 kg/ha in T_1. Here also the same trend of decrease in nitrogen content of the soil with increase of sulphur and potassium application was observed. DMR test revealed that only T_9 treatment was significantly lower than all other treatments. There was no difference among T_1, T_2, T_3 and T_4; T_2, T_3, T_4 and T_5; T_3, T_4, T_5 and T_6, T_4, T_5 and T_6 ; T_5, T_6 and T_7 and T_6; T_7 and T_8 treatments.

e) Available phosphorus

i) At 0 to 22.5 cm depth, there was no significant difference due to treatments, in available phosphorus content of soil. The values ranged from 19.59 kg/ha in T_1 plot to 19.63 kg/ha in T_9 plot.

ii) At 22.5 to 45 cm depth, significant difference of available phosphorus content of the soil, due to treatments was observed. The values ranged from 8.48 kg/ha in T_1 to 8.53 kg/ha in T_6 and T_9 treatments. DMR test indicated that T_6 and T_9 were significantly higher than T_1, T_2, T_3 and T_4 treatments. There was no difference in treatments T_1, T_2, T_3 and T_4 . There was significant difference in T_7, T_5, T_8, T_6 and T_9 compared to T_1; T_5, T_8, T_6 and T_9 compared to T_2; T_6 and T_9 compared to T_3 and T_4. The differences among T_7, T_5, T_8, T_6 and T_9 were not significant among themselves.

f) Exchangeable potassium

i) At 0 to 22.5 cm depth, the exchangeable potassium content of soil differed significantly due to treatments and the values ranged from 319.5 kg/ha in T_1 to 321.7 kg/ha in T_9. The DMR test indicated that except T_2 and T_7 treatments all other treatments were significantly higher in value compared to T_1. All other treatments did not show significant differences among themselves.

ii) At 22.5 to 45 cm depth also significant difference was observed. The values ranged from 159.8 kg/ha in T_1 to 160.9 kg/ha in T_9 treatment. From DMR test it is quite clear that only T_6 and T_9 treatments were significantly higher than other treatments. There was no difference among T_1, T_4 and T_7; T_4, T_7 and T_2; T_7, T_2, T_3, T_5 and T_8 treatments. T_6 and T_9 treatments were significantly different from all other treatments.

g) Exchangeable calcium

i) At 0 to 22.5 cm depth, no significant difference in the exchangeable calcium content of the soil, due to treatments was observed. All treatments recorded the same value of 6.8 meq/100 g.

ii) At 22.5 to 45 cm depth also, no significant difference was observed as in the first depth. The value recorded was 6.2 meq/100 g, slightly less than the first depth and was the same for all treatments.

h) Exchangeable Magnesium

i) At 0 to 22.5 cm depth the exchangeable magnesium content of the soil did not differ significantly due to treatments. The values recorded ranged from 0.40 meq/100 g in T_1, T_2 and T_3 plots to 0.41 meq/100 g in T_4, T_5 and T_6 plots and 0.42 meq/100 g in T_7, T_8 and T_9 plots.

ii) At 22.5 to 45 cm depth also there was no difference in exchangeable magnesium content of soil, due to treatments. All the treatments have recorded the same value of 0.40 meq/100 g.

i) Available sulphur

i) At 0 to 22.5 cm depth the available sulphur content of the soil did not differ significantly due to treatments. The values recorded range from 0.0039 per cent in T_1 to 0.0044 per cent in T_9 treatment. Treatments T_2 and T_3 have recorded 0.0040 per cent, T_4 and T_5 have recorded 0.0041 per cent, T_6 has shown 0.0042 per cent and T_7 and T_8 have shown 0.0043 per cent.

ii) At 22.5 to 45 cm depth also there was no significant difference in available sulphur content of the soil, due to treatments. The highest value recorded was 0.0036 per cent in T_5 to T_9 treatments and lowest value was 0.0034 per cent in T_1 treatment, while T_2, T_3 and T_4 have recorded 0.0035 per cent.

DISCUSSION

CHAPTER V

DISCUSSION

Sulphur fertilisation is known to improve crop quality. Under certain conditions they are infact more important to the growers than the increased yields.

With the objective of investigating the optimum level of application of sulphur and potassium on the yield of radish and carrot and to determine the effect of these nutrients on the quality parameters of the crops and the properties of the soil, investigations were carried out with two crops at the District Horticultural Farm, Tumkur, during the kharif season of 1978.

5.01. Physical and Chemical Properties of the Soil

The soil on which the experiments were conducted was red clayey having more than 40 per cent clay at both the depths. The soil was slightly acidic and the salt content was very low. The CEC of the soil was moderate. The nutrient status of the soil was moderate to poor. The available sulphur status of the soil was fair at 0.0035 to 0.0042 per cent.

5.02. Response of radish and carrot crops to sulphur and potassium applications

There are many reports in the literature to suggest the significant response of crops to sulphur under different conditions. In the present study significant differences in the yield of radish and carrot was obtained due

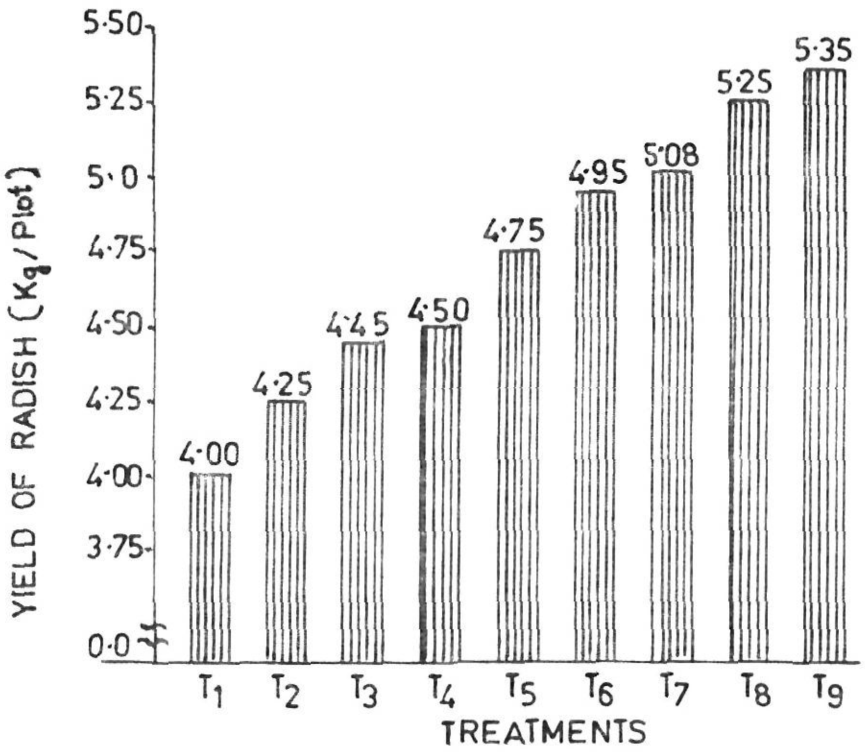

FIG.2(a) YIELD OF RADISH.

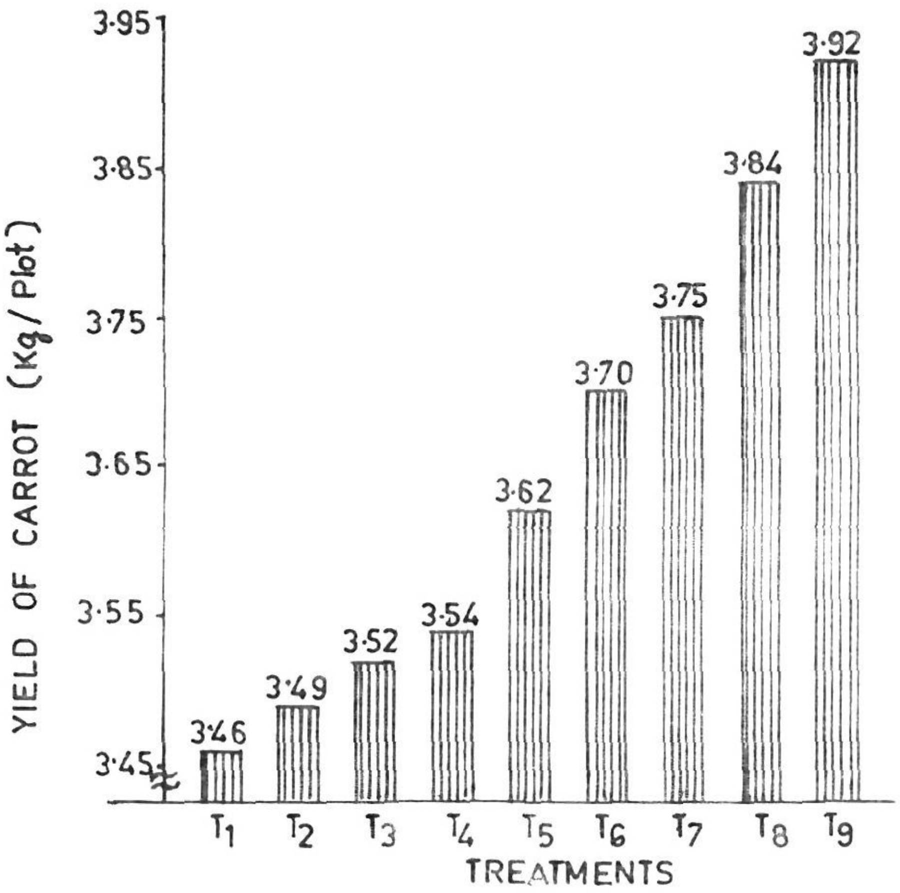

FIG.2(b) YIELD OF CARROT.

FIG.2: EFFECT OF SULPHUR AND POTASSIUM APPLICATION ON THE YIELD OF RADISH & CARROT.

to sulphur and potassium applications which has been clearly depicted in figure 2. Addition of sulphur at 10 ppm and potassium at 75 kg/hectare (T_9 treatment) produced the highest yield. Lowest yield was obtained in T_1 treatment where in, no sulphur was applied and potassium was applied at the rate of 37.5 kg/ha. Slightly better yields were obtained in treatments where sulphur was applied at the rate of 5 ppm.

According to Kanwar (1963) soils containing sulphur less than 15 ppm are rated as deficient, upto 15 ppm as medium and if above 15 ppm as good. Muhr et al. (1963) classified soils with respect to potassium as low, medium and high if they contain less than 140 kg K_2O /ha, 140 to 336 kg/ha and more than 336 kg/ha. As the soils of Tumkur fall under medium to poor category, significant response in the yield of crops to sulphur and potassium application was observed.

Harward et al. (1962) reported that there is a close relationship between sulphur uptake and yield of dry matter. Conrad (1950) and John (1950) showed that application of sulphur results in doubling the yield of some of the legumes. Chopra and Kanwar (1966) noticed significant higher yields in groundnut by the application of sulphur with nitrogen phosphorus and potash. Muthuswamy and Muthukrishnan (1971) observed that the fresh weight of radish roots increased due to phosphorus and potash applications. Aulakh et al.(1977)

observed that the application of sulphur at the rate of 25 to 50 kg/ha as gypsum increased yield of potato tubers. Somasekhar (1980) reported that in case of Knolkhol, nitrogen at 225 kg/ha and sulphur at 25 kg/ha will result in maximum dry weight of plant, percentage dry matter and yield per hectare.

In the present experiment also, a general trend of increase in the yield of radish and carrot with increase in the dose of sulphur and potassium was observed, and sulphur application along with potassium favoured the increase in size of the roots.

5.03. Changes in the nutrient concentration and quality parameters of radish and carrot crops due to sulphur and potash application

i) Nutrient concentration of radish roots

The concentration of any constituent, especially inorganic elements in plants is not constant under variable nutritional and environmental conditions. Sulphur fertilisation is known to create favourable effects for the absorption of nutrient elements due to the action of acid produced by the added sulphur.

In the present study it can be seen that there has been a significant increase in the nitrogen content of radish roots. Application of sulphur with potassium increased the nitrogen content of roots and leaves. Availability of sufficient sulphur usually results in the increased protein synthesis by the utilization of more and more of synthecised carbohydrates by way of sufficient available sulphur. Aulakh *et al.* (1977) observed that in potato tubers the content of protein sulphur, total soluble sulphur and total nitrogen increased with increased application of sulphur.

Pathak and Bharadwaj (1968) noticed higher contents of sulphur, phosphorus, calcium and magnesium in berseem plants with sulphur treatment. Dhillon and Dev (1978) reported that sulphur uptake by soyabean increased with increasing levels of sulphur. The utilization of applied sulphur decreased when the dose was raised to 20 ppm of sulphur.

In the present experiment also, there is a significant increase in the phosphorus, calcium and sulphur contents of roots but the content of phosphorus and calcium was not significantly different due to treatments. All the 3 nutrients phosphorus, calcium and sulphur behaved quite uniformly, that highest concentration of these nutrients was observed in the case of T_9 treatment, where both sulphur and potassium were applied at highest dose and the lowest value was obtained in T_1 treatment where sulphur was 0 ppm and potassium was 37.5 kg/ha. No significant difference in the potassium and calcium content of radish was observed.

ii) Quality parameters of radish roots

All the quality parameters like protein, Vitamin 'C' and pungency except crude fibre content of radish roots differed significantly due to treatments, An increase in the protein, Vitamin 'C' and pungency of radish roots due to increased application of sulphur and potassium was observed and is depicted in Fig.3.

The reduction in the protein content of sulphur deficient plants has been reported by Dube and Misra, (1969). The main reason for less protein appears to be due to the reduction in the rate of protein synthesis of young growing leaves, resulting in the depression of yield contributing factors.

Beaton et al.(1971) adduced that sulphur fertilization increases the protein content of plants as proteins contained sulphur. Plants need sulphur to synthesize protein and when adequately supplied with sulphur, will contain more proteins than plants without adequate sulphur, In the present study highest protein was accumulated in T_9 treatment where both sulphur and potassium were applied in adequate amounts. On the other hand least protein accumulation was observed in T_1 treatment where there was no addition of sulphur. Dube and Misra (1969) reported that sulphur deficiency reduced the growth of plants, yield, quality and protein content of the seeds in peas, Blackgram and Groundnut. Somasekhar (1980) reported that the quality parametre of the stem tuber (Knolkhol) such as ascorbic acid, crude protein, ash content and nitrogen content of the leaves were most favaourably

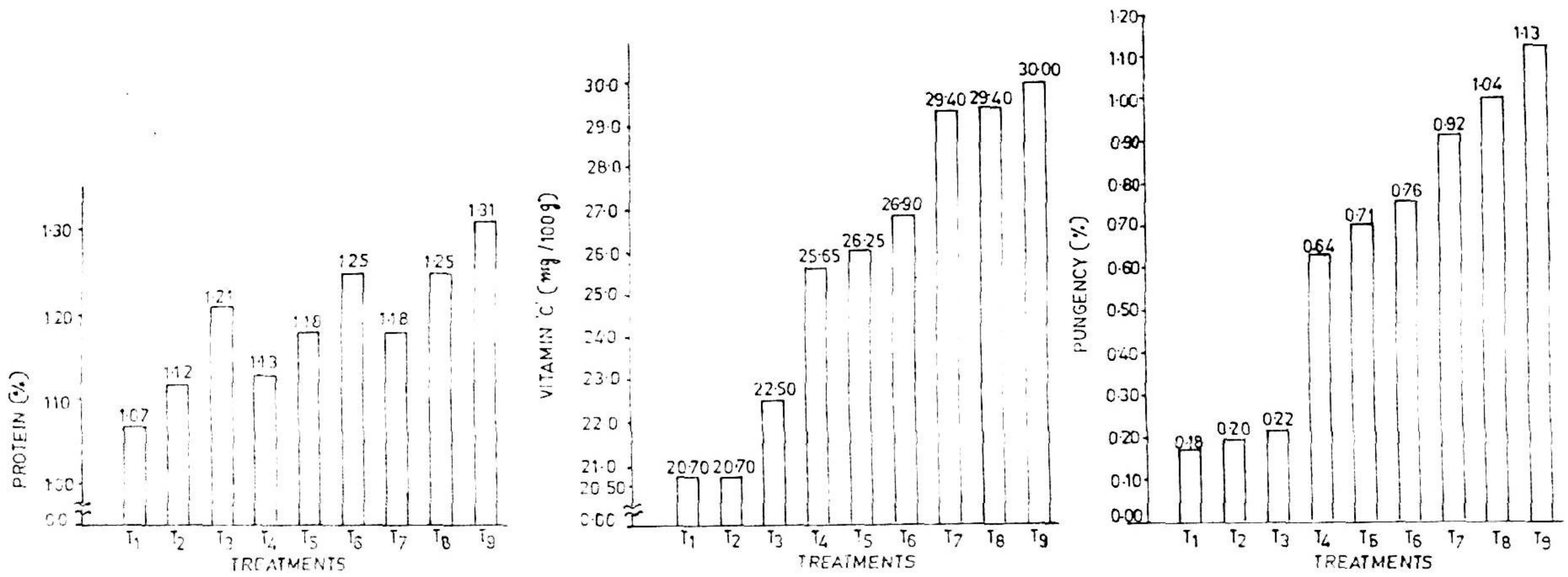

FIG-3(a) PROTEIN CONTENT IN RADISH

FIG-3(b) VITAMIN 'C' CONTENT IN RADISH

FIG-3(C) PUNGENCY IN RADISH.

FIG. 3: EFFECT OF SULFHUR AND POTASSIUM APPLICATION ON THE QUALITY PARAMETERS OF RADISH CROP

influenced by the highest levels of nitrogen at 225 kg/ha and sulphur at 25 kg/hectare. Though the crude fibre content of the roots did not differ significantly, appreciable increase in the crudefibre content was observed in T_9 treatment compared to T_1 treatment.

The ascorbic acid content (Vitamin C) of radish roots differed significantly due to treatments. Vitamin C content of the roots varied with the amount of sulphur supplied and the highest ascorbic acid content was observed in T_9 treatment and lowest in T_1 treatment. Sharma et al.(1976) reported that the sulphate present in potassium sulphate increased the ascorbic acid content by 2.7 mg/100 g of fresh weight of potato tubers.

The pungency of radish roots measured in terms of percentage of allyl-iso-thiocyanate differed significantly due to treatments and the values ranged from 0.18 to 1.13 per cent. This clearly indicated that the percentage of allyl-iso-thiocyanate accumulation is directly proportional to the quantity of sulphur and potassium applied.

Misra and Keshavaprasad (1966) reported that sulphur at 100 pounds per acre increased the allyl-propyl-disulphide content of onions which is responsible for the pungency of onions.

iii) <u>Nutrient concentration and quality parameters of radish leaves</u>

Significant differences in the nitrogen, phosphorus, sulphur and protein content of radish leaves was observed due to sulphur and potassium applications, but the potassium, calcium and magnesium content of the leaves did not show any significant difference. The increased nitrogen and sulphur accumulation in leaves may be due to the absorption of more of these nutrients. This has been made possible by the creation of favourable conditions for the absorption of these elements. The increased concentration of sulphur was because of the added sulphur. The increased protein content was because of the added sulphur. The increased protein content was because of the increased uptake of the nutrients and the synthesis of more of carbohydrates by photosynthesis and its conversion to proteins by various metabolic activities of the plants.

Though the Vitamin 'C' content of leaves did not differ significantly, appreciable increase in the Vitamin 'C' content of radish roots was observed due to increased sulphur and potassium application.

iv) <u>Nutrient concentration of carrot</u>

Significant increase in the nitrogen, calcium and sulphur content of carrot due to sulphur and potassium applications was observed but there was no significant difference in the phosphorus, potassium and magnesium content of the crop. In all the treatments increase in the nutrient content with the increased sulphur and potassium application was observed as in the case of radish. This may be because of the creation of favourable conditions in the soil which help in the uptake of many nutrient elements and due to better metabolic activities of the plant system.

v) Quality parameters of carrot

Significant increase in the protein, vitamin 'C' and β-Carotene content of carrot with increased application of sulphur and potassium was observed. There was however, no significant difference in the crude fibre content of carrot. All this has been clearly depicted in Fig.4.

The increased β- Carotene content of carrot with increased sulphur and potassium applications may be because of the role played particularly by sulphur in its synthesis and accumulation.

5.04. Changes in the soil properties due to sulphur and potassium applications

i) Radish crop plots

a) 0 to 22.5 cm depth: There was significant difference in the pH values of the soil with increase in the quantity of sulphur and potassium applied. This decrease in pH values may be due to the conversion of applied sulphur to sulphuric acid which increased the hydrogen ion concentration of the soil.

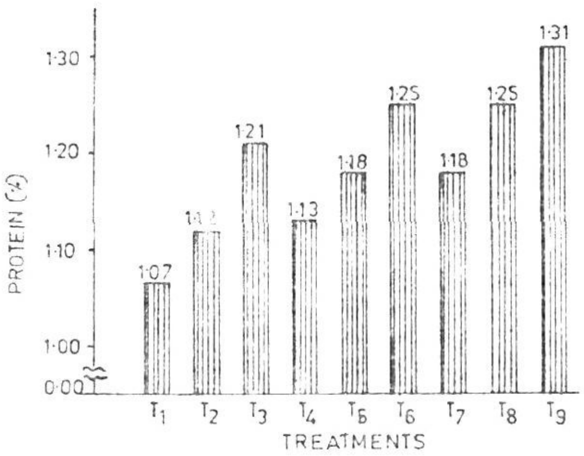

FIG 4 (a) PROTEIN CONTENT OF CARROT

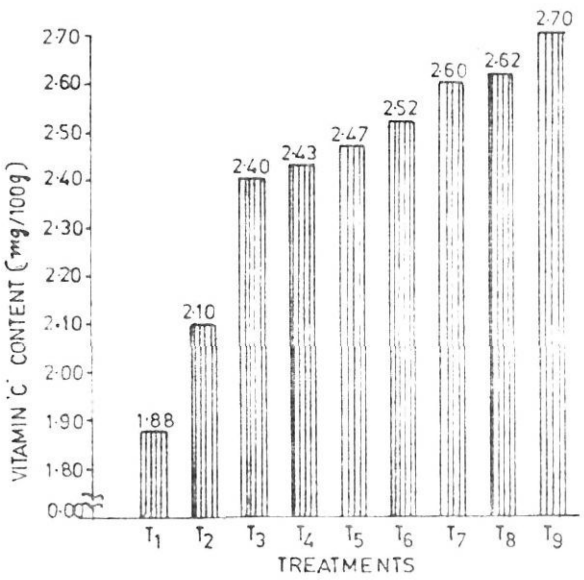

FIG 4(b) VITAMIN 'C' CONTENT OF CARROT

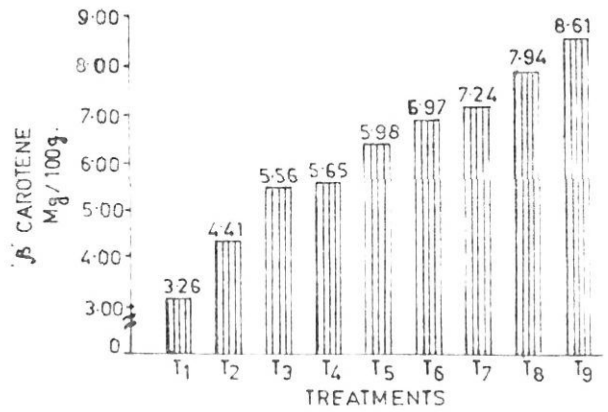

FIG 4 (C) 'β' CAROTENE CONTENT.

FIG-4 : EFFECT OF SULPHUR AND POTASSIUM APPLICATION ON THE QUALITY PARAMETERS OF CARROT CROP.

The electrical conductivity value of the soil does not show any significant difference due to treatments and the values were less than 0.2 millimhos per cm. The organic carbon content of the soil also did not x differ significantly due to treatments and the values ranged from 0.70 to 0.71 per - cent. There was significant difference in the available nitrogen content of the soil due to treatments. There was a general trend of decrease in the nitrogen content of the soil with increase in the quantity of sulphur and potassium applied. This may be due to the enhanced root growth and metabolic activity which might have depleted nitrogen from soil.

There was no significant difference in the available phosphorus content of the soil and the values ranged from 19.65 to 19.69 kg/ha. The potassium content of the soil differed significantly due to treatments. There was a gradual increase in the potassium content of the soil with increase in the quantity of potassium applied. No significant difference in the calcium, magnesium and sulphur content of the soil was observed due to treatments.

b) 22.5 to 45.0 cm depth: The pH of the soil did not differ significantly due to treatments. Here also a general trend of decrease in the pH of the soil with increase in the quantity of sulphur and potassium applied, was observed. In case of electrical conductivity there was a significant difference due to treatments. There was no significant difference in the organic carbon content of the soil and almost all the treatments recorded the same value.

The nitrogen content of the soil differed significantly due to treatments. Here also a negative trend of decrease in the nitrogen content of the soil with increase in the quantity of sulphur and potassium applied was observed. The phosphorus and potassium contents of the soil also differed significantly due to treatments. The increase in potassium content of the soil was because of the applied potassium. There was no significant difference in the exchangeable calcium, exchangeable magnesium and available sulphur content of the soil due to treatments.

ii) <u>Carrot Crop Plots</u>

a) <u>0 to 22.5 cm depth:</u> As in the radish plots here also there was significant difference in the pH, available nitrogen and available potassium of the soil, and no significant difference in the electrical conductivity, organic carbon, available phosphorus, exchangeable calcium, exchangeable magnesium and available sulphur content of the soil. The treatment effect was almost similar to that in the soil of the radish plot.

b) <u>22.5 to 45 cm depth:</u> Here also similar trend of results were obtained as in the case of soil in radish plots. This may be because of the fact that the plots are adjacent to each other.

It has been found that when sulphur is applied as elemental sulphur or in sulphate form to the soil there will be a decrease in soil pH which exerted considerable influence on the availability of other nutrients (Bertramson et al., 1954).

Bharathsingh and Mahendrasingh (1975) reported that sulphur availability increased with increased levels of sulphur irrespective of its source but decreased with increasing soil phosphorus concentration.

5.05 Conclusions

Based on the results obtained it can be said that the crops grown in soils around Tumkur (Lakkanapalya series) will definitely respond to the application of sulphur and potassium. It has been found that sulphur at 10 ppm and potassium at 75 kg/ha (T_9 treatment) has resulted in highest yield of both radish and carrot. An increase in the nitrogen, phosphorus and potassium content of the crops was observed due to treatments. The quality parameters (-protein, Vitamin 'C' and Pungency) of radish significantly increased by the application of sulphur and potassium at the rate of 10 ppm and 75 kg/ha in combination. In a similar manner the quality parameters of carrot were also influenced by sulphur and potassium applications. A gradual increase in the values of all the parameters were observed with the increased quantities of sulphur and potassium applied.

5.06. Future line of work

1) A comprehensive study should be made to ascertain the effect of long term usage of sulphur and potassium applications on - (a) the yield and quality of radish and carrot; (b) the soil properties; and (c) the residual effects, if any, of the applied sulphur on succeeding crops.

2) A detailed study should be made to establish and classify, soils which are deficient and/or rich in sulphur and potassium and the yield response of crops grown on the soils to the application of sulphur and potassium.

3) Efforts should be made to work out the economics of sulphur and potassium application on the production of radish and carrot.

4) A detailed study should be made with different sources of sulphur and potassium fertilizers and the best source for these crops should be arrived at.

5) Similar response studies may be carried out for other vegetable crops like onion, potato etc.

SUMMARY

CHAPTER VI

SUMMARY

With the objective of investigating the optimum level of sulphur and potassium application on the yield of radish and carrot crops and to determine the effects of these nutrients on the quality of these vegetables and the properties of the soil, investigations were carriedout at the District Horticultural Farm, Tumkur, during the kharif season of 1978. The experiment consisted of nine treatments with two levels of sulphur (5 and 10 ppm) and 3 levels of potassium (37.5, 56.25 and 75.0 kg/ha) and their combinations. Sulphur was applied in the form of Factamphos and Potassium in the form of muriate of potash. Each treatment was replicated 3 times.

Significant increase in the yield of both radish and carrot was obtained due to sulphur and potassium application. An increasing trend in yield of both the crops with increase in the quantity of both sulphur and potassium was observed. In both the crops highest yield was obtained in T_9 treatment (sulphur at 10 ppm and potassium at 75 kg/ha) and the lowest yield was obtained in T_1 treatment wherein no sulphur was applied but potassium was applied at 37.5 kg/ha.

Application of sulphur and potassium resulted in a significant increase in the nitrogen, phosphorus, calcium and sulphur content of radish roots but not those of potassium and magnesium content of the roots. All the quality parameters like protein, Vitamin 'C' and pungency except crude fibre content of radish roots differed significantly due to treatments. An increase in the quantity of these parameters was observed with increased application of S and K and highest value was observed in T_9 treatment.

Significant differences in the nitrogen, phosphorus, sulphur and protein content of radish leaves was observed but the potassium, calcium, magnesium and Vitamin 'C' content of the leaves did not show any significant difference. T_9 treatment (sulphur at 10 ppm and potassium at 75 kg/ha) resulted in highest nitrogen, phosphorus, sulphur and protein content of leaves.

In case of carrot, significant differences in the nitrogen, calcium and sulphur content due to sulphur and potassium application was observed, but not in case of phosphorus, potassium and magnesium content of the crop. An increase in the values was observed with increase in the quantity of sulphur and potassium applied as in case of radish.

The protein, Vitamin 'C' and β-Carotene content of carrot (quality parameters) also increased significantly with increased application of sulphur and potassium. However, no significant difference in the crude fibre content of carrot due to treatments was observed. T_9 treatment gave highest values of protein, Vitamin C and β-Carotene content of carrot compared to other treatments.

No drastic change in the physico-chemical and chemical properties of the soil was observed at both the depths (0 to 22.5 and 22.5 to 45.0 cm). Significant differences in the pH, available nitrogen and available potassium content of the soil was observed but there was no significant difference in the electrical conductivity, available phosphorus, organic carbon, exchangeable calcium and magnesium and available sulphur content of the soil due to treatments.

The study has shown the effects of varying levels of sulphur and potassium application on the yield and quality of radish and carrot crops. Further need to work on the long term effect of these nutrients and their residual effect to be studied has been indicated.

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CHAPTER VII

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* Original not seen

APPENDICES

APPENDIX I

Rating chart for soil test data in India

	Category		
	Low	Medium	High
1. Available Nitrogen (Pounds/acre)	Below 250 (" 280)	250-500 (280-560)	Above 500 (" 560)
2. Available Phosphorus (P_2O_5)(Pounds/acre)	Below 20 (" 22.40)	20-50 (22.40 to 56.00)	Above 50 (" 56.00)
3. Available Potash (K_2O)(Pounds/acre)	Below 125 (" 140)	125-300 (140-336)	Above 300 (" 336)
4. Organic carbon (per cent)	Below 0.5	0.5 to 0.75	Above 0.75

Note: Values in parenthesis indicates values in kgs/ha

Source: Muhr, G.R. et al., 1965, "Soil Testing in India" U.S. Agency for International Development Mission in India, New Delhi.

APPENDIX II

Effect of Sulphur and Potassium application on the yield of Radish and Carrot

Sl.No.of treatment	Treatment	Yield of radish in kg/plot	Yield of carrot in kg/plot
T_1	S_0 K_1	4.00a	3.46a
T_2	S_0 K_2	4.25b	3.49a
T_3	S_0 K_3	4.45c	3.52a
T_4	S_1 K_1	4.50c	3.54a
T_5	S_1 K_2	4.75d	3.62ab
T_6	S_1 K_3	4.95e	3.70bc
T_7	S_2 K_1	5.08ef	3.75cd
T_8	S_2 K_2	5.25fg	3.84de
T_9	S_2 K_3	5.35g	3.92e
	'F' Test	**	**

Note: Notations indicate significant differences - in this case increase in yield - due to treatments.

Principle: a) Each treatment is compared to the other of higher values. So the same notation continues till the next value is significantly different.

b) Since values are arranged in ascending order, before analysis, notation 'a' indicates least value. If 2 or more treatments carry the same notation, it shows that they are not significantly different to each other, when 2 or 3 notations are carried by the same treatment, it shows that there is no significant difference among the treatments carrying the notations individually or otherwise, inclucing that treatment.

Example: a) Yield of Radish: T_1 treatment shows the least yield of 4.00 kg/plot and notation 'a' is given. The yield of 4.25 kg/plot in T_2 treatment is significantly different from T_1 and is given notation'b'. So is notation 'c' for T_3, as there is no difference between T_3 and T_4, both carry notation 'c'. T_5 carrying notation 'd' is significantly different over T_4. T_6 is significant over T_5 and carries notation 'e'. T_6 and T_7 are the same compared to each other and so carry notation 'e'. So are T_7 and T_8 carrying notation 'f'. So also T_8 and T_9 which are the same and carry notation 'g'.

..Contd..

Appendix II

b) <u>Yield of carrot</u>: Compared to T_1, T_2, T_3 and T_4 treatments, T_5 is significantly different. Therefore T_1, T_2, T_3 and T_4 carry notation 'a' and T_5 carries notation 'b'. Compared to T_4 treatment T_5 is not significantly different and so T_5 carries notation 'a' also. Further T_5 and T_6 carry notation 'b', T_6 and T_7 carry notation'x', 'c', T_7 and T_8 carry notation 'd' and T_8 and T_9 notation 'e' indicating that there is no difference between those carrying similar notations.

Appendix II - (Contd.)

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
	4.00	4.25	4.45	4.50	4.75	4.95	5.08	5.25	5.35
T_1 / 4.00	-	*0.25	0.45	0.50	0.75	0.95	1.08	1.25	1.35
T_2 / 4.25	-	-	*0.20	0.25	0.50	0.70	0.83	1.00	1.10
T_3 / 4.45	-	-	-	0.05	*0.30	0.50	0.63	0.80	0.90
T_4 / 4.50	-	-	-	-	*0.25	0.45	0.58	0.75	0.85
T_5 / 4.75	-	-	-	-	-	*0.20	0.33	0.50	0.60
T_6 / 4.95	-	-	-	-	-	-	0.13	*0.30	0.40
T_7 / 5.08	-	-	-	-	-	-	-	0.17	*0.27
T_8 / 5.25	-	-	-	-	-	-	-	-	0.10
T_9 / 5.35	-	-	-	-	-	-	-	-	-

Yield of radish MSSe = 0.01

Appendix II - Contd.

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
	3.46	3.49	3.52	3.54	3.62	3.70	3.75	3.84	3.92
T_1 / 3.46	-	0.03	0.06	0.08	*0.16	0.24	0.29	0.38	0.46
T_2 / 3.49	-	-	0.03	0.05	*0.13	0.21	0.26	0.35	0.43
T_3 / 3.52	-	-	-	0.02	*0.10	0.18	0.23	0.32	0.40
T_4 / 3.54	-	-	-	-	0.08	*0.16	0.21	0.30	0.38
T_5 / 3.62	-	-	-	-	-	0.08	*0.13	0.22	0.30
T_6 / 3.70	-	-	-	-	-	-	0.05	*0.14	0.22
T_7 / 3.75	-	-	-	-	-	-	-	0.09	*0.17
T_8 / 3.84	-	-	-	-	-	-	-	-	0.08
T_9 / 3.92	-	-	-	-	-	-	-	-	-

Yield of carrot   MSSe = 0.003

APPENDIX III

Extract from Analysis of variance tables for yield and different quality Parameters

Sl.No.	Parameters	Mean sum of squares: Treatment / Degrees of freedom 8	Mean sum of squares: Error / Degrees of freedom 16	Remarks
1	2	3	4	5
I.	Effect of treatments on yield of Radish and Carrot Crops:			
	a) Radish Crop: (i) In Kgs/plot	-	0.01	
	Effect due to Potassium	0.332		**
	Effect due to Sulphur	2.225		**
	Effect due to interaction of K x S ..	0.006		NS
	(ii) In Tons/ha	12.705	0.187	**
	b) Carrot crop: (i) In Kgs/plot	..	0.003	
	Effect due to potassium	0.04		**
	Effect due to Sulphur	0.28		**
	Effect due to interaction of K x S ..	0.0025		NS
	(ii) In Tons/ha	1.607	0.053	**
II.	Effect of treatments on the nutrient contents of the crops			
	(i) Nitrogen percentage			
	a) Radish (roots) ..	0.0005	0.000018	**
	b) Radish (Leaf) ..	0.00075	0.0000625	**
	c) Carrot - ..	0.0005	0.000018	**
	(ii) Potassium percentage			
	a) Radish (root) ..	0.00025	0.0000625	**
	b) Radish (leaf) ..	0.00025	0.0000625	**
	c) Carrot - ..	0.000125	0.000125	NS
	(iii) Potassium percentage			
	a) Radish (root) ..	0.00075	-	-
	b) Radish (leaf) ..	0.0000625	0.0000313	NS
	c) Carrot ..	0.001	-	-

Appendix III - (Contd.)

1	2	3	4	5
	(iv) Calcium percentage			
	a) Radish (root) ..	0.000375	0.0000625	**
	b) Radish (leaf) ..	0.000375	-	-
	c) Carrot ..	0.0005	0.0000625	**
	(v) Magnesium percentage			
	a) Radish (root) ..	0.00025	-	-
	b) Radish (leaf) ..	0.00012	-	-
	c) Carrot ..	0.00012	0.00006	NS
	(vi) Sulphur percentage:			
	a) Radish (root) ..	0.0004	0.0000313	**
	b) Radish (leaf) ..	0.0003	0.000025	**
	c) Carrot ..	0.00025	0.0000625	**
III.	Effect of treatment on the quality parameters of the crop:			
	i) Protein percentage:			
	a) Radish (root). ..	-	0.0038	-
	Effect due to potassium	0.009		NS
	Effect due to sulphur	0.0285	-	**
	Effect due to Interaction of K x S ..	0.0132	-	*
	b) Radish (leaf)			
	Effect due to potassium	0.0027	-	NS
	Effect due to sulphur	0.106	-	**
	Effect due to interaction of K x S	0.0007	-	NS
	c) Carrot ..		0.00381	
	Effect due to potassium	0.009		NS
	Effect due to sulphur	0.0285		**
	Effect due to interaction of K x S ..	0.0132	-	*

Appendix III- (Contd.)

1	2	3	4	5
ii)	Vitamin 'C' (mg/100 g)			
	a) Radish (root)		0.532	
	Effect due to potassium	3.83		**
	Effect due to sulphur	157.0		**
	Effect due to interaction of K x S ..	0.47		NS
	b) Radish (leaf)	47.723	26.846	NS
	c) Carrot ..	-	0.015	
	Effect due to Potassium	0.11	-	**
	Effect due to sulphur	0.59		**
	Effect due to interaction of K x S ..	0.05		*
(iii)	Pungency percentage in Radish:		0.0006	
	Effect due to potassium	0.035		**
	Effect due to sulphur	1.56		**
	Effect due to interaction of K x S	0.005		**
(iv)	β-Carotene content in Carrot		0.0002	
	Effect due to potassium	6.265	-	**
	Effect due to sulphur	27.865	-	**
	Effect due to Interaction of K x S	0.269	-	**

Appendix IV

Meteorological data showing daily maximum and minimum temperatures and rainfall during the period of cultivation of Radish and Carrot crops (10th Aug.1978 to 15th December 1978) as recorded at Tumkur Observatory

Date	August 1978			September 1978			October 1978			November 1978			December 1978		
	Temp.°C		Rainfall (mm)	Temp.°C		R.fall (mm)	Temp°C		R.fall (mm)	Temp.°C		R.fall (mm)	Temp.°C		R.fall (mm)
	Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
01				29.1	18.9	1.2	27.1	19.4	6.0	29.1	20.4	3.0	28.1	17.4	0.0
02				28.6	19.9	0.0	26.1	18.4	0.0	26.1	19.4	0.0	28.6	17.4	0.0
03				28.1	19.4	0.0	28.1	18.4	0.0	28.1	19.9	0.8	28.1	16.9	0.0
04				28.1	19.4	0.0	28.6	18.4	0.0	26.1	20.9	3.6	26.6	18.4	0.0
05				30.1	19.4	0.0	28.6	17.9	0.0	22.6	20.9	19.8	28.1	17.4	0.0
06				29.1	20.4	0.0	28.6	18.9	0.0	25.6	20.9	0.6	25.6	18.4	0.0
07				29.6	20.9	0.0	29.1	20.4	0.0	28.1	20.9	0.4	25.1	18.9	0.0
08				27.1	20.9	0.0	29.6	20.9	Trace	28.6	20.4	0.0	24.1	19.4	0.0
09				29.1	20.4	0.0	30.1	18.9	0.0	29.1	19.9	0.0	24.1	17.9	9.8
10	27.1	20.4	0.0	30.6	19.9	0.0	29.6	20.9	0.0	28.6	17.9	0.0	26.6	16.4	0.0
11	27.1	19.9	12.4	29.6	20.4	4.6	31.6	20.4	10.8	29.1	17.4	0.0	26.6	16.9	0.0
12	28.1	19.4	0.0	25.1	17.9	70.8	30.1	21.4	3.0	29.6	17.9	0.0	25.1	17.4	0.0
13	28.1	19.4	0.0	26.6	18.9	1.8	29.1	20.9	0.0	29.1	20.9	0.0	24.1	18.9	0.0
14	27.6	20.4	0.0	28.1	19.4	0.0	30.1	20.4	16.2	26.6	18.4	Trace	25.6	18.9	0.0
15	23.6	18.4	5.4	28.1	18.9	19.0	29.1	17.9	0.0	29.1	17.9	0.0	24.1	18.4	0.0

Appendix IV - (Contd.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
16	23.1	19.4	0.6	26.6	19.4	0.4	28.1	17.9	0.0	29.1	17.4	0.0			
17	26.1	19.4	3.6	28.1	18.4	0.0	28.6	19.9	0.0	29.1	18.9	0.0			
18	26.6	18.9	0.0	29.1	19.9	0.0	29.1	20.4	23.6	29.1	18.9	0.0			
19	26.6	19.9	0.8	29.1	19.9	0.0	28.1	20.4	24.1	28.1	16.4	0.0			
20	28.1	18.4	11.2	28.1	20.9	0.0	26.6	20.9	4.0	28.1	15.9	0.0			
21	25.6	19.9	6.0	28.6	20.9	1.4	28.1	20.4	0.0	28.1	16.9	0.0			
22	26.6	19.4	3.4	27.1	20.4	0.6	29.1	19.9	0.0	28.6	16.4	0.0			
23	27.6	19.9	2.0	25.6	19.4	0.0	29.1	19.9	0.0	28.1	15.4	0.0			
24	27.1	19.9	0.2	25.1	19.9	0.0	29.1	20.9	0.2	28.1	17.4	0.0			
25	27.1	19.9	0.2	27.1	20.4	1.6	28.6	20.9	0.0	25.1	19.9	Trace			
26	27.1	19.9	0.4	27.1	20.9	0.8	29.1	21.9	1.6	26.1	18.4	0.0			
27	27.6	19.4	0.0	27.6	18.9	94.0	29.1	20.4	Trace	28.1	19.9	0.0			
28	27.1	19.9	0.2	27.6	19.9	0.0	28.6	21.4	0.0	29.1	17.9	0.0			
29	27.6	19.9	0.6	28.6	19.9	10.[illegible]	28.6	21.9	0.0	28.1	14.9	0.0			
30	28.1	19.9	0.0	27.6	20.4	1.2	30.1	21.4	0.0	28.1	17.4	0000			
31	28.1	19.4	0.0				28.6	20.9	0.0						

By courtesy of: India Meteorological Department, Government of India, Meteorological Centre, Palace Road, Bangalore-560 001.